A Comprehensive Human Factors Analysis of Wearable Computers Supporting a Hospital Ward Round

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Abstract

This paper focuses on the social computing and usability issues connected to the use of a wearable computer as support of the clinical ward round. An evaluation of a prototype system was performed with a group of doctors and nurses, who physically tried out the system in a simulated ward round scenario and were interviewed about their experiences. Generally, the doctors and nurses felt such system would be helpful in diminishing paper work and enhance collaboration. The most critical component of the prototype system was the navigation in electronic patient documents using gesture interaction. The doctors found the gestures difficult to learn and were worried the patient contact would suffer as a result of too much attention being needed by the gestures.

Introduction

In healthcare scenarios, wearable technology promises advantages such as hands and touch-free operation and context-aware user interfaces. The obtrusiveness present in today's desktop applications, which demands the full user attention, can be minimized by using novel interaction techniques that better coexist with the clinical work at bedside. Moreover, such systems have the potential to change and streamline existing workflows. Combining wearable technology with pervasive computing devices, such as sensors or actuators, is an approach with high potential for being an important part of IT solutions for applications in hospital environments [1][2][3].

The wearIT@work project is based on a user centred design UCD approach and thus emphasises the importance of studying users' acceptance of the wearable computer, its potential impact on social, organizational and human factors as well as usability issues [4][5][6]. These topics were examined in an evaluation of a wearable prototype system aimed to provide support for doctors and nurses during the ward round. The study described and discussed in this paper was performed in a hospital of the Gespag group in Austria.

Today, the ward round itself and the related activities often require tedious and redundant documentation work and long communication chains. In order to prepare the ward round nurses have to make sure that the relevant patient documents are printed out and correctly sorted into the files in the document cart. The ward round itself is comprised of the following basic tasks, which have to be performed by the doctor/nurse team:

• Elicit information about the patient's current condition,
• Interact with the patient (talking, examinations),
• Make decisions about and order further treatment.

As of now, almost all patient information is elicited from the paper documents. Any orders for further treatment are typically noted by a nurse and later entered into the computer or written on special paper forms for communication with the appropriate department (for a detailed account of the scenario see [7]). The prototype system allows for automatic identification of a patient and a doctor, touch free accessing of patient documents at the bedside and immediate entering of examination orders.

In the first section, the setup of the experiment is described, including a brief description of the system, of the test environment and the test procedure and the evaluation method. Next the results concerning social computing are presented and discussed, followed by the results on the more practical interaction issues. Finally, a conclusion is given.

Experiment setup

Nine doctors and eight nurses with different amounts and types of experience and roles participated in the tests, which took place in a real patient room but with a dummy patient. Below, the prototype system itself and the test procedure are described

Technical Setup

The system's setup is depicted in figure 1. A patient room was prepared to test the prototype. The fixed installation included the swivel-mounted bedside display attached to the patient's bed (1) and a patient dummy from the training department (2) which was equipped with a RFID wristband for identification (3). A video camera (9) was positioned in such a way that it could capture the doctor during his interactions with the bedside display and the patient. The technical infrastructure necessary to keep everything running was positioned on a table in the corner of the room.

End users tested the system in pairs of a doctor and a nurse. The doctor (4) wore the interaction wristband with an RFID-tag and an acceleration sensor (to facilitate gesture interaction) (5) and a Bluetooth headset (6) for speech input of examination requests). The nurse (7) was given a PDA for entering examination request data.

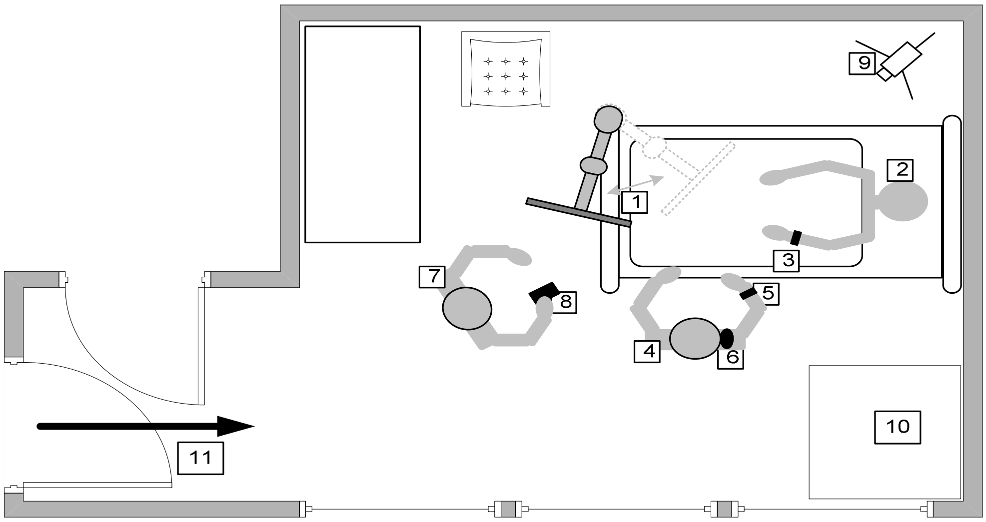

Figure 1: 1.swivel-mounted bedside display 2.patient dummy 3.patient RFID wristband 4.doctor 5.interaction wristband 6.bluetooth headset 7.nurse 8.PDA 9.video camera 10.table with technical infrastructure 11.entrance into the room during the tests

Test Sequence

Each evaluation session started with an introduction to the project and an explanation of the prototype. Following, participants practiced the interaction (especially the gestures). The training session was split into two halves. During the first part, the doctor and nurse received an explanation as to the system's usage and were asked to familiarize themselves with the interaction methods. Next, a sequence of activities similar to that of the actual tests was explained and performed. After the training, three test sequences were performed.

A test sequence began with the doctors and nurses entering the room via the door (11) and proceeding to the patient's bed. The doctor then used the interaction wristband to scan the patient's identification wristband in order to advice the system to bring up the patient's file on the bedside display. Next the doctor opened a document and scrolled to its end. There she found instructions to perform the next steps, e.g. opening another document which number was given. The last document contained instructions on performing an examination of a certain body part of "the patient" and on issuing an examination request afterwards. The details of the request were completed by the nurse, finishing the sequence.

During the training run, instructions were given to the participants, but in the test sequences the participants worked mostly independently.

Evaluation method

The purpose of the tests was to evaluate how well the doctors and nurses could interact with the system in the context of a typical, slightly simplified ward round work flow. In order to analyze the performance of the participants, identify problems and capture spontaneous comments, each test sequence was filmed in its entirety for later analysis. At a later point in time, practical interaction problems, conflicts between system interaction and work flow and comments were documented.
Due to the novel nature of the system interaction and the limited time for practicing in the experiment, the results of a quantitative analysis of performance was not considered to be representative for the use of the system after a longer training period. Thus, the results presented here describe the beginner problems and already observable learning tendencies/performance improvements, and should not be understood as a final evaluation of a ready-to-be-used system.

Following the users testing of the system, participants were interviewed – doctors and nurses separately - in German or English according to preference. In addition they were asked to fill out a questionnaire concerning their physical experience using the system and another concerning the social computing aspects. The questionnaires were constructed using Likert scales.

Results and Discussion

Social computing

Recognizing the projects goals

Most of the doctors and nurses explained the project goals as aimed at creating a paperless ward round, making the work process faster, easier, more efficient, and more convenient. In other words, optimizing the workflow of all the tasks performed for the patient while minimizing errors. We find that the overall understanding of the purpose of the project is the result of a real need for improving the work process and conditions which currently exist in the ward round. Most, expressed an interest in a technology that could assist them.

Doctors and nurses reported that currently much time and information is lost between the start of the ward round and its end, at which point the information is documented into the patients' files, processed and translated into actions. At the moment laptops and paper charts are used simultaneously, with different kinds of information being found on each format. The process of searching for information on one or both systems is time and energy consuming and uncomfortable. Moreover, while the amount of time to conduct the ward round is limited the number of patients to check is large, plus using a laptop or notebook on the ward round is neither convenient nor fast. For these reasons the current process makes it difficult to access and capture all the necessary information. One subject describes the current situation as follows, "[today] we don't have the time to find the right data even though we need it”.

Furthermore, the need to manually and after the fact enter the data collected in the rounds into the patients' charts is a cause of confusion and mistakes. Following the ward round, the nurse inserting the information and ordering the examinations has a lot of double work. She has to rewrite information into certain charts and get a new authorisation for the exams, creating a long and superfluous workflow. In addition, at times data might get lost and misinterpreted.
Regardless of these difficulties expressed by nearly all interviewees, one doctor very specifically emphasized there was no need for any electronic system that may complicate the work process- “I don't really need the wearable, everything works without it”. We believe that this reaction is an example of the concern and automatic refusal to technological change that illustrates the need for controlled, slow and carefully planned implementation plans. Furthermore, in some cases the objection to the technology is a result of the computerized system not serving the user and only burdening them with a new process. Hence, at times the cost of a new technology is bigger than the utility of it: "When his wife was in the hospital the Doctor was so busy with the computer that she didn't even talk to my wife, the computer was a huge distraction and in the end she just walk away, never talking to my wife".

Perceived changes of the work process

All interviewees, doctors and nurses, reported that they believe the wearable will enable less paper work. This will benefit doctors who will not have to do the extra work of reauthorizing. The direct dictation of the examination question, allows exactly the question and information intended by the responsible doctor to be entered. The wearable system will probably, however, be especially beneficial for nurses who today carry the brunt of the work load concerning documentation during and after the ward round.
As for the tasks taking place at bedside there were different opinions among the nurses about to what extent these would be easier or go faster. The differences can be ascribed to the fact that the nurses came from various departments. At some departments, the nurses currently perform a great deal of documentation work per hand at bedside. These nurses were generally of the opinion that the PDA would help them do things faster or at least as fast as now. In other departments, for example in the pediatrics department, very little of no documentation work is performed at bedside by the nurses. This would mean that having to perform the designated tasks on the PDA would be an addition in workload at the bedside. In general, however, most subjects stated that the wearable will facilitate faster access to accurate and updated information, and the application of on the spot authorized requests. These functions should result in a faster, easier and more efficient workflow.

Another outcome of using the wearable mentioned by most interviewees was the comprehension that the technology presented would result in the creation of a more standardized work process. Some mentioned that this would bring to a calmer, more organized ward round, and that this would, in turn, free some time for other tasks, such as the nurses being able to prepare for the next day and better schedule examinations and staff work. Young doctors and all nurses found the standardization process to be a positive outcome of the device. However, some doctors showed discontent with a more standardized process which they felt might limit their freedom and independence.

Nearly all interviews, doctors and nurses alike, reported that a faster more efficient system should allow them to focus more on “what's important”, on the patient and on medicine, and enable to spend more time and attention to the patient.

Perceived effect on collaboration

The wearable was reported to affect the interaction between staff members in several ways. Most importantly, doctors and nurses both mentioned that using the device could help in the future in collaborations with other hospitals and institutes. For example, since all patient data would be computerized, if one hospital needed to order tests from other hospitals the wearable could assist by transferring the information—with extreme accuracy and speed-- to the different sites. Another instance when the wearable is deemed to be of use is when a patient needs to be admitted to a different institution after his release from the hospital. Presently, all data is transferred via paper. But, once the information is entered into the wearable as the ward round is going on, its transfer will be faster, easier and more exact, and the communication between those who already know the patient and those who will be helping him next will be much easier.

Many of the interviewees also mentioned that using the wearable would also foster better collaboration between staff members in the ward round, especially between doctors and nurses, and between the medical staff and the patients (see next section for further elaboration on interaction with patients). The more efficient ward round would in turn, as stated by some interviewees, enable doctors and nurses to have more time for each other, cooperating and assisting one another. Easier and faster communication with other departments will also be possible as a result of easier information sharing, cutting time and creating better cooperation and more efficient work processes.

In sum, the interviewees' responses seem to indicate that the wearable would serve as a basis for a knowledge management system, facilitating the creation of a storage area for all information and documents pertaining not only to patients' data but also to procedures and processes (which others can also learn from).

Nonetheless, some doctors were concerned that the wearable could hinder teamwork. Today while the doctor examines the patient on the ward round she may ask the nurse to find and inform her of the patient's medical data as reported in the medical chart (temperature, blood pressure, etc). In its current state the device allows the doctor alone to navigate and access the patient's information through gestures. When directly asked if they would miss having access to the patient documents, the nurses' opinions were relatively divided. Some would like to be able to look into the patient documents to get an updated picture of the condition of the patient, without having to disturb the doctor. Other nurses would rather inform themselves at the station before the ward round, and would consequently be fine with not being able to navigate the documents at bedside. We recommend, however, that the device be accessible also to the nurses, and be unobtrusive for them too, since they assist the doctor in several ways. In addition, some doctors felt that the system may impede the conversation between nurse and doctor due to doctor's concentration on operating the system.

Direct effect on patients

All interviewees stated that the extra time created by the more efficient work process would allow doctors and nurses to spend more time and attention taking care of patients. Displaying the medical information on the screen in front of the patient should also bring to better communication with him/her. The screen will allow the sharing of information and a better explanation of the procedures and situation to the patients. It may also stimulate a growing patient involvement in the procedure, making more comments and asking more questions. One doctor mentioned that the device may even impress patients and comfort them.

However, doctors also stated that the wearable may create communication problems with patients. Having to look at the screen may hinder direct eye contact and conversations with the patient. Some doctors suggested audio feedback as a good solution for this communication obstacle. Doctors also pointed to the fact that the patient may not always be able to look at the screen, for instance, if she is lying down or not facing the screen. We recommend that the screen be easy to move so as to fit the patient's position and place. Doctors also seemed concerned about the patients' reactions to the gestures. Some believe that patients will find them to be strange, funny, awkward or even dumb. Similarly, the paediatric staff members voiced concern of children being scared of the system, and possibly easily breaking any equipment left in the room. The nurses from the paediatric department were also the ones most negative to the use of a PDA during the ward round. Today, the main responsibility of the paediatric nurses is to talk to the children and comfort them during the ward round. Any further tasks that would task attention away from the children are not welcome.

Effect on working conditions

Nurses who were interviewed all believed that the wearable would help their work process and lower their work load. The paper work, for which they are mostly in charge of today, would be reduced and this would allow their work to become more efficient and more focused on taking care of patients. In addition, some nurses reported that better communication with doctors and a standardized work process would give rise to more autonomous nurses. The result of these changes would be a more satisfied nurse.

The positive aspects notwithstanding, some nurses expressed concern regarding the possibility that due to the more efficient work process fewer nurses might be needed. Other nurses looked at this from a more optimistic side reporting that the end result of the efficiency could be less working hours for the nurses. In the paediatric department, nurses commented that the wearable could add to their work load, since currently while on the ward round their job is to help the doctor by assisting the treatment of the kids and not by writing down or accessing information.

All interviewees, doctors and nurses alike, expressed their concern regarding learning how to use a new technological system. Some believed it would create temporary stress for the staff until they learn how to use it. Many spoke of the training that will be needed to learn to use the wearable until it becomes as automatic as 'driving a car" so no extended mental effort is put into it and "the wearable computer doesn't come before medicine". Most were of the opinion that a training period would be acceptable if it didn't become too extensive, but they would rather not go through one if it wasn't absolutely necessary. One doctor commented that there are already too many non-patient related activities (project meetings, consultations etc) and more training would lead to even less time spent on the patient.

Prospective on documentation and monitoring aspects

Many doctors expressed concern and dismay of the idea of being monitored through the wearable computer, which would document each and every step they made. Doctors showed more apprehension to being monitored than nurses. Nonetheless, some doctors did point out the benefits of documentation. For example, the wearable could enable monitoring the performance of doctors so that lessons will be learned, cutting down errors and reducing re-operations. In addition, they mentioned that this documentation may help cope with patients' complaints and even lawsuits.

Nurses expressed an interest in a more accurate documentation of the work and in principle would be happy of a monitoring function. They believe that documenting all work steps would result in less oral assignments being lost, and on the other hand a clear output of the assignments and responsibilities would be created. The consequence would be the prevention of errors. Nurses added that such a process could help them learn and understand problems and furthermore could bring their supervisor to understand what other skills and training staff members need to improve their performance. Both doctors and nurses mentioned the cut in faults which are presently caused by mistaken hand writing.

Suggested improvements of wearable functions

Other useful functions suggested by doctors and nurses include: ordering of pharmaceuticals, a database which checks the patient's sensitivity to them and the interaction with other drugs the patient is already taking; ordering examinations at other hospitals on the spot; direct voice communication with other colleagues to explain the procedure decided on; an entertainment system which would include a TV, games, an electronic newspaper, the internet, etc.
The system should also display information regarding the reason for hospitalization and the first diagnosis. In addition an easier way to scroll down the information should be applied, and there should be a high priority signal which can be used.

Implementing the usage of wearable computers in the hospital

Doctors mentioned that in the past resistance to several new ICT systems has been experienced throughout different hospitals. To implement wearable computers in the workplace, lessons from past situations and experiences should be taken into consideration. This will hopefully maximize adoption while minimizing the resistance that often accompanies changes in the established social processes. In the test here described there were a few lessons that were recalled:

Staff members felt that the introduction of new ICT systems in the past have been coerced on them. The benefits of the new systems were not emphasized; instead the negative aspects of the old system were underlined. Staff members found this implementation process caused the adoption of the ICT to extend over a long period of time. Many automatically opposed to using the new systems as a result of the coerced implementation process. Furthermore, training was at times limited and staff members did not feel they knew how to use the system correctly.

Another example is the use of personal phones by each doctor that allowed all staff members and patients to contact the doctor at any time and anyplace. On the one hand this facilitates collaboration though it also is disruptive to the work processes. Always being accessible can harm the doctors' functioning. Conversations with staff members and patients can at times disturb the performance of an examination or even the performance of an operation. Some doctors feel they cannot turn off their phones due to fear of being portrayed as lazy or irresponsible. Others believe they must always be available in case of an emergency. Still, the fact remains that the phones are at times more harmful than helpful. The wearable will also enable always on communication and thus lessons from the usage of private phones by doctors in the hospital should be learned and further studied.

Usability interaction issues

In the first part of this section, the results concerning gesture interaction specifically will be described. In the following part, the qualitative results based on questionnaires, interviews and comments will be discussed.

Gesture interaction

The gesture interaction was by far the most controversial aspect of the prototype, which is not surprising considering the novelty of the concept and that none of the test participants had had experience with anything similar before.

Below, the most frequently occurring issues and their potential causes are discussed. Most of them can be classified as 'beginner-problems', i.e. these issues would most probably become less frequent if the test participants had been given the possibility to practice the gestures for a longer period of time. Due to the short training-period included in the experiments, most of the participants did not reach a level of proficiency where they could work comfortably. A certain learning effect can already be observed from the tests results. In the following the seven different gestures supported by the system are described and illustrated (see figure 3). In the pictures, the arms/hands drawn using non-dashed lines indicate the starting position of the gesture, and the ones drawn using a dashed line indicate the second 'anchor point'. The performance technique is described in more detail in the text. All gestures are performed with the right hand/arm.

Up: In order to make the cursor in the document browser move one document up, the user has to hold his right hand out slightly in front of him with the edge of the hand (the one with the thumb) towards the ceiling. After holding the hand still for a moment, the user then has to move the underarm upwards, using the elbow as a pivot point, and then back to the starting position (see figure 2a).

Down: The gesture used to move the cursor down one document follows the same principle as the up-gesture described above. The only difference is that the movement goes down first and then upwards (see figure 2b).

Open: To open the currently selected document, the user must again hold the hand out slightly in front of him with the thumb-edge to the ceiling, and then move the underarm using the elbow as a pivot point to the left and back (see figure 2c).

Close: When the user wants to close a document, he has to hold the arm/hand slightly horizontally angled to the left and then move it, using the elbow as a pivot point, to the right and back (see figure 2d).

Activate: In order to activate the system, the user has to let the arm hang straight down then direct the back of the hand of the hand to the front and then rotate the wrist clockwise twice (right-left-right-left, see figure 2e).

Deactivate: Similarly to the activate-gesture, the deactivate-gesture is performed by letting the arm hang down. However, the thumb-edge of the hand must be directed to the front, and the wrist should be rotated counter-clockwise twice (left-right-left-right, see figure 2f).

Record: In order to start entering/recording an examination request, the user has to move the hand from a hanging position to in front of his ear and hold it still (see figure 2g).

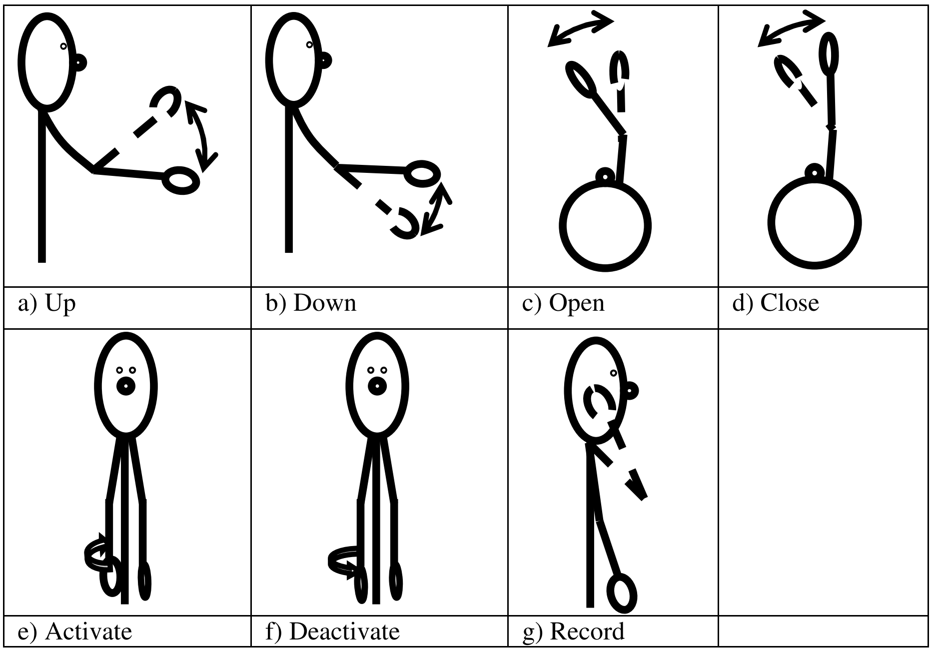

Figure 2: Principle performance of the gestures

General issues with the performance of gestures

Shape: Many doctors had problems performing a gesture without striking out in the other direction first in order to 'get power' for the movement. This often led to a situation where the 'opposite' gesture was recognized, i.e. for example that the cursor moved up instead of down or vice versa. This issue was mainly caused by the fact that the doctors had no direct feedback, i.e. the effect of striking out is not perceived while doing it only the end-result is seen.

About half of the doctors sometimes forgot to perform the second part of the gestures, i.e. the movement back to the original position. We believe this was a result of the back-movement going in the direction opposite of the effect wanted, which was not intuitive. This is the case at least for the up-down gestures, i.e. in order to move the cursor up, one must move the hand up – but then also back down to the original position.

Timing: Many of the doctors had problems performing the gestures in the right tempo. Most frequently, they carried them out too slowly, i.e. under the threshold speed defined in the gesture recognizer. However, a clear learning effect was observed from the beginning of the experiment to the end. In the initial practice phase, 5 doctors performed the gestures too slow, while during the third and last experiment task, only one doctor made this mistake. Some doctors also performed the gestures too fast to be recognized.

Conceptual*:* Most of the doctors at some point confused the gestures. A couple at some point forgot completely how to perform a gesture, or at least had to think for a long time before remembering it. Most confused the 'paired' gestures with one another, for example 'open' with 'close' or 'activate' with 'deactivate'. After a bit of practice, however, the confusion decreased, and in the last phase only one doctor confused the gestures with each other. The 'up' and 'down' gestures were rarely confused at all.

Issues concerning the de/activation gestures

Conceptual: The de/activation gestures were most frequently confused with one another. One reason for this might be the similarity between these two gestures. The only difference is the direction of the first and the last movement, while the movements "in between" are rather identical. While some doctors found a metaphor by which they were able to remember the two gestures (turning water on and off) this was not the case for all the doctors. Another obvious reason for the confusion was, as mentioned by a couple of doctors, that the de/activation and open/close gestures were crosswise illogical (for example, the direction for deactivate and open was the same). Although most doctors had learned the difference at the end of the experiment, at least one solved the problem by simply turning the wrist back and forth at random and just hoping to be 'lucky' enough to have the right gesture recognized. Admittedly, this strategy worked quite well.

The most frequent problem observed, was that the de/activation gesture was completely forgotten, i.e. the doctors tried to interact with the system without activating it or started with non-system-related activities (like examining the patient) without deactivating it. We find this was due to the experiment context which was not realistic enough in terms of other activities involving the hands. For example the test did not contain a full patient examination (most doctors only symbolically touched the dummy patient when asked to do so) or lively communication with neither nurses, colleagues, nor the patient. Consequently, doctors did not really see a need for the de/activation action and thus forgot about it.

Issues concerning the up/down/open/close gestures

Shape: Many of the doctors made the gestures larger than necessary. Consequently the acceleration pattern created in connection with the larger movements did not always correspond with the pattern defined in the system and the gestures were frequently not recognized. We believe extensive practice could reduce the unnecessarily large gestures.

There were several beginner mistakes related to the position of the hand and/or arm. For example, holding the arm stretched and performing the gesture with rotation from the shoulder instead of from the elbow, keeping the arm completely still and trying to move the wrist and hand only, keeping the hand bent in a strange angle, holding the hand with the palm down when performing the up/down gestures. Most of these mistakes were only observed occasionally and only in the first stages of the experiment.

Timing: Occasionally, a doctor did not leave enough time between the gestures for them to be recognized 'individually'. Usually, this happened when the doctor wanted to scroll down or up in the document list or inside a document, and was slightly impatient. In addition the break made between the two halves of a gesture tended to be too long, resulting in the system not recognizing that the two halves belonged together. At the initial stage of the experiment, about half of the doctors made this mistake. At the last stage, however, the problem was not observed at all.

Conceptual: At the beginning of the experiment, several doctors confused the 'open' with the 'close' gesture. Similar to the probable reason for the confusion of 'activate' and 'deactivate', it seems there is no intuitive metaphor to help remember the direction of the two gestures. However, at the end of the experiment, nobody confused 'open' and 'close' anymore.

Qualitative results concerning practical interaction

In this section, the results collected through questionnaires, interviews and comment are described and discussed.

General use

When asked if they would use a system such as represented by the prototype, the doctors were hesitant. Most likely, this can be explained by issues connected to the novelty of the gesture interaction and its major part in the prototype. Several doctors were reluctant to the idea of performing gestures in front of the patient, concerned that they would be perceived as ‘crazy’ or ‘strange’, ‘waving around’ with their hands in the air. Also, there were concerns that the interaction with the document browser would take away too much attention from the patient. However, several doctors could imagine using gesture interaction ‘if the gestures were smaller and/or more elegant. Further, there were several positive comments on the use of touch free interaction from a hygiene perspective.

The nurses were generally very positive about using the PDA. It should be said, however, that the nurses had quite a small role in the experiment and their tasks were not very extensive. Further, the time pressure that is often present during a real ward round was not part of the experiment setting.

Interaction control and comfort of use

Most doctors did not feel they had the system under control. Most of the negative comments were about the gesture interaction, while the dictation part got positive mentioning. Though feeling not in control having to concentrate heavily on the systems, most acknowledged that with time and practice control over the system should increase.

The doctors’ subjective answers regarding how easy and comfortable it was to perform the respective gestures mirrored the observed performance quite well. In average, they felt that the ‘record’ gesture was the easiest to perform, followed by the ‘open/close ‘and ‘de/activate’ gesture. The ‘up/down’ gestures were found to be the most difficult. Some claimed that the gestures were a physical strain on them and that their hands were cramped after the tests. It is possible that after constant training on the system the cramping would stop, however, this is a matter that requires further research. One doctor did not like the feeling of the device on the skin and warned that the system should be designed to be worn on all kinds of clothes in order to permit doctors to freely wear what they want. Another personalization aspect requested by a few doctors was that the system allows each doctor to keep their own personal way of conducting the ward round.

The nurses all felt they had the PDA under control. The comments revealed that they found the interface easy to understand and the touch screen interaction simple to perform. In addition, most of the nurses thought it was fun to work with the system. Many had a problem using the interface buttons, which were to be pressed by the tip of a finger. Since the buttons on some screens were separated by a small distances, in some cases a wrong button was pressed resulting in the comment ‘my fingers are too big’. Furthermore, some of the nurses requested clearer feedback after pressing a button. The feedback used was that the buttons turned a darker shade of the original color when pressed. This may have been difficult to see, depending on the light conditions in the room. Further, more than one nurse commented on the lack of a ‘back’-button to make it possible to return to the previous step in the request. There was also some confusion as to what was left and right on the initial screen showing the contours of a human, allowing for the selection of body parts.

All nurses also found the PDA physically comfortable to handle, stating that the PDA is small, compact and handy and fits well in the hand. One nurse expressed the need for some kind of a carrying system (belt or the like) where the PDA could be put away when not in use, as she felt the system was too loose when lying in the pocket of the gown.

Suitability of speech input for entering examination request

Almost all doctors agreed that speech input was a suitable method to perform the examination request. We find this is as a result of doctors currently dictating the examination request to the nurses who write down the information. There is no great principal difference dictating to the system instead of the nurse.

Position of bedside display

Most doctors said that the position of the bedside display at the foot of the bed was good and that they could see the information on the screen from any position (after turning the swivel arm). The doctors commented that it was good to be able to easily show the patient the screen and involve him/her more in his/her own treatment. Also, the potential parallel function of the display as a TV/patient computer for Internet etc. was mentioned as a plus for the foot end position. However, it was noted that when the doctor sits/stands beside the bed, s/he has to turn his/her head away (direction foot of bed) from the patient in order to look at the display. This could possibly make the patient feel neglected. At least one doctor proposed to place the display at the head of the bed, so that only the gaze had to be turned away from the patient when interacting with the screen. Using the swivel arm, the patient could still be able to look at the screen. One concern was also that it would be difficult for the doctor to control the swivel arm him/herself when standing at the head of the bed. Most doctors had no problem seeing the information on the display from any position at the bedside.

Ideas for alternative interaction methods

Doctors and nurses alike commented on the need of smaller gestures that are more inconspicuous. They also observed that the whole system should be smaller, around the size of a watch. Many doctors and nurses suggested that as an alternative to the gestures, a touch screen would also be a solution for navigating through the patient documents. They remarked that a touch screen would be easier and more intuitively useable. However, a touch screen would not be 'touch free' and thus would require much more frequent disinfection of the hands than the gesture interaction. Also, speech interaction was suggested by many doctors. They found that voice would enable them to look at the patient in all positions and actions while accessing information. According to the doctors, this type of interaction would not scare, bother or be strange to the patient. More difficult patients, such as children, would not be able to "mess" with the system in this way.

Summary and conclusion

Social computing

The hospital staff members who tested the wearable expressed an interest in this technological innovation, and stated there was a true need to improve the current work process. They found the system could assist in diminishing paper work, could enhance collaboration, could help create a more autonomous nurse and could help patients be more involved in the ward round. However, even though a true need for assistance and change is found in the ward round, some interviewees stated pertinent concerns regarding the implementation of the wearable. Some of the reasons for these concerns have been addressed here, and we feel that they must be dealt with the utmost importance and thought, so as to prevent the automatic rejection of the system.

In addition, although positive responses to the overall system were found, some interviewees expressed scepticism regarding the gesture controlled navigation system, which they feel will not only hamper their relationship to patients, but also require extra concentration and effort from them. One option is to offer more training on the gestures, which should allow smaller and less noticeable movements. Another option mentioned before, is that of a touch screen or a voice recognition system, which many interviewees feel would be easier to use and less obtrusive to doctor and patient contact. Furthermore, we found that the navigation system should be accessible to the nurses as well; allowing them to assists doctors as they already do today.

In order to implement wearable computers in the hospital, or elsewhere, new norms of behaviour should be established that take into consideration the new interactions that are facilitated by the device. These norms serve as guidelines of how people work together and behave when socially interacting. This code should combine lessons learned from other ICTs used in the hospitals, such as personal phones or laptops. For example, when a doctor is in the operating room an automatic message on the screen will inform the caller the doctor may not be available for the next two hours and direct them to call later. In future tests it would be of great help to have the presence of real patients so as to learn of their feelings and reaction to the use of the wearable computer by the staff.

System Usability

The intrinsic features of the system, i.e. accessing the latest patient information through touch-free interaction at bedside and the possibility to immediately enter examination requests created positive response concerning most practical usability issues. Speech interaction was found by the doctors to be a good method to enter examination requests, and the nurses all found the handling of the PDA to be easy and comfortable. Also, the bedside display was considered helpful to involve the patient in the discussion about his condition. The gesture interaction used to navigate the patient documentation was – as expected – the most critical part of the system. Due to the novelty of this interaction technique, the test participants had problems learning how to use it efficiently. Mistakes in gesture shape and timing were made by all doctors to some degree. Further, the gestures were sometimes conceptually mixed up. Although these problems were quite frequent, most were beginner mistakes which would disappear or improve with more training. Even in the short duration of the experiment, a learning effect could be observed for most of the problem types. Nevertheless, there are features of the gesture interaction that could be optimized for more intuitive use. Providing the user with direct feedback of system status seems to be one of the most important improvements needed.

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