Pervasive Pain Monitoring System

User Experiences and Adoption Requirements in the Hospital and Home Environments

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Abstract— **We have developed a new, pervasive system for the monitoring and recording of subjective pain experiences. The system was tested in six healthcare organizations. The testing covered 27 personnel members and 27 test users. During the field testing of the pain monitoring system, we studied the user experience from the perspective of patients and nursing personnel. The study also focused on the system's adoption requirements at home and in the hospital environment. The pervasive pain monitoring system increased the test users' feeling of security and supported their experience of continued treatment. We noticed that the experience of care supports and that acceptance requires observing the users' physical and psychological capacities. The pain meter and patient application supports a patient's pain treatment of acute and long-term pain in hospital conditions and in follow-up treatment at home. It also promotes continuity and enhances the availability of treatment. Also, a clear connection was found between the users' technical abilities and their willingness to start using the system.**

Keywords-component; pain; technology acceptance; user experience; design; environmental factors; egolocical theory

I. INTRODUCTION

Pain manifests itself as a subjective feeling and a source of problems in everyday life. According to the International Association for the Study of Pain [1] pain is an unpleasant sensory and emotional experience related to past or potential tissue damage or it may be described through the concepts of tissue damage. Due to the nature of pain, the starting point of its treatment is a person's subjective conception of his or her pain. In pain measurement a patient's subjective pain experience is converted to and recorded as a numerical value, from which it is possible to assess e.g. the treatment response of analgesics and the effect of other pain treatment methods and to improve the quality of treatment. Presently, a hand-written pain diary is often used in home conditions. Even hospitals are using systems based on multiphase, manual recording, which increases the workload of nurses.

Our system consists of a patient's terminal, nurse and administration applications on a mobile phone, and an access point. The patient's terminal may be either a cell phone with a patient application or a handheld device designed for this purpose. In this study the handheld device is referred to as the *pain meter*. Patients can report their subjective experiences of pain in real time even if there are no nursing personnel nearby. The system can be used anywhere and anytime. The information is sent to the nurses' cell phones and it is stored on a server. The administration application is used to follow long-term developments and to examine pain levels as a graphical view. The users of the service concept may consist of hospital patients, persons living at home, or persons living in a sheltered home. The pain monitoring system was tested within the nursing processes of six organizations. The testing focused on the system's applicability to the treatment and management of pain in different environments. Further, the user experiences were examined from the viewpoints of nursing personnel and test users. This research investigates the adoption requirements of the pervasive pain monitoring system in hospital and home environments. Detailed usability issues and quantitative data are not discussed in this paper as the qualitative approach was selected for this research. Answers were sought to the following questions:

- How is the system experienced in hospital and home conditions?
- How can we support the adoption of a new healthcare application in the hospital and home environments?

The article first gives a short description of the challenges related to the assessment of the subjective experiencing of pain. After this, the factors influencing user–product interaction and the challenges of user experience evaluation in varied surroundings are discussed. The following chapter gives a more detailed description of the system, and thereafter the research material and methods are presented. The final two chapters contain the findings from the study and a discussion of the user experiences and adoption requirements in the hospital and home environments.

II. BACKGROUND

Due to the multidimensionality of pain there are very few objective means to demonstrate the sensation, and therefore its recognition may remain deficient. Individual pain treatment means that each patient's situation is assessed in terms of the focus of the monitoring, the goals or the treatment, and the

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potential obstacles [2,3,4,5]. In both acute pain and long-term pain effective treatment requires systematic monitoring and measuring of pain.

Pain is an individual and personal experience for everyone. It may therefore be difficult to describe it in such a way that one feels like being understood by others. There are various clinical measuring devices that are based on the patient's description of the nature and intensity of pain. With the help of these devices we can understand better the experience of pain and develop its treatment. Meters are mostly one-dimensional – designed for measuring pain intensity. The Visual Analog Scale (VAS), that is, the pain score, has proven its reliability in the measurement of both pain intensity and treatment response [2] especially when repeated; it yields valuable information on the success of pain treatment. Together with the VAS scale or as its alternative, a verbal or numeric scale can be used [6]. Pain recording is important in the development of patient security, the patient's and personnel's legal protection, and the quality of treatment. According to the Ministry of Social Affairs and Health Statute [7], the essential records on the arrangement, planning, implementation, and follow-up of treatment must be entered into patient documentation.

The measurement of pain at home is problematic. When pain is long-lasting, the effect assessment of different treatments (medicine or other treatment) should be done regularly and in normal life situations in order to work out the causes and situation of pain as reliably as possible. This type of monitoring calls for methods, which are applicable in both hospital and home conditions. End user research on equipment used in healthcare and hospital environments is challenging due to the special requirements of these user environments. We should therefore understand the basic elements of the product-user interdependence in order to evaluate this interaction. Norris and Wilson [8] have presented a model depicting factors influencing the interdependence between the user and the product. In their model the basic elements of the interdependence are: product features, user characteristics, environmental factors, and usage.

Buchenau and Fulton Suri [9], on the other hand, have stated that the key element of user experience is dynamic interaction, which is formed through the product-user interaction between the user, the product, and the environment of use. The interaction becomes concrete through usage in particular. Similar models of the key elements of interdependence have also been introduced by other researchers [10, 11]. Forlizzi et al [12] have presented an ecological approach to research on the experience of aging. It helps in examining the interaction between people, products, functions, and experiences. The components of the ecology of the aged are humans, the product, the constructed environment, and the community. Several researchers [12,13,14,15] have constructed environmental classification systems in which the common denominator is the number of environments or systems covering at least three levels. The different levels of these environments can be classified coarsely as follows: 1) private/personal level, 2) semi-public/group level, and 3) public level / level of organizations and communities.

The framework of the study is presented in Figure 1. Study settings are based on model on factors influencing the interdependence between the user and the product [8]. Basic elements of the interdependence are: product features, user characteristics, environmental factors, and usage. In the study special attention is paid to environmental factors in product-user interaction. In this study environmental factors are inspired by Bronfenbrenner's ecological theory [13].

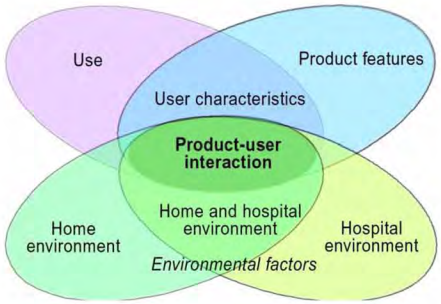

Figure 1. The framework of the study

In this research, the user experience was examined in both the hospital and the home environment. The home environment represents the private-level environment. The hospital is defined as a semi-public environment. It brings together a patient's relatives and the nursing staff; combined with the patient, these three form a unique environment of its own. Compared to a hospital, a sheltered home resembles the home environment because its users have the option to be in charge of their own apartments. On the other hand, the sheltered home has semipublic, common spaces and therefore the private and the semi-public environments unite in these facilities. Healthcare resources and the organizations providing them represent the public and organizational level in this study.

III. THE PAIN MONITORING SYSTEM

The pain monitoring system contains wireless terminals for the patients and nurses and a server mediating messages between these terminals and storing reported pain values. The most important service that the system offers to its users is the real-time delivery of reported pain values from patients to nurses. Nurses can also send responses back to the patients, or send, for example, a request to report the pain value. Patients can either use a pain meter (Figure 2), a special device designed for this single application, or a mobile phone equipped with a patient application (Figure 3).

Figure 2. The pain meters

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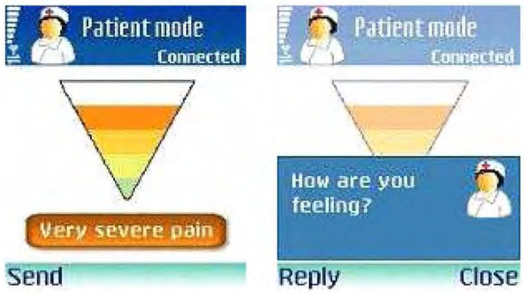

Figure 3. Screen shots of a patient application

We selected a six-level scale for the pain values. A zero to ten value scales is used in many hospitals, but after consulting nurses and doctors we decided to use six different values for pain. We hypothesized that it is easier for the patients to differentiate six pain values and that this resolution is adequate for the nurses. These values have clear textual descriptions that can be explained to the patients. The descriptions help to select the correct value and to minimize the patients' memory load. In addition, the patient application provides the previous pain rating as a memory help to the patient. The latest pain rating can be seen until the value is changed. The pain values were described textually for the patients. For the nurses, the values were shown on scale [0-10] as shown in table 1.

Table 1: The pain values

Textual descriptions for the patients	Numerical values for the nurses
No pain	0
Mild pain	2
Moderate pain	4
Severe pain	6
Very severe pain	8
Worst possible pain	10

The pain meter device contains only six buttons and no display. Each button is associated to a pain value. The patient application running on a mobile phone displays a pain scale on the screen and the user selects a pain value using the keypad.

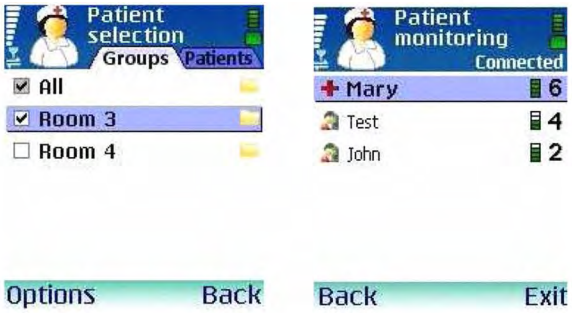

Figure 4. Screenshots of a nurse application

The nurses use a mobile phone equipped with a nurse application. The main screen of nurse application shows the list of patients that this nurse has subscribed. Each patient line contains a status icon, patient name, the battery status of the patient device, and the latest reported pain value (Figure 4). In addition to real-time monitoring, nurses and other staff can study pain value trends and administer the system using the administration application that is run on a desktop computer (Figure5).

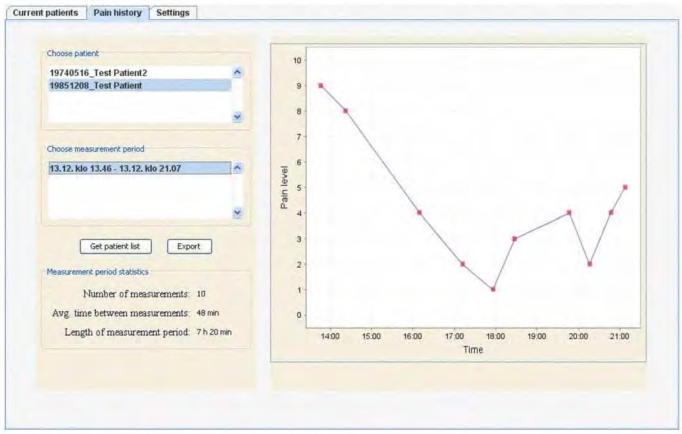

Figure 5. Screen shot of the administration application

The system architecture is shown in Figure 6. The pain meters are connected to the access points with a short-range, low-power wireless radio. The access points, in turn, communicate with the server over either a wired LAN or a WLAN connection. The patient and nurse applications run on mobile phones that have a GPRS connection to the server.

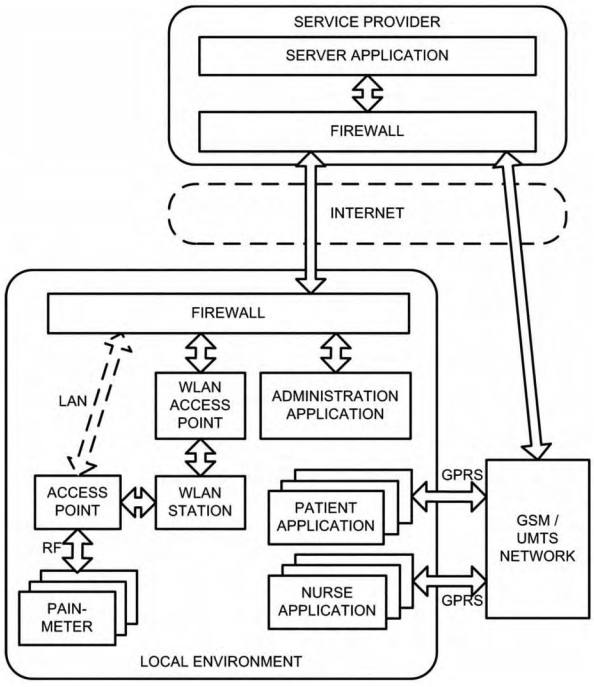

Figure 6. System architecture

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IV. Material and Methods

A. Procedure

Twelve pain meters and four access points were made for system testing. We also installed the nurse and patient applications into 15 Nokia phones (Nokia 6630 and 6600). Eight testing cycles were carried out in six organizations (university hospital, central hospital, private hospital, health centre, rehabilitation centre, and sheltered home). The first six testing cycles were carried out in spring 2007 between March and June. The last two testing cycles were run in October 2007.

The test users were selected from among the normal patient flow in the hospitals and health centers. Adequate motor and cognitive abilities were defined by the personnel as the selection criteria for the test users. Nurses selected patients for the study based on defined criteria's. The nursing personnel told the patients about the possibility to participate in the testing. This was done during hospital reception interviews or some other convenient situation within the treatment process. The researchers taught the personnel how to use the system, and the personnel taught the test users how to use the equipment and assess the pain. We wrote a user manual for the nurses and they also practiced using both patient and nurse devices before the trial started.

The ethical committee statement was not requested for the study as physical inviolability was not threatened and we did not depart on the principle of personal conscious approval of participation. The ethical instructions set by the Finnish National Advisory Board on Research Ethics in human sciences [16] were followed in this research. We performed qualitative research and applied these ethical intructions in gathering and analysing data. Acceptability, reliability and credibility of findings in the scientific research presume that the research is in accordance with the best research practices.

As this is a sensitive research topic we took special attention to the patients' personal conscious approval of participation and to respecting patients' rights. In addition, special emphasis was placed on the humane treatment and privacy of the informants. The participants agreed to take part voluntarily and signed an agreement. The organisations where the research took place also signed agreements for the research. The researchers did not meet the test users at any point. During testing, the test users were identified using alphabetical codes. The implementation of the testing was carried out by the responsible nurses of the organizations. In problem situations the test users primarily contacted their personal nurses, and the nurses, in turn, consulted the researchers when necessary. In a few cases there was a technical problem that the nurse and the test user could not solve. When such a case occurred, a researcher would call the test user and solve the problem at hand.

The study was carried out as an additional operation which was included in the normal nursing processes. Goals, methods and rights of the participants were explained to all patients. It was made sure that the participants of the recearch knew what the testing was about and how it affected their pain treatment. The pain meter did not replace any routines in patient care done by the medical doctors. The pain values provided by the system were not used in clinical decision making and no treatment decisions were made before a nurse had discussed with the patient in question. The pain values provided extra information to the nurses. In addition, the hospitals own alarm systems were normally available during the tests.

B. Methods

Qualitative approach was used in this study. Qualitative approach is to get an in-depth understanding of human behavior and in addition, try to find the reasons for such behavior [17,18]. The purpose of analyzing qualitative material is to make the material more clear and distinct. The discipline investigates the why and how of decision making, not just what, where and when. Hence, smaller but focused samples are more often needed rather than large random samples.

At the end of the testing cycle the nursing staff interviewed the test users either during check-out or as a phone interview when the test user was already at home. The interviews were conducted using the methods of theme interviews. All the interviews were recorded and transcribed for a later analysis. After that, emerging themes and patterns were identified and the material was organized into meaningful gategories. Whole thought concepts were used as units of analysis. The transcribed material was encoded using Atlasti [19] – a program designed for the processing of qualitative material.

C. Material

The material of the study is formed by the transcribed interviews of 27 test users (table 2). The test users included persons with leg fractures requiring acute operative treatment and patients checking in for previously agreed end prosthesis treatment or vascular surgery. In addition, the testing covered cancer patients as well as pain patients and sheltered home occupants taking part in group rehabilitation.

Table 2: Testing environment, patient details, quality of pain, and operation

Organi-zation	users	women	men	Mean age (range)	Quality of pain, Operation
Central Hospital	4	1	3	67,5 (42-85)	Cancer pain, Operative treatment
Health centre	2		2	47, 5 (38-57)	Long-term pain, Post operative monitoring
Private hospital	4	2	2	52,5 (44-60)	Acute pain, endoprosthesis surgery
Private hospital	4	3	1	56,3 (43-66)	Acute pain, endoprosthesis surgery
University hospital	2		2	64 (62-66)	Acute pain, lower limb fracture
University hospital	2	1	1	48,5 (44-53)	Acute pain, vascular surgery
Rehabilitation centre	7	6	1	48,6 (42-54)	Long-term pain, rehabilitation course
Sheltered home	2	2		79 (76-84)	Long-term pain, supporting older people
Total	27	15	12		
Mean age (range)		55 (42-84)	60,5 (38-85)	57,9 (38-85)	

Feedback from the nursing staff was gathered in group discussions. The group discussions were held between 27 persons who had been responsible for the test adoption and test

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user interviews in their units. Every group consisted of 2 to 5 persons. The participants included 4 doctors, 19 nurses of whom three had specialized knowledge on pain treatment, 2 practical nurses, 1 physiotherapist, and 1 occupational nurse. The mean age of the testing personnel was 40.6 (ranging from 29 to 53). There was only one male participant among the nurses. As background information, the personnel were asked to state their own opinion on their skills in using a mobile phone. The majority (59%) considered their skills to be good, while minority (41%) considered them satisfactory.

D. Testing environments

The environments in which the testing was carried out can be grouped to the 1) home, 2) hospital and 3) both hospital and home environments. Table 3 shows the number of the users and tested applications in different environments.

Table 3: Number of the users in different environments

	Pain meter	**Patient application**	**Total**
Home environment	2	2	4
Hospital	11	1	12
Hospital and Home		11	11
Total	**15**	**12**	**27**

1) Home environment

The target group consisted of aged occupants at the sheltered house. Two women age of 76 and 84 in need of pain treatment were chosen for the testing. The test users used the pain meter for three days. The test users were selected in cooperation with the staff of the sheltered house. The second testing at the home environment was carried out in cooperation with the health centre. Two men under age of 38 and 57 from health centre took part in testing. The test users were shown how to use the patient application when they visited the health centre. They used the patient application at home for a week by reporting their pain levels three times a day. The nurses acknowledged the pain values only during office hours. The pain values received outside office hours were checked each morning.

2) Hospital

At the hospital four test users of the pain meter and patient application were patients in a university hospital. Two women age of 62 and 66 who had lower limb fracture were chosen to test pain meter device. In addition, men and women age of 44 and 53 who were waiting for vascular surgery and whose treatment period was at least three days were chosen. In the testing, another patient used the pain meter and another used the patient application for one week. The test users reported their pain level when necessary. The second testing at the hospital environment was the recovery department of a private hospital. In the recovery department and ward, three men and five women aged 44-66 recovering from endoprosthesis surgery used the pain meter during their treatment period. In both the recovery department and the ward the test users reported their pain levels when necessary or at the nurse's request.

3) Hospital and Home

Long-term pain patients participating in a rehabilitation course and residing in the centre for a period of one week took part in testing at the hospital and home. The test users were in the working age, men and women 42-54 years of age. Six women and one man tested the patient application on a mobile phone for a period of two weeks. During the first week they used the application while on the rehabilitation course and during the second week they used it at home. In the rehabilitation centre the pain levels were reported four times and at home three times a day. The nurses carried the nurse application with them 24 hours a day and seven days a week.

Another group of test users at the hospital and home were cancer patients from the Central Hospital. Three men and one woman aged 42-85 started using the mobile phone patient application in hospital, and after returning home they continued using it for approximately a week. In hospital the pain values were reported every two hours or whenever necessary 24 hours a day. A zero to ten value scale was used in the Central Hospital. After the patients had come home, they reported their pain values three times a day.

V. RESULTS

The following results were obtained from the recorded and transcribed interviews and group discussions. Both patients' and nurses' appreciations on the pain monitoring system are presented. The results are classified under the model presented by Norris and Wilson [8].

A. Product features

The pain meter's user interface was found to be easy to use. The pain meter was, however, commented to be slightly too wide to be held conveniently in hand. The width of the case was constrained by the width of the circuit boards. We hypothesized that it would be easier for the patients to adopt a scale of six pain values. This hypothesis was supported by the nurses who had used both six-level and ten-level scales.

According to the nurses, the simple looks of the pain meter support its use and encourage the reporting of pain values. They also thought that the meter is suited for a larger number of users because of the easy to use interface. The pain meter had no text message function, which was assumed to lower the threshold to start using the device. The pain meter was considered useful in the treatment of both long-term pain and acute pain. Uncertainty of the success of the pain data transmission was considered to be a problem with the pain meter. The pain meter gave insufficient feedback on the success of the pain data transmissions. However, the pain meter responded quickly to button presses. Roundtrip- time to the access point was about 25 milliseconds and to the server about 0.6 seconds. On the other hand, the nurses point out that the pain meter does not provide enough communication possibilities. A diverse interaction possibility was considered necessary in patient–nurse communication. Hence, messaging features in the patient application were seen as a great opportunity among the patient who has sufficient skills to use text messages. A user in a poor condition may find diverse interaction possibilities too complicated; in such cases the mere reporting of pain might suffice.

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In one case the thick walls of the old hospital building (some concrete walls are over 50 cm thick) reduced the operation range of the access points but otherwise the system worked as expected. In the beginning, the mobile phone's GPRS connection dropped for some reason. Sometimes the connection worked for several days before failing, sometimes it was broken faster. This problem was solved by modifying the application to reconnect the phone automatically to the server without notifying the user. The applications running in mobile phones operated well, the only problem was the one related to GPRS. As the applications do not require heavy computations or complex GUI, and also the amount of communicated data is small, the applications do not stress the mobile phones very much. The round-trip-time between the server and mobile phones was between 0.5 and 1.2 seconds, depending on the mobile phone network and application.

B. User characteristics

The users of the pain meter had feelings of uncertainty when expressing their pain experience. The uncertainty was primarily related to defining one's own pain level, not to using the device itself. The test users had felt that the nurses were not always committed to using the system at the private hospital. Some of the patients' comments also suggested that they doubted whether the pain meter was worth using at the hospital. In particular, people wondered about the benefits of the pain meter in comparison to the traditional buzzer in the hospital environment. The majority of the test users, however, noted that the pain meter and the patient application strengthened their feeling of security and experience of care. The system also reinforced the feeling of proficient care. The pain meter and the patient application supported the patients' feeling of security because it provided a direct connection with the nurse. Interactivity was experienced as an especially positive issue. On the other hand, one also expected a quick response from the nurse to a sent pain message. Too slow a reply could even induce a feeling of insecurity.

There were distinct differences in the test users' attitudes toward the patient application running on a mobile phone. Especially technical problems were handled in a variety of ways. Some of the testers got frustrated quickly if the device created problems. The most patient testers solved problems by themselves or contacted the given service numbers and then continued the testing. To some patients, the mobile phone was even somewhat intimidating if they could not use it well enough. Loss of control may induce a rejection reaction, which might be prevented by providing proper instructions to the user. The possibility to send text messages seemed to disturb many test users of the mobile phone application. The users doubted their own skills in messaging and were afraid of it, which created reservations toward the patient application. These test users were not used to writing text messages. This type of reticence was not detected among the pain meter users. According to the nurses, all extra applications and functionalities should be removed from the mobile phone to avoid problem situations. Personal contacts to the service provider and support systems were considered essential. It was also observed that these contacts clearly supported the use of the equipment.

C. Environmental factors

In general, people were willing to use the patient application both at home and in hospital. In the home environment, the users considered the documentation of pain to be the core benefit. The system's ability to convert invisible pain into a visible format was therefore considered important. The users noted that the contemporary treatment processes do not support the system's adoption enough in the home environment. A lack of resources was mentioned as a concrete factor that may slow down the adoption of the pain monitoring system. When benefits were discussed the test users repeatedly brought up the sharing of experiences. They felt that sharing an experience of pain with another person supports using the system. Using the pain meter at home for an extended period was also experienced as an extra burden and arduous experience. Especially the additional care required by the pain meter, the charging procedures, and the pain value transmissions were experienced as a burden. Temporary use, on the other hand, posed no problems. The continuous monitoring of pain levels made the users think about their experiences of pain. Thus, the pain meter was, in a way, a continuous reminder of one's pain.

Besides usage instructions on the actual equipment, the adoption process should also include stronger motivation to start using the new system. Further, the nursing staff wanted the superiors to state clearly how the system would support the work done in the organization. According to the nurses, pain metering increases the work load, but on the other hand and regardless of this, some organizations considered it a top priority to develop the efficiency of pain recording. The pain meter may encourage people with activity limitations and moving difficulties to continue living at home. In the nurses' opinion the mobile phone is clearly better suited for home use, whereas the pain meter has more potential in the hospital environment.

D. Use

The nurses were willing to use the pain monitoring system if it supports their work and if the resources drawn by it will be regained one way or another. In some cases the patient orientation process was so tedious that one hoped for a sufficiently long pain metering period to compensate for the lost resources. In the users' view, the user instruction left much to hope for. More than anything, they wanted more time for practicing before use and individual, hands-on guidance.

The nurses evaluated the pain monitoring system to be useful. They commented that the system saves their time because when a patient needs medication they need to visit the patient only once: they receive a message from the patient and they can fetch the medication before they go to see the patient. Some nurses even invented new ways of using the system; when new patients arrived into their ward, they sent greeting messages to the patients using the nurse application. The nurses wished for the integration of different systems and the avoidance of overlapping recording. Up to this date, pain levels have been entered manually into patient records. The nurses requested a quick change to this practice. In addition, logging into the systems should be as simple as possible. The system login procedure was also seen as a threat to implementation.

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Information security issues should be handled in such a way that a minimal number of usernames and logins are needed in healthcare institutions. The nurses' mobile phone handling skills were considered to be of crucial importance in the implementation. There were many references to the nurses' being afraid of system malfunctions after erroneous use. The nurses stated that in order to successfully implement the system the users' physical and psychological capacities must be observed. In this study, knowing how to send text messages was the indicator of sufficient technical skills. In short, benefits and technological skills by and large define the willingness to implement a system. Using the mobile phone application in a versatile way was considered far more challenging than using the pain meter in the evaluation of pain. The greatest potential was found in the follow-up treatment of patients who have been sent home after surgery. However, the use must be based on voluntary action in all cases. This clearly supported the implementation.

VI. DISCUSSION

According to the results, using the pain meter and patient application in the treatment of acute and long-term pain in hospital conditions and in follow-up treatment at home supports a patient's pain treatment. It also promotes continuity and enhances the availability of treatment. The present research suggested that the feeling of security created by the pain meter could even decrease the experiencing of pain. The registration of pain data into existing systems is one of the greatest challenges in the concept's implementation. Hospitals already have several overlapping systems requiring logon procedures. Full exploitation of the pain monitoring system is not possible unless existing processes are changed in a way that enables the integration of pain data into other patient data systems. The adoption of the system also requires pain treatment-related training and motivation. We hypothesized that it would be easier for the patients to adopt a scale of six pain values. This hypothesis was supported by the nurses who had used both six-level and ten-level scales. The learning and teaching processes were easier to carry out using six pain values instead of ten.

The test users were rather old in this study. In the results, this is manifested by the difficulty using a mobile phone, for instance. Especially writing text messages proved to be a problem of surprising magnitude. We suppose that the younger generation won't face problems with text messaging. The test users were chosen from among normal patient flow during the testing period. Thus, the age scale represents well the actual patient base in hospitals. We did not make any extra arrangements in order to get younger patients involved in to the study. The testing was based on voluntary participation, so in that sense the group of patients is a selection of individuals. We suppose that the younger generation won't face the problems with text messaging.

Even though, the pain meter was considered to be simpler as a concept and more user-friendly as a terminal than the mobile phone. On the other hand, the patient application was seen to have better potential for wide-scale usage at the home environment. As the patients' own cell phones can be used, implementation of the pervasive pain monitoring system would be easy to carry out.

Research results indicate that adoption of a new healthcare application in the hospital and home environments can be supported by ensuring that key actors receive sufficient training before new systems are implemented. If a system is still under development, as is the case here, it must be explained to everyone participating in the testing process. Otherwise the participants may have too high expectations on the system's functionality. Healthcare environments set challenges to the developers of technologies. For example, the present project emphasized privacy to such an extent that the researchers never met the patients; instead the nursing staff communicated with the patients.

Before integrating systems into treatment processes, the reliability of the technologies should be ensured through sufficient piloting. Technical problems reduce people's trust in a pilot system. Testing is the only way to influence the creation of the best possible first impression in an authentic environment in which one deals with people requiring treatment and care. We tested the system extensively before field tests and the system behavior was monitored continuously during the field tests. After correcting few minor technical problems at the beginning of the first field test, the system functioned in a reliable fashion.

Carrying out a user study in the hospital environment also requires special carefulness and emotionality from the researchers. A reliable study of user experiences requires the observation of a variety of user environments. This is not often possible in practice. Therefore, the differentiation of user environments into private, semipublic, and public environments appears to be a promising way to analyze contexts of usage. This classification lays a good foundation for assessing pervasive systems from many different angles.

The study created several new challenges for further research. There is reason to study the difference between reporting a pain experience directly to a nurse or doctor and reporting it via a technical device. We decided to focus in this study on good usability. Hence we implemented the simplest possible functionality to both the pain meter and the phone application. Although the system proved to be robust we need to consider how to minimize the effects of malfunctioning and human errors to patient care. In this study we considered human errors made by patients. If patients entered accidently a wrong value, they were instructed to enter straight away the correct one. Nurses were instructed to acknowledge new pain values as soon as possible. An acknowledgment was informed both to the patient that reported the value and to all nurses. To handle human errors made by nurses there could also be an additional alarm if a pain value were not acknowledged in a predefined time. For example, a nurse might forget to charge her/his cell phone and hence fail to receive pain values from patients. To improve the robustness of the application, this alarm could be sent by different means, not through the pain monitoring system. This and other extensions need to be considered in the next version.

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More development work and testing is required before the pain monitoring system's effects on patient overall treatment can be analysed. In this study, the pain values provided by the system supported the care of the pain and routines of the normal nursing processes at the test organizations. Integrating the pain monitoring system seamlessly into the patient care processes and clinical decision making requires more work. The pain values need to be delivered to the hospital's patient records and the processes need to be modified to utilize this data. Research could also be focused on how the usage of pain meter affects the quality of life and what other measurements can be done instead of pain level monitoring by using the same technology.

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