# User Acceptance of Pervasive Computing in Healthcare: Main Findings of two Case Studies


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***Abstract*— The successful implementation of Pervasive Computing technologies in healthcare does not only depend on technical issues but also on acceptability and acceptance issues. In this paper we focus on factors that facilitate or inhibit user acceptance of Pervasive Computing in healthcare. We present selected findings of the research project 'PerCoMed – Pervasive Computing in Healthcare'. The project is based on two case studies in pre- and post-clinical healthcare. In the first study, the potential of Pervasive Computing technologies for the treatment of acute cardiovascular diseases is investigated, in the second case study, the potential for the treatment of multiple sclerosis (MS) is evaluated. A qualitative user acceptance analysis of the two case studies shows the following results: the main factor of user acceptance is the perceived medical usefulness. Furthermore, acceptance is strongly inhibited if data privacy or if subjective norms are violated. Usability only presents a decisive factor of acceptance if problems with usability reduce the perceived usefulness.**



***Keywords: user acceptance, case study, usefulness, usability, data privacy***


## I. INTRODUCTION

'Pervasive Computing' is a technological vision or a paradigm so far. Pervasive Computing technologies are perceived as the next generation of innovative information and communication technologies (ICT). The vision of a pervasive environment is characterized by five criteria [1]. Very tiny sensors and devices which are more portable than traditional ICT (miniaturization), embedded into other devices and everyday objects (embeddedness), are working invisibly in the background (invisibility). Pervasive Computing components can take up information about their environment (context-sensitivity) and communicate them through wireless data exchange (networking).

New technologies in healthcare mostly do not yet fulfill these five criteria, i.e. – following this definition – one cannot talk about genuine Pervasive Computing applications in healthcare today. But a strong tendency towards these characteristics can already be observed, with existing devices and applications that fulfill these characteristics in part and where the other features are imaginable. We are facing a technological vision on its way to be realized.



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The research project 'PerCoMed – Pervasive Computing in healthcare'[1] analyzes the opportunities and risks of Pervasive Computing technologies for healthcare in an interdisciplinary approach. The aim of the project is a case-based analysis of the use of 'Pervasive Computing' technologies for the integrated medical care of various user- and interest-groups.

Thus, our perspective is proactive: we analyze a technological vision and aim to assess its consequences and conditions before the technologies have become widely implemented. To assess the phenomenon of Pervasive Computing in healthcare, we focus on social, economic and technical aspects. The aim of this 'technology assessment' is to create knowledge that can be used in the further process of implementing Pervasive Computing in healthcare by anticipating contexts, avoiding problems and adapting more closely to users' needs, attitudes and behavior.

In this paper, we first present our theory based focus on four factors of acceptance of Pervasive Computing in healthcare namely 'perceived usefulness', 'usability', 'data privacy' and 'subjective norms' (2), then we describe our design of two case studies and of our user acceptance analysis (3). Subsequently we present the technology, processes and stakeholders of the first case study 'Stroke Angel' (4) and the main findings of the user acceptance analysis of this case study (5). In parallel, the second case study 'MS Nurses' is described via its technology, processes and stakeholders (6) and we summarize the main results of user acceptance analysis in this case (7). Afterwards, the findings of user acceptance of Pervasive Computing in healthcare are generalized and discussed (8). To conclude, the central results are summed up and further fields of research are opened up (9).

## II. RESEARCH QUESTIONS AND THEORETICAL BACKGROUND

A successful implementation of Pervasive Computing technologies in healthcare certainly depends on technical features like interoperability, battery capacity, (data) security and connectivity. But social and organizational environments, processes and stakeholders are decisive conditions, too. [2] To


[1] This project is funded by the German Federal Ministry of Education and Research under grant number 16I1546 (www.percomed.de). Partners are the Institute for Futures Studies and Technology Assessment (IZT), Berlin; the Research Center for Information Technologies, Karlsruhe (FZI) and the Institute for Technology Assessment and System Analysis Karlsruhe (ITAS).

implement Pervasive Computing technologies in healthcare successfully, issues of acceptability and acceptance cannot be ignored as e.g. in Germany, the physicians' opposition to the implementation of the electronic patient card has shown [3]. In healthcare, we are confronted with very particular environments and very particular users. There are diverse environments as accident settings, intensive care and adapted domestic environments and there are patients on the one hand, people mostly suffering, ill or handicapped and hospital professionals on the other hand, people working under considerable stress [2]. That is why we focus on the following research question:

Which factors facilitate or inhibit user acceptance of Pervasive Computing in healthcare?

Furthermore, we ask if it is possible to distinguish between more fundamental and rather subordinate factors of acceptance of Pervasive Computing in healthcare and if there are major differences in acceptance of Pervasive Computing between different groups of stakeholders.

Acceptance, defined as the adoption and the use of objects by persons [4], depends on the subject of acceptance, the object of acceptance and the context of acceptance: 'Who does accept what under which parameters?'.

To guide our analysis, we focus different factors of acceptance referring to two theoretical models. Our study refers to the Technology Acceptance Model (TAM) [5, 6] and the Theory of Planned Behavior (TPB) [7, 8]. The TAM is a technology adoption model that considers user acceptance of information systems. This model posits that perceived ease of use and perceived usefulness are the significant factors for the acceptance of information systems. The TPB is a model from social psychology which is concerned with the determinants of intended behavior. The model posits that behavioral intention is determined by attitudes, subjective norms and perceived behavior control.

We decide to examine four factors of acceptance: The first factor of acceptance, referring to the TAM, is the factor 'perceived usefulness'. This factor means on the one hand "the degree to which a person believes that using a particular system would enhance his or her job performance" [6] and on the other hand, perceived usefulness means medical or therapeutical use. Hypothesis 1: Perceived usefulness facilitates the acceptance of Pervasive Computing in healthcare.

The second factor, also proposed by the TAM, is the factor 'usability' (equivalent to 'perceived ease of use'[6]). Usability can be understood as a combination of the effectiveness and efficiency of a technology and the users' satisfaction (see EN ISO 9241-11: 1998). Hypothesis 2: Perceived usability facilitates the acceptance of Pervasive Computing in healthcare.

For the third factor of acceptance 'subjective norms', we refer to the TPB. Subjective norms define "the person's perception that most people who are important to him think he should or should not perform the behavior in question." [9]. We understand 'subjective norms' as perceived accordance to social norms and satisfying interpersonal communication. Hypothesis 3: Accordance to subjective norms facilitates the acceptance of Pervasive Computing in healthcare.

Furthermore, because in the field of ICT collecting personal data is a very sensitive area [10] [11], we decided to include the factor 'data privacy' and the 'perception to be permanently controlled' into our focus. Hypothesis 4: Perceived threats for data privacy inhibit the acceptance of Pervasive Computing in healthcare. Likewise, the perception to be permanently controlled inhibits the acceptance of Pervasive Computing in healthcare.

These hypotheses are guiding our research. We apply the following methodology.

## III. Methods

Based on an analysis of trends and stakeholders in the field of Pervasive Computing in healthcare, we first designed and realized two case studies. Within each of these case studies, we then performed a qualitative user acceptance analysis.

### *A. Design of the two Case Studies 'Stroke Angel' and 'MS Nurses'*

In the case studies 'Stroke Angel' and 'MS Nurses' the usage of real Pervasive Computing technology is designed and analyzed in different sections of healthcare.

The Stroke Angel project[2] intents to speed up the treatment of patients in the intersectional stroke chain of survival with help of a mobile stroke diagnosis and data transmission device – called the Stroke Angel system – applied in Emergency Medical Service (EMS). Different aspects of the Stroke Angel System are analyzed: First, to figure out the specifications and functions required, a requirement and functional analysis is conducted: Second, a process analysis delivers the different impacts of such an introduction: This process analysis comprises modeling of stroke chain processes just as comparative time measurements with and without Stroke Angel. [12]

In the case study 'MS Nurses'[3] [13], we purpose to set up an environment to support the Multiple Sclerosis (MS) diagnosis and treatment. The wearable actibelt system is utilized as tool for movement analysis in a medical study. The aim of this study is to analyze the correlation between MS-patients' activity patterns and their state of health. Thus, we first exemplarily analyze the implementation of pervasive technologies in a medical study, second we anticipate the implications of its future usage as an activity monitoring system in home care.

### *B. User Acceptance Analysis within the Case Studies*

Within the two case studies, the qualitative user acceptance analysis is based on several methods to collect and to interpret empirical data.

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[2] www.strokeangel.de. In this case study we were collaborating with Neurologische Klinik Bad Neustadt/ Saale, Bayerisches Rotes Kreuz Bad Neustadt/ Saale, Heinrich-Heine-University in Düsseldorf, as well as Philips Research from Aachen. Together, they join forces to apply the technical solution from Philips Research in the two test regions Düsseldorf and Bad Neustadt/ Saale with the support of Boehringer Ingelheim Pharma and the Stiftung Deutsche Schlaganfall-Hilfe (German stroke foundation).

[3] www.msnurses.de. This study is driven by the PerCoMed research partner, Sylvia Lawry Multiple Sclerosis Research (SLMSR), Trium Analysis Online, Neurologische Klinik Bad Neustadt/ Saale and Sanofi-Aventis Pharma.

In the case of Stroke Angel, we first conducted qualitative semi-structured interviews [14, 15] with all relevant stakeholders affected by the Pervasive Computing application (EMT-I, physicians, nurses). Second, to deepen the analysis of the perception and the assessment of Pervasive Computing, two focus group discussions [16] [17] have been conducted with citizens in the role of 'potential patients'. We addressed the participants via notices in public spaces. We divided these potential patients into two groups the following way: at the first contact, we asked them to asses themselves as open minded towards technology or as skeptical towards technology.

In the case study 'MS Nurses', we included the chronic MS patients participating at the medical study at the hospital from the outset. We first addressed them via questionnaires before and after they had used the actibelt (n= 12). Second, we conducted semi structured qualitative interviews with all relevant stakeholders (patients, physicians, nurses and physiotherapists). Third, we discussed with the patients during two focus groups.

In total, during the two case studies, we conducted n= 45 qualitative semi-structured interviews and did focus group discussions with 24 persons. The perspective of the four focus group discussions was opened up on Pervasive Computing in healthcare in general and not limited to the concrete technologies of each of the case studies.

The records of the interviews and focus groups have been treated by the method of qualitative content analysis [18], the questionnaires have been analyzed by descriptive statistical methods and we compared the results before and after the testing.

## IV. Technology, Processes and Stakeholders in the Case Study 'Stroke Angel'

Stroke is one of today's most threatening diseases in Europe.[4] Even though the existing treatments of stroke are able to provide substantial benefits, stroke still takes a leading position on statistics of causes of death. Recent technical and medical developments give reason to hope for improved stroke care. One important step in this direction was done in Germany by the approval of the thrombolysis for the treatment of the ischemic stroke in 2000. This acute therapy for stroke improves the chances for survival and healing[5]; but this treatment has to be started if possible within a time-frame of three hours after onset of symptoms. [19]

The aim of the Stroke Angel project is to speed up the treatment of patients in the intersectional stroke chain of survival with help of mobile technology. The Stroke Angel system consists in a structured checklist for stroke diagnosis (Los Angeles Prehospital Stroke Screen – LAPSS) on a portable computer (PDA), a patient card reader and a mobile phone to send the corresponding information through radio transmission from EMS to the hospital.

The stroke chain of survival commonly comprises the whole process from discovering the affected person to the patient's admission and treatment in hospital. Figure 1 illustrates the architecture of the Stroke Angel system and the communication links between the EMS which collects patients' data and sends them via Bluetooth connection of the mobile phone to the Stroke Angel server of the hospital.

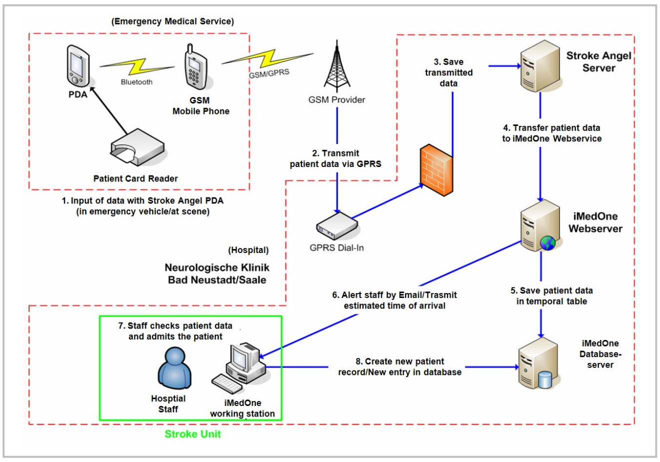


Figure 1. Stroke Angel architecture with communication links [20]

The first step of the process analysis mentioned above comprises the identification of the parties involved. In this context, the Red Cross, which assumes the coordination between the EMS, the emergency physicians and the neurological clinic have been identified as the four important stakeholders. They are directly involved within the Stroke Angel system and their interventions affects the workflow of decision making and information.

In general, the results lead to the conclusion that Stroke Angel has improved the emergency management in total. Surprisingly, even though the 'time in situ' retards in average around 5 minutes for all patients (4 minutes for all patients with lysis), it is compensated by the shorter transportation time, i.e. paramedics seem to need more time to enter the data, but they get alarmed earlier by the LAPSS. Consequently, the signal alarm was used more often in 2006/ 2007 in order to speed up the transportation process. Even though the 'time in situ' using Stroke Angel has been increased, the 'time-to-imaging' has been improved due to more fundamental decision making and due to earlier information and preparation of the neurological clinic saving 9 minutes (mainly on treatments of lysis-candidates).

Since the operation of the Stroke Angel system in 2006/ 2007, the total time entering the hospital to brain-imaging by CT (computer tomography) or MRT (magnetic resonance tomography) has been reduced from 32 to 23 minutes for around 30% of the patients with lysis, due to parallel preparation and faster recording of the patient at the hospitals reception desk. In case of incoming patients whose stroke symptoms are less than three hours ago the 'time-to-imaging' could be decreased by around 25% from 48 to 36 minutes.

Hence, preliminary results of the process analysis offer promising insights. Although not all influence factors and dependencies are checked so far and statistical measures haven't

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[4] About 575,000 case a year, a mortality rate of 29%, another 25% of disablement within 12 months, and total costs of about 34 billion Euros in the EU per year.

[5] The thrombolytic therapy effectuates the blood clod that blocks the arteries with the help of dissolving medicaments, so that the degree of consequential damages can be reduced or rather completely avoid.

been applied in detail, there is a strong indication that the system allows for significant progress in decision making quality and hence resource allocation arbitrations. Exact results will have to be provided with the final data. Hopefully expectations can then be approved and experiences of the Stroke Angel study transferred to other emergencies scenarios.

Finding reliable diagnosis as early as possible in the preclinical phase can clearly assure that treatment alternatives for the clinical phase remain possible. This is likely to provide an overall increase in quality of medical care.

## V. Main Findings of User Acceptance within the Case Study 'Stroke Angel'

First, the overall acceptance in the case study Stroke Angel is described, then our findings regarding the four factors of acceptance 'usefulness', 'usability', 'subjective norms' and 'data privacy' are presented.

### *A. Overall Acceptance*

The object of acceptance in this case study is the Stroke Angel system, the context of acceptance is the chain of survival from the pre-clinical EMS to the clinical emergency care. The main subjects of acceptance are emergency physicians, EMT-I (Emergency Medical Technician, Intermediate) but also further hospital staff as well as (potential) stroke patients.

The user acceptance analysis in the case study 'Stroke Angel' shows that all groups of medical professionals do have an overall positive attitude towards the Stroke Angel system. Emergency physicians, EMT-I and hospital staff would like to continue the case study and favor an extension of the Stroke Angel system beyond the pilot.

However, some stakeholders are more reluctant and consider well trained medical personnel to be the better alternative to optimize stroke care. They are afraid of structural changes in healthcare and specifically in the EMS, which could favor the cheaper technologies to the disadvantage of human work.

In the group of potential patients open minded towards technology, the overall attitude towards Pervasive Computing in healthcare is positive. They state enormous hopes towards these technological applications. "I feel better since I know there is Stroke Angel, if I get a stroke one day", as one citizen turned it. For the potential patients skeptical towards technology, the overall attitude is similar. Even if they seriously discuss a lot of negative aspects, the balance finally drawn clearly shows that the potential medical benefit is more important than any concerns.

### *B. Factor of Acceptance: Usefulness*

The decisive factor of acceptance of the 'Stroke Angel' application is – and this holds true for physicians, hospital staff and patients – the perceived usefulness. If the device is perceived as useful, acceptance is high, if on the contrary, there are doubts on the usefulness of the application, acceptance is missing. Medical benefit is perceived to be the main and most important use of Stroke Angel, organizational use as assistance in daily work is manifestly of secondary importance.

Almost 75 % among the physicians and medical staff perceive an important medical use, which consists – according to them – in the possibility to save lives or to reduce remote damages of stroke patients by shortening 'time-to-imaging'. This time gain is achieved by organizational changes at two levels, during the emergency service (pre-clinical-level) and at the hospital (clinical-level): First, with the calculated stroke-probability, the direct transport of patients to the specialized hospital (stroke unit) is made without detours to other hospitals. Second, with the patients data available via the Stroke Angel report as the patients name, date of birth, address and health insurance, the medical staff at the hospital can already prepare the arrival of a stroke patient and e.g. by booting up CT. The application of the Stroke Angel system provides quantitative time improvements in the rescue chain and qualitative medical benefits for stroke patients. Therefore, the effective usefulness is perceived by most of the stakeholders.

But there are also skeptical voices that are not sure about this medical use and express doubts about the gain of 'time-to-imaging' because of two reasons: First, half of the interviewees perceived a loss of time during the data entry. The process of entering data over the PDA takes – according to the interviewees – between 3 and 15 minutes. Especially in the case of short-distance transports, the time loss is perceived as unproportional. "This just doesn't make any sense.", as one EMT-I said Some report that the data entry procedure had clearly delayed the start of the transport. Second, some of the emergency medical service report of the frustrating experience that even though the Stroke Angel report had been send to the hospital, they arrived at an emergency room with closed doors. The survival chain is sometimes blocked. This is due to different but all organizational reasons: sometimes the physician on duty does not cooperate; sometimes the physician himself is informed and present but not the other relevant medical actors as nurses or the radiologist, who finally has to allow the patient to the CT. When Stroke Angel is thus perceived as a zero-sum application, because the time gain is too small to compensate for the time loss of data entry, or if the chain of survival does not work well, the acceptance is clearly reduced.

Most of the potential patients do consider Stroke Angel to be a very useful system. The idea that everybody could become a stroke patient one day, and then he or she would hope for the fastest help possible, fosters the acceptance of this application. Health is considered to be the most important priority and the aim to save more stroke patients is considered to be highly valuable.

### *C. Factor of Acceptance: Usability*

In the case of Stroke Angel, usability is a relevant factor of acceptance, because it directly affects the perception of medical use.

The Stroke Angel software is overall assessed as positive by emergency medical technicians (EMT-I), the main users of the system. The entry mask is characterized as user-friendly, clear, appropriate and even outranging the classical paper report, because it helps to collect more and more precise information on the patient. In contrast, the hardware has room for improvement. The display is criticized by EMT-I as being too small, as it is very difficult to enter data while the transport is driving. The difficulty of slipping on the display and not matching the correct input field is reported several times. Sometimes, this leads to losses of time, which are perceived to nullify the time gain for patients and thus to endanger the efficacy of the system.

These problems with usability lower the perception of medical use and consequently, the acceptance of the application is endangered. Furthermore, the EMT-I criticize that Stroke Angel is generally not perfectly adopted to the working conditions in an ambulance, where more robust, chemical- and waterproof, one-piece "plug and play" devices are required.

### D. *Factor of Acceptance: Subjective Norms*

In the setting of this case study, the factor 'subjective norms' applies above all job roles and job images of different groups of medical professionals.

The Stroke Angel application interferes with the established work and power relation between emergency physicians and EMT-I and could induce changing job images: with the help of Stroke Angel, EMT-I do not need an emergency physician anymore to decide whether to bring a patient to a stroke unit or not. Thus, they gain autonomy and competence. Some of the interviewed EMT-I experienced Stroke Angel as a reassessment of their role and position, classically subordinated and dependent to the emergency physician. Emergency physicians on the contrary, feel a loss of competence and of power for the benefit of EMT-I. Furthermore, emergency physicians are afraid, cost efficient technologies like Stroke Angel could in the long run completely substitute their work. One emergency physician said: "in the future, there will be no emergency physicians".

Consequently, some emergency physicians are highly critical towards to the Stroke Angel system and could entirely block its successful implementation.

### E. *Factor of Acceptance: Data Privacy*

Overall, for the involved stakeholders, data privacy turned out to be no issue with Stroke Angel.

Data privacy is no point of concern for any of the interviewed medical professionals. Confronted with our questions on data privacy, some report they not even had thought about it and that "everybody uses mobile phones everyday" as a physician said. Three of the interviewees developed the ad hoc assessment that data privacy may perhaps not be guaranteed with the Stroke Angel application, but that data privacy has no priority at all in case of emergency.

Potential patients overall do share this attitude, but one can distinguish between two groups of positions: People opened minded towards technology clearly consider the medical use of Stroke Angel to be more important than data privacy. Among people skeptical towards technology, there are some who are afraid about data privacy questions even in case of emergency (e.g. a stroke) and demand transparent regulations which precisely and restrictively define the case of emergency in which data are accessible without further consent.

After having presented the results of the case study 'Stroke Angel', we expose in parallel our case study 'MS Nurses' and the main findings of its acceptance analysis.

## VI. Technology, Processes and Stakeholders in the Case Study 'MS Nurses'

MS is thought to be an autoimmune disorder that leads to the destruction of myelin, oligodendrocytes and axons in the central nervous system (CNS) [21]. MS primarily affects adults, with an age of onset typically between 20 and 40 years, and is more common in women than in men. MS may take several different forms, with new symptoms occurring either in discrete attacks or slowly accruing over time. Between attacks, symptoms may resolve completely, but permanent neurological problems often persist; especially as the disease advances. MS currently does not have a cure, though several treatments are available which may slow the appearance of new symptoms.

In MS the Expanded Disability Status Scale (EDSS) is a frequently used disability score for the evaluation of clinical disease burden on progression. [22] It helps monitoring the course of MS and is part of the treatment optimization model recommended for the observation of effectiveness of immunomodulatory therapies. The EDSS score ranges from 0 until 10. Between the scores 0 and 3.5 patients are assessed being able to walk on their own without limitations. Patients with the scores 4 to 5.5 are able to walk a maximum distance of less than 500 meters and above 6 they are unable to walk on their own.

Within periodic intervals (in most cases every three or six months), the EDSS score is evaluated by physicians during basic examination. But even though these examinations are done regularly, they can only give an instant impression of the disease's status. It would therefore be desirable to learn more about everyday occurrences between the examinations so that tendency and progress of the patient's condition can be monitored more precisely. The sooner the tendency of the disease's progress can be detected, the better measures can be taken and therapy can be adequately adapted to preserve the patients' mobility. Recently, medical studies were performed showing that there are correlations between gait parameters and the EDSS score. [23] It seems possible to stage the patients' status of health by his patterns of activity. The objective is to find a way to monitor patients' activity over a long period by using pervasive technologies. With the help of the measured parameters and the comparison of activity and EDSS score physicians could be supported in detecting tendencies of patients' aggravations. Therefore, we set up a study which aims to associate the data of the activity monitoring with specific MS symptoms.

The clinical study is divided into an ambulant and a stationary setting with patients with an EDSS score less than 5. In the ambulant setting, MS patients wear the device one week at home and bring the device back to the hospital. The stationary patients wear the device over one day in the hospital.

Our scenario has to meet the critical factors according medical, technical and user specific aspects. As the device will be used in an ambulatory home care and will collect information about every day activity of the patients, all techniques that need a laboratory setting are not applicable. Furthermore, the device should collect data about patient's general activity that allow for classifying activities he is performing. In particular running, walking, sitting and standing activities should be detectable. The device shall also include fall detection and gait asymmetry. Additionally, it must be possible for the patient to use the device easily by himself at home. The device has to be wearable

wearable without disturbing the patient during his normal activities and needs to provide a reliable informative base. [24] Accelerometers are used most frequently in early activity studies. [25-27]

For our proposes, we use the actibelt® of Trium Analysis Online GmbH[6] and a corresponding software environment to collect and analyze the activity data of MS patients. It has the advantage of being embedded in a daily wearable belt close to the body's centre of mass and therefore it is unobtrusive and does not disturb the test person in its daily life. The belt is in operation if the button on the backside is pressed for three seconds and the LED close to the button blinks every three seconds. The actibelt® is switched off if the button is pressed again for three seconds and the LED stops blinking.

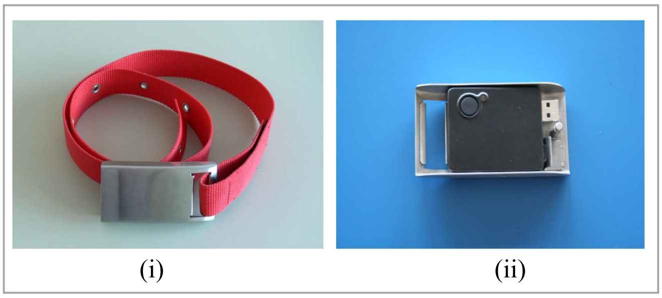


Figure 2. Belt buckle front side (i), belt buckle back side (ii) [13]

The belt can be connected to a PC via USB. The client software allows belt administration (like downloading files, checking battery status and/ or storage capacity). Additionally users can upload files from PC to the actibelt® server to be analyzed.

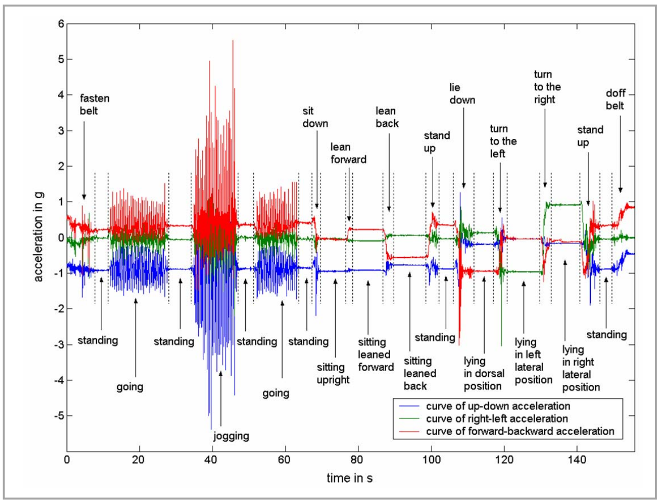


Figure 3. Determination of movement with actibelt® [13]

The analysis software currently distinguishes 6 different movement types: jogging, walking, standing, sitting, lying and undefined movements as standing up or lying down (Figure 3).[7]

For the movement analysis the step number, the duration of every step, the step frequency, the step amplitude and the asymmetry depending on the difference between the duration of right and left steps are calculated. The software also estimates the traveled distance and the maximum distance walked in one draught with an accuracy of approx. +/- 10 % [28] and estimates the energy consumption. The results of the analysis are summarized in a report and are transmitted to the web application. The measured and calculated parameters are saved in a text file to allow additional user-defined statistical analysis.

## VII. Main Findings of User Acceptance within the Case Study 'MS Nurses'

First, the overall acceptance in the case study 'MS Nurses' is described, then our findings regarding the four factors of acceptance 'usefulness', 'usability', 'subjective norms' and 'data privacy' are presented. The technology actibelt® does not yet fulfill the five criteria of Pervasive Computing mentioned above. Consequently, during the interviews with all stakeholders we asked not only about the existing technology, but we also presented a scenario and asked our interviewees about the vision of an 'intelligent-Pervasive Computing-actibelt'. This intelligent actibelt was described as wireless exchanging data and interconnecting to data bases and medical technologies.

### *A. Overall Acceptance*

In the case study 'MS Nurses', the object of acceptance is the actual actibelt® but also the vision of the 'intelligent actibelt' described above. The context of acceptance today is a medical study, with patients wearing the device at the hospital and at home. In the future, the context of the actibelt will be the ambulant medical care. The subjects of acceptance are first of all MS patients but also physicians and medical staff (nurses and physiotherapists).

The results of the user acceptance analysis show that most of the patients, the physicians and the medical staff have an open-minded attitude towards the actibelt and towards Pervasive Computing technologies in general. Almost all of the queried patients believe that technologies as the actibelt are a positive technical development, "It could be a good and useful thing for me and my chronic illness." Only one patient out of ten thinks the actibelt is a negative technical development. However, there are differentiated assessments concerning the different Pervasive Computing characteristics. Embeddedness and context-sensitivity, characteristics already given with the actibelt, are assessed positively by all stakeholders. Further characteristics as wireless data exchange and networking are assessed to be ambivalent; patients confront possible medical use with threats of autonomy and self-determination; medical staff hopes for better medical care but fears new work loads.

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[6] The actibelt® has a triaxial accelerometer integrated into its buckle (see Figure 2 (iii)). For further technical information see www.slcmsr.de.

[7] For this segmentation the signal is broken up into a series of time segments of 1 second. For all time segments the arithmetic mean value, the robustified range, defined as the difference between the mean of the 10 largest and 10 smallest measurement values, and the absolute deviation are calculated. A type of movement is assigned to every 1-s segment using a threshold method with thresholds depending on multiples of g. These thresholds have been determined by exploring measurement values taken from approximately 20 healthy volunteers of different gender, age, height and weight.

*B. Factor of Acceptance: Usefulness*

Perceived medical usefulness is the most important factor of user acceptance for all involved stakeholders.

For chronic patients, the crucial condition to accept new technologies is to perceive personal and/ or medical benefit, i.e. an amelioration of their state of health. In the MS Nurses case, most of the patients expect pervasive technologies to be potentially very helpful for their MS. If the technology actibelt® is able to reveal a solid correlation between movement and effectiveness of therapy, pervasive monitoring technologies could be advantageous for diagnosis and therapy of MS. Long-term objective data of individual movements are considered to be essential to objectify subjective assessments. Patients also hope that anamnesis (documentation of preliminary medical history) will get easier and more certain because their personal medical data could be up to date all time in the hospital data base. One patient said, "For me it is very useful, if the doctor has a better overview of consistent medical data about my course of disease."

After having tested the actibelt, patients clearly and steadily express a need for individual feedback, i.e. they want to know "what is the result" of the actibelt® records. Without getting any report, some patients start to develop severe doubts about the usefulness of the device. Thus, an important condition for patients to perceive usefulness of pervasive technologies seems to be the experience of individual feedback.

Physicians and medical staff also expect medical and – but to a lower degree – organizational use from pervasive technologies. Most of the physicians and the medical staff see on the one hand possibility to reduce efforts, thus to save time and in consequence to save money. On the other hand, objective clinical data and long-term-data are eagerly expected because they could simplify diagnosis and treatment. Like patients, physicians and medical staff expect a medical benefit from the use of Pervasive Computing technologies for anamnesis, diagnosis and therapy. But medial professionals clearly state they would only accept pervasive technologies if their medical use is proved to be significant. Second important condition for this group is that treatment and analysis of new data flows can be done automatically and will not produce higher work load for them.

*C. Factor of Acceptance: Usability*

In the case study 'MS Nurses', only patients directly use the new technology actibelt®. In the main, patients do not have serious problems using the new technology actibelt® and are satisfied with its usability. "The belt is very discreet and easy to handle.", so a patient. Still, some patients criticize the size of the buckle and the length of the belt. They also reported that the buckle sometimes opens up of its own volition. Other patients explain that it is difficult to apply the belt if their clothes have no or too small belt loops.

The physicians notice a problem that sometimes affects the effectiveness of the actibelt: Some patients seem to have motor problems with starting and stopping the actibelt®. Also the flashing on/off signal is not always easily and clear enough to understand, especially for MS patients, who sometimes suffer from impaired vision. This sometimes leads to unwished battery discharges and missing data records – mostly unnoticed by the patients themselves.

Furthermore, the software to readout data requires IT capabilities which overburden some of the medical stuff.

*D. Factor of Acceptance: Subjective Norms*

In this case study, 'subjective norms' mainly concern satisfaction with information and support as well as consequences for the physician-patient relationship and also job roles and job image of nurses.

The analysis shows that the acceptance of most patients is linked to their satisfaction with information and support given by their attending physicians. Acceptance is high between the majority of patients who is satisfied with their medical care in general and with the information they got about the technology actibelt® and who have confidence in their attending physician. Furthermore, they appreciate that a contact person has been available for all possible problems at any time during the study. This role is fulfilled today by physicians, but in the long run is planned to be overtaken by MS-Nurses, which could disburden the physicians.

A few patients but also some of the medical professionals argue that Pervasive Computing technologies in healthcare could substitute the personal dialog between chronic patient and physician. A patient said, "It is important for me, that my doctor sees me as a full person and doesn't consider only my medical parameters." In particular for chronic patients, this dialog is of crucial importance not only for a confiding physician-patient relationship but also for adherence and compliance to the therapy and thus finally for a patient's health and well being. In sum, the effect on the physician-patient relationship is seen to be open. The individual physician or staff member is seen to be responsible to avoid negative developments and to determine how Pervasive Computing influences the physician-patient relationship.

As only group of medical professionals, nurses state some fears, new technologies like the actibelt could substitute their work. Consequently, they expect their job profile of the future will comprise only duties of care and they will loose medical responsibilities. This development is anticipated as loss of status and as a de-qualification. Otherwise, nurses anticipate also they could be the ones who explain new technologies to patients and who support them in their ambulant use.

*E. Factor of Acceptance: Data Privacy*

Before testing the actibelt, almost none of the patients was strongly concerned with questions of data privacy. Only some of the patients had a negatively assessed perception to be permanently controlled during they wore the actual actibelt. In contrast, most patients report about having forgotten during their daily routine that the actibelt was more than a simple belt. But after the test, the patients were clearly sensitized for privacy issues.

The idea of possible wireless data exchange amplified the perception of being controlled and raised concerns of data privacy. Some patients were really afraid of this option. "It would be a nightmare for me, if the actibelt sends an emergency call, unnoticed, and I don't need medical help." "Automatic data exchange leaves a bad feeling, I feel too transparent." Our findings suggest that this attitude depends on a patient's concrete situation: The stronger a patient is suffering and the more he hopes for the technologies to save or to ameliorate his life, the more the uncomfortable perception to be observed and data privacy concerns become unimportant. "In case of emergency it could be very helpful, when I'm alone at home.", so patient. Ergo, in case of emergency, chronic patients agree with data exchange without specific accordance but for daily routine, they reject it. In everyday life, chronic patients want to decide when and to whom they send which personal medical data and who has access to medical data bases. "I want to know who will receive my medical data and what they want to do with that. Do they have good or bad faiths?" On the one hand, the respect of autonomy and self-determination seems to be a crucial restriction for patients to accept Pervasive Computing technologies, on the other hand, data privacy regulations are requested to deal with risks of misuse of data through "wrong addressees" as insurance funds and employers.

Certainly, physicians and medical staff both agree that collecting a huge amount of personal medical data could present hazards of data privacy and data security. But they do not anticipate the patients' account of self-determination. Moreover, physicians do consider data privacy questions from the opposite perspective than patients. They argue that already today, the respect of existing data privacy regulations does present an important extra-workload which could even grow in the future. Furthermore, these regulations could endanger the patients' medical benefit because of incomplete information flows.

## VIII. Discussion and Generalization

Most of the individual results of our user acceptance studies of the two cases 'Stroke Angel' and 'MS Nurses' do not contradict already existing findings or presumptions [29] [30]. But our results allow to support these findings via the broad empirical base of our research and to consider user acceptance of Pervasive Computing in healthcare in a generalized way. The findings show first that all four factors under analysis – usefulness, usability, data privacy and accordance with social norms – do influence the acceptance of pervasive technologies in healthcare. This holds for patients, physicians, EMT-I, nurses and physiotherapists. Second, it is possible to distinguish the factor perceived usefulness as fundamental factor of acceptance.

The perceived usefulness seems to be the crucial factor of acceptance. Within this factor, it is the aspect of medical usefulness that is the most important criteria for acceptance. When there is no medical use perceived, the acceptance of all groups of stakeholders is very low. Inversely, if medical use is seen, the acceptance is high. The potentials for optimal health and lifesaving are fundamental arguments in favor of Pervasive Computing in healthcare of all the interviewed stakeholders. One can thus deduce that pervasive technologies can easily be accepted in healthcare, if – and only if – its medical use is convincing and convincingly communicated. The organizational usefulness, i.e. the facilitation of daily work has lower importance. Still, acceptance depends on the condition that Pervasive Computing technologies do not require any extra-effort as e.g. the treatment of higher amounts of data. Ergo organizational efforts should not grow to assure acceptance of hospital professionals.

Usability certainly influences user acceptance but does not finally determine a users' attitude. Usability seems to be less important for user acceptance than the perceived use [31]. Usability only presents a decisive factor of acceptance, if problems with usability harm the effectiveness or reduces the perceived medical usefulness, as we have illustrated by the case of Stroke Angel. The experience from both case studies also shows that it is still important to demand to adopted every Pervasive Computing application precisely to its specific health care setting (ambulance, clinic, home etc.) and to the patients' and professionals' abilities or disabilities and life or working conditions.

The influence of data privacy issues on the acceptance of pervasive technologies has to be considered in a differentiated manner. Our findings suggest there are two distinctive contexts of acceptance: In case of emergency, data privacy is no issue but lifesaving has absolute priority; whereas in normal case, the respect of data privacy is a necessary factor of acceptance. In normal case, people demand to respect data privacy and the possibility of self determination. In everyday life they want to decide whom and when they send their personal medical data. These conditions have to be considered to guarantee user acceptance in the context of normal. The case of emergency has to be clearly defined in advance to allow different data privacy standards. Furthermore, the perception of being permanently observed could be an additional barrier of acceptance when technologic devices are sending data automatically. Finally, data privacy and self-determination turn out to be issues that reveal opposing interests and perspectives among different stakeholders and these issues might turn out to be the most complex issues of user acceptance of Pervasive Computing in healthcare.

The acceptance of Pervasive Computing applications depends on the accordance of the technical system and its usage with established social norms. When subjective norms are violated, this can present serious barriers to acceptance. If social roles (as job images) are changing because of newly implemented pervasive technologies, the opposition from stakeholders, who feel they are loosing status or competences, is possible and this opposition can inhibit the successful implementation of pervasive technologies. The opposition of occupation groups is thus one factor which can inhibit the implementation of Pervasive Computing in healthcare. Idem, an impairment of the physician-patient relationship presents a risk which has to be taken into consideration and the fear of loosing 'human quality' in healthcare should be taken seriously to stabilize the acceptance of Pervasive Computing.

## IX. Conclusion

In sum, medical usefulness seems to be the decisive factor of acceptance of Pervasive Computing in healthcare for both, hospital professionals and patients. The respect of data privacy and the accordance to subjective norms are additional factors, which surely could inhibit the acceptance of pervasive technologies. Patients demand to control the access at their personal data; medical professionals demand not to augment their effort as the treatment of data is concerned. Usability only presents a decisive factor of acceptance, if problems with usability reduce the perceived usefulness.

Thus, for a successful implementation of Pervasive Computing in healthcare, a given and well communicated medical use seems to be a stable starting basis. Furthermore, the active integration of different stakeholders, physicians, medical staff and patients, each with their specific priorities and needs, could facilitate the acceptance of Pervasive Computing in healthcare.

In conclusion, these two case studies point out that there are already possibilities to implement Pervasive Computing technologies in real world medical scenarios. The partners of the case study 'Stroke Angel' plan to make the technology usable for heart attacks emergency cases. Furthermore, they started thinking about a roll-out in Bavaria and throughout Germany. The case study 'MS Nurses' will be continued at least until December 2008 and the participating doctors wished to extend the application context to Parkinson and Trombolyse. Though there is a need for new pervasive technologies, the implementation of this kind of technologies turned out to be challenging and the consideration of user acceptance proved crucially.

A further important field of research is the question of funding and of cost-benefit ratio of Pervasive Computing in healthcare. And questions of funding certainly will influence user acceptance and general social acceptability, too.

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