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Patient interaction in homecare systems to treat cardiovascular diseases in the long term

Ignacio Peinado, María Teresa Arredondo, Elena Villalba, Dario Salvi, Manuel Ottaviano

Abstract—**The rapid aging of the population worldwide will dramatically increase the number of people affected by chronic diseases in the next years. This social situation makes it necessary a paradigm shift from reactive care to preventive care. New technological paradigms, like Ambient Intelligence and Ubiquitous Computing, allow the development of Personal Health Systems (PHS) that guarantee the continuity of care and a better use of health resources. Therefore, patients should become the centre of the health care process, and PHS should be designed to fulfill the patient's goals and needs. User-centred methodologies provide a good framework for designing general use applications, but they do not usually take into account factors like the context where the interaction is taking place or the medical, social and business contexts that surround the patient. This paper presents a model for designing user's interaction in medical applications. The final goal is to develop highly usable user interfaces and to improve the user experience, aiming to guarantee the patient's adherence to the medical protocols and recommendations.**

I. Introduction

Cardiovascular diseases (CVD) are the leading cause of death in the western world, causing 45% of all diseases [1]. Among all cardiovascular conditions, Heart Failure (HF) is considered the paradigm of CVD, affects mainly people older than 65. In the European Union, the proportion of elderly population (65 years and above) is expected to rise from 16.4% in 2004 to 29.9% in 2050 [2]. This will increase the number of population suffering chronic diseases, which will state a significant burden on the health care services.

On the other hand, the widespread advances in hardware and nanotechnologies and Information and Communication Technologies (ICT) have allowed the creation of new paradigms, such as the Ambient Intelligence (AmI) paradigm. The AmI vision implies the creation of intelligent environments where users interact with the surrounding naturally without additional effort. Therefore, the technology is integrated into the user's daily life [3]. This paradigm allows the development of Personal Health Systems (PHS) that will facilitate ubiquitous personalized care, the continuity of care in time and space and that will shift the paradigm from reactive care to preventive care [4].

This new social and technological paradigm claims for a new way of designing user interaction and systems that enable services to be ubiquitous and adaptable to the user's characteristics. Although personalization offers the possibility to adapt the system execution to the user's preferences, this new interaction model needs adaptation in real time to the user context.

The research described in this paper is based on the iterative design, development and validation of a model that aims to improve the quality of life of patients living with a chronic disease. The model is validated through a solution to assess heart failure patients. The solution is called Heart Failure Management (HFM), and it is one of the four products that were developed within the EU funded project MyHeart.

II. Methods

Human-Computer Interaction (HCI) studies the interactions and the relationships between humans and computers. HCI emerged as a research discipline in the early 80s, initially as a specialty area of computer science. HCI has expanded rapidly for the last three decades, attracting and incorporating researchers from many different fields. Nowadays, HCI aggregates a collection of semi-distinct fields of research and practice in human-centred informatics that include fields such as ethnography, human factors, organizational psychology, artificial intelligence and computer science, among others.

In the first ten to fifteen years of HCI, the focus was on the design of Graphical User Interfaces (GUIs), following the WIMP (Windows, Icons, Menus and Pointing devices) paradigm developed in the first personal computers. Later, HCI focused on improving the way people use computers work, think, communicate, learn, critique, explain, argue, debate, observe, decide, calculate, simulate and design [5]. Usability became a quality feature of computerized systems and several researchers proposed methodologies that put the user in the centre of any development process.

In 1999, ISO published a standard that aimed to provide guidance on achieving quality in use by incorporating user-centred design activities throughout the lifecycle of interactive computer-based systems [6]. The model comprises five stages, four or which are implicitly joined in a loop. Fig. 1 shows an overview of the ISO 13407 model:

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All authors are with the Life Supporting Technologies (LST) research group, Telecommunication Engineering School, Technical University of Madrid (UPM), Spain (email: ipeinado@lst.tfo.upm.es).

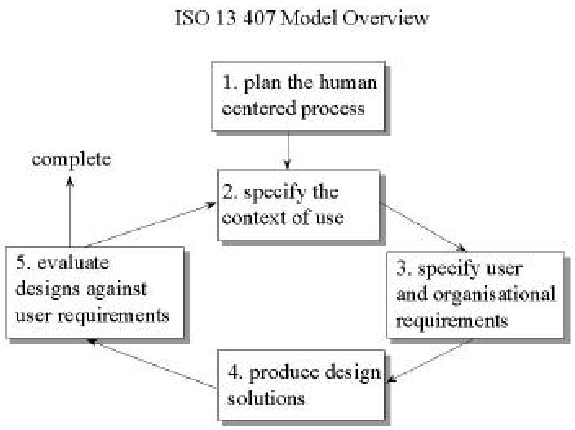

Fig. 1. ISO 13407 model overview (adopted from [6])

ISO 13407 provides not a methodology, but a framework for user-centred development activities that can be adapted to numerous development activities. The true benefit of this model emerges when it is used to guide an iterative development process. An improved version has been published as ISO TR 18529. It is intended to make the contents of ISO 13407 accessible to software processes assessment and improvement specialists and to those familiar with or involved in process modeling. Most user-centred methodologies follow the principles described in this framework. Nevertheless, different methodologies focus on different aspects of the framework. Usage-Oriented Design, proposed by Constantine & Lockwood [7] is a task-oriented methodology, while Goal-Oriented Design (GOD), proposed by Alan Cooper [8] is oriented to the development of commercial products, aiming to fulfil the needs and goals of its potential users. The design principles of GOD were used to design the HFM system.

Nevertheless, so far most HCI models address explicit interactions, where the user gives direct instructions to the system and receives a feedback from the system, establishing a dialog between the user and the system. Within the new paradigms of Ambient Intelligence and Ubiquitous computing, the influence of situation, context and environment offers a key to new ways of HCI. There are many factors that influence the interaction between humans and ubiquitous systems that are not considered in traditional HCI methodologies. Therefore, it becomes crucial to include implicit elements into the interaction in addition to the explicit dialogs already in use.

Implicit Human Computer Interaction (iHCI) is an action performed by the user that is not primarily aimed to interact with a computerized system but which such a system understands as input [9]. Applications that make use of iHCI take the context into account as implicit input and also have an influence on the environment by an implicit output.

The Holistic Patient Interaction Model (hPIM) is based on the iHCI.

Heart Failure Management (HFM) was designed following the principles of iterative and participatory design, involving all stakeholders since the early stages of the development process. The whole process is divided into three iterative phases: Conceptualization phase, Implementation Phase and Deployment Phase. Each phase follows the principles of User-Centred Design and Goal-Oriented Design (GOD). GOD is divided into the next phases: Research, Modeling, Requirements, Framework and Design (Fig. 2).

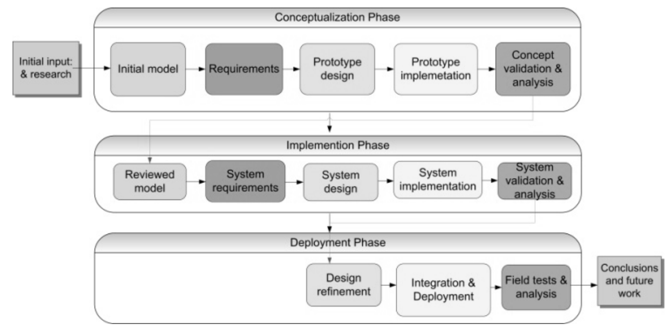

Fig. 2. HFM development process lifecycle

The requirements, the definition of persona, scenarios and key paths are based on GOD techniques. GOD employs ethnographic techniques that will help designers to build models that capture the user's preferences, goals, motivation and nearby context. In order to assure the success of solutions for the self-management of chronic conditions, all the actors involved in the health care process of chronic patients have to be identified.

The Holistic Patient Interaction Model (hPIM) proposed in [10] comprises three contexts around the patient: the Patient Context, the Medical Context and the Social and Business Context. The Patient Context defines the human factors or the personal routine of the patient, and comprises all the sensors that will interact implicitly with the patient. The Medical Context rounds the Patient Context, and comprises all the tools and services which provide the patients with a remote assessment. Social and Business context contains the previous contexts, and states the social and clinical rules that have to be considered. Therefore, this holistic three-layer model studies all actors involved in the assessment of chronic patients, and sets up a framework that allows us to effectively design the human-computer interaction and to enhance human-human interaction.

III. Results

The defined Holistic Interaction Model was used to design, develop and validate a self-management system for patients with chronic cardiovascular diseases. According to the model, the first phase consisted of the identification of all relevant actors that participate in the health care process of heart failure patients. Then, ethnographic techniques were used to characterize the most important stakeholders. This phase comprised interviews with potential users and actual users of similar systems, interviews with health professionals and other stakeholders, participation of subject matter experts and studies of the state of the art. The outcome of this initial phase was the collection of qualitative and quantitative data that helped designers to define the Patient Context.

Following the design principles of GOD, the data gathered during were used to build Personas. Personas are user archetypes that aim to capture the target user's goals, needs and motivations. The persona of HFM was Carlos Gomez, 72 years old. His main goals were self-assurance and self-confidence when performing his daily routine. He also aimed to control his own health evolution by self-managing his health status. He wished to live normal, thus making it crucial to provide a system that is non-intrusive and adaptable to his daily routine.

Next, scenarios were created. Scenarios are stories about ideal user experiences that aim to describe how the system fits into the persona's life and their environment, and helps them achieve their goals. In the HFM context, the end users were prompted to follow a daily routine that included a set of activities. This routine was different for every patient, but following some rules defined in the Medical Context of the hPIM. There were two scenarios defined within the system: indoors and outdoors. The former contained a set of measurements, using wearable garments and devices at home. The user answered to two questionnaires defined by the medical team. The latter contained an exercise scenario (i.e. a short walk) that aimed to promote a healthy lifestyle and to improve cardiovascular capacity.

Personas and scenarios were the basis for defining the functional, user and interaction requirements of the system. Adaptability to daily routine was one of the most important user requirements.

Adaptability to user preferences and routines was achieved via dynamic workflow execution. First, a taxonomy was defined: a session was a day using the system; a session was divided into contexts, that represented different time frames that were tailored. Each context comprised a set of activities that complied with the medical protocols for HF patients, and that included questionnaires, vital sign measurements and, in some cases, a monitored slight exercise session of 5-6 minutes. The user interaction device should be able to communicate with the sensors and to send the information to a server. The application must also be intuitive, user-friendly, and must allow natural interaction.

Taking into account the user, interaction and functional requirements the HFM was designed. The system was divided into two main platforms. The user interaction platform comprising the user interaction device and the sensors the user will have at home. The chosen device was a PDA with Bluetooth capabilities, GPRS connection and a touch screen. The sensors includes wearable sensors to measure parameters as the ECG, and portable sensors, such as a weight scale, a blood pressure cuff and bed sensors to measure the night activity. The professional platform includes the intelligence to analyze the data stored in the databases, and a web portal which provides ubiquitous access to the professionals. Fig. 3 shows the general structure of the HFM system.

Fig. 3. HFM system overview

The interaction framework comprised the definition of the interaction workflows that the users have to perform to accomplish their goals. The interaction workflows for the most common tasks are called key paths. Key paths are "best case scenarios", and they do not take into account any possible human or technical error. These ones were considered to build the variants of the key path. The look and feel of the application was defined including the visual aspects of the Graphical User Interfaces, both of their static and dynamic elements.

All these steps were followed to build the prototypes. Every prototype was then validated. The results of the validation were used to refine some aspects of the designs. These refinements could go from the review of the hypothesis of persona to changes in the look and feel.

According to the philosophy of participatory design and involvement of users in all stages of the process lifecycle, the validation was performed along three phases. The next table summarizes all evaluations and testing.

Process phase	Validation	Place	N Patients	N non-patients
Conceptualization	Conceptual validation	Spain	10	16
Implementation	Experts – Heuristic evaluation	Eindhoven, the Netherlands		4
	Usability tests with final users	Eindhoven, the Netherlands	5	
	Field test with final users	Basel, Switzerland	4	
Deployment	Field tests with final patients	Madrid, Spain	37	
	Field test with final non-patient users	Aachen, Germany		6
Total			82	

Table 1. Iterative evaluation along the process

The conceptual validation took place during the first half of 2005, and consisted on a set of personal interviews to different stakeholders, including HF patients and health professionals. The goal of the conceptual validation was to study the viability of the ideas.

During the Implementation phase, three different validations were performed. The first one was a Heuristic Evaluation that took place in October 2006 in Eindhoven, the Netherlands. Heuristic evaluations are performed by experts, and consist on a screen-by-screen analysis of the application to check its compliance with a set of recognized usability principles, known as "heuristics" [11]. Soon afterwards, the interfaces were confronted to real patients in Eindhoven.

The results of the two validations served to revise the initial premises of the interaction design. A new prototype was built and tested with 4 patients in a field test that took place in Basel, Switzerland in July 2007. The goal of the study was to validate the global system in a real environment with real users who will use the system in their homes. The version tested was version 1 of the system [12].

In the deployment phase, the final system was validated with patients and non-patient users. This last validation took place between January and March 2008, in Aachen, Germany, and Madrid, Spain. The test in Madrid included 31 patients recruited at the Hospital Clinico San Carlos (HCSC) in Madrid and 6 in Getafe. All patients were cardiovascular patients. Tests at HCM were performed under the supervision of technical staff, user interaction experts and medical professionals. The chosen methodology was a confrontation with patients, where patients were prompted to use the system for 15 minutes and to fill in a final scoring questionnaire. The objective of the questionnaire was to gather quantitative data of the insights of the users.

IV. DISCUSSION

The results of these tests were highly positive, especially during the last iterations. All usability and acceptability problems that were detected during the first iterations were addressed within the last iterations and most patients showed no problems to interact with the PDA. The overall opinion about the concept was highly positive. Most patients expressed that they would feel more secure knowing that health professionals would remotely manage their health status. Most concerns were related to the vest, and night monitoring was considered as intrusive by many patients.

In general all results regarding ease of use and usability were over 3.70 over 5. Older patients that initially expressed their reluctance to new technologies valuated the ease of use of the PDA. On the other hand, the vest and body sensors were considered too bulky, and many patients expressed found it difficult to put the vest on.

Therefore, the resulted final solution can be considered to be suitable to be used by heart failure patients. It is also important to remark the difference between the response of the patients during the first iterations and their response to the final system.

V. CONCLUSIONS

The research presented in this paper models the patient interaction in an Ambient Intelligence Environment. A thorough research has been made in Human-Computer Interaction methodologies, aiming to guarantee a good and natural user experience for chronic patients. Goal-Oriented Design served as a good starting point, as it allowed designers to empathize with Heart Failure patients and to know better the patient's needs and goals. The main goal of the designers was always to achieve user acceptance, and this acceptance will only occur if technology, systems and interactions are designed for and with the real patients and other stakeholders. Nevertheless, chronic diseases not only affect the patient, but their social and medical environment, and suppose a burden on the health care systems. The proposed model takes all these contexts into account, aiming to improve both patient-system interaction and human-human interaction.

The results are very promising in terms of the interaction modalities implemented. These modalities can also be extended to the healthcare of other chronic diseases, and in the near future co-morbidities should also be included. Nevertheless, a detailed analysis to enhance individuals experience incorporating this system into the daily routine is still lacking. A framework to be followed considers the analysis of different variables.

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