User Interaction for people living with a chronic disease

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***Abstract*— Ambient Intelligence (AmI) allows the intelligent and natural interaction between the context and individuals. This paradigm will facilitate user support through novel medical protocol design for chronic disease treatment, based on the healthy lifestyle promotion.**

Cardiovascular Diseases (CVD) account for 45% of all deaths in the western world according to the 2004 World Health Organization statistic report. Heart Failure (HF), CVD's primary paradigm, mainly affects people older than 65. The European MyHeart Project's mission is to empower citizens to fight CVD by leading a preventative lifestyle and allowing early diagnosis. This paper presents a model based on contexts to identify the patient interaction and the implementation of this model into a Heart Failure Management solution. Heart Failure Management daily monitors vital body signals, using wearable and mobile technologies, to continuously assess this chronic disease. The methodology applied herein has involved stakeholders in an iterative process: Model validation, feasibility, efficiency, user experience, and acceptance. These carefully designed systems play an important role in motivating people to adopt healthier lifestyles by using technical solutions. These solutions allow patient self-management of their chronic condition.

I. INTRODUCTION

Intelligence vision implies the creation of intelligent environments where users interact with the surrounding naturally without additional effort. The technology is integrated into the user's daily life. The environment is adapted to the users in a pro-active context [1].

The proportion of elderly people (aged 65 or over) in the European Union is predicted to rise from 16.4% in 2004 to 29.9% in 2050 [2]. This will increase the number of elderly suffering from chronic diseases such as cardiovascular disease (e.g. heart failure) and significantly strain personal health care services with novel technologies, especially wearable and mobile systems [3][4].

The AmI aims to re-design the user interaction and systems that enable ubiquitous and adaptable services to the user's particularities. The novel interaction model requires real-time adaptation to the user's context despite personalization that allows the user to adapt the system execution.

The research presented in this paper, which follows AmI principles, is based on the design and development of novel solutions that improve the quality of life in patients with chronic diseases (e.g. heart failure). The interaction is natural and the ambient reacts, adapting and preparing the system to the user via complex intelligent systems.

The Heart Failure Management (HFM) monitors the heart using wearable garments (to measure electrocardiogram (ECG) and respiration), and portable devices (weight scale and blood pressure cuff) with Bluetooth capabilities.

HFM aims to decrease the HF population's mortality and morbidity. The system aims to improve healthcare resource efficiency, and maximize HFM cost-benefit rate.

Figure 1 illustrates the holistic adopted solution, which consists of both a user and professional interaction problem.

The sensor uses a weight scale, blood pressure, bed garments, and wearable garments to monitor electrocardiogram and respiration during exercise and rest.

The user platform groups all sensors into a personal digital assistant (PDA) which receives data from monitoring devices, processes it, and encourages patients in their daily healthcare. The professional platform includes the processing server (that analyzes all data), databases, and a portal that provides ubiquitous access for the professionals.

The daily routine data are processed and evaluated to survey functional capacity, worsening heart failure and other complications.

Because user interaction plays an important role in the system's success, we carefully designed and adapted user-centered methods to wearable and mobile systems to monitor chronic diseases.

II. MODELING

The methodology used for this research has been ad-hoc adapted following the design principles of User Centered Design [5] and Goal Directed Design [6] together in an Iterative Software Design (ISD) process [7].

We divided the process life cycle into 3 iterative phases (Conceptualization, Implementation and Deployment phases), each focusing on observing and interviewing stakeholders, (medical experts and patients) in all stages of the process. Each phase comprises modelling, requirements elucidation, design, implementation and validation. This way the system is evaluated in different maturity stages.

We modelled the solution during the Conceptualization Phase.

In a generic scope, the interaction is modelled as several contexts and several interaction loops. Figure 1 illustrates the holistic interaction model for people who live with a chronic disease.

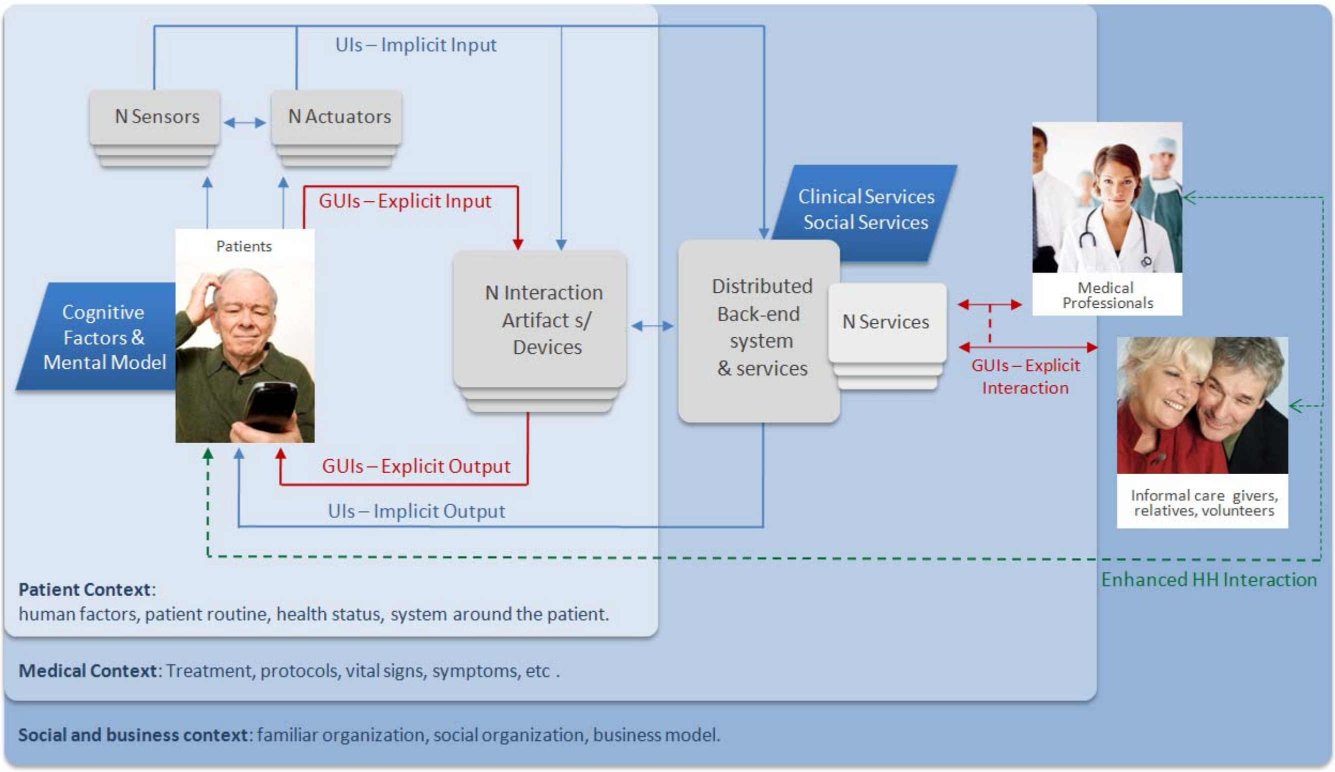

Fig. 1 Holistic Patient Interaction Model comprising all contexts that round the patient

The holistic Patient Interaction Model is organized in three contexts, the Patient Context which defines the human factors or the patient personal routine. Sensors around the patient play important role in their interaction since allows implicit interaction without specific patient input. Around this first context, the Medical Context comprises also the services which provide the patients with a remote monitoring assessment. This context groups all medical professionals. Social and Business Context appears around all. This context states the social and clinical rules that must be taken into account. With this holistic approach all actors are studied enhancing also the human-human interaction.

We adapted this holistic model to a particular target group: people who suffer from heart failure.

We defined the solution goals by reviewing existing similar solutions working together with technical and medical experts, and researchers. This multidisciplinary team stated the initial hypothesis for the system. The technicians created a prototype based on the team's advice.

The prototype consists of an application running in a PDA and a web portal. The patients used the PDA to perform some measurements, such as ECG, and to answer a short questionnaire to assess their condition. The professionals (cardiologists and nurses), via the web portal, could see an overview of all their patients. Professionals have access to patients' current health status.

The preliminary scenario in this prototype was a short walk to promote exercise among heart failure patients. This controlled walk requires a pre-walk phase measured the heart condition and stated the activity's maximum duration (5-10 minutes). We monitored the patient's heart rate using a wearable device such as a T-shirt and activity with an accelerometer). The patient then filled out a short questionnaire and all data was sent to the doctor for further assessment. The medical team accessed all the patients' data via internet.

The standard user was a person aged 65 or older with no disabilities and heart failure. The professionals were both cardiologists and nurses.

Three groups were tailored within the conceptual validation: heart failure patients, medical specialists (cardiologists and nurses), and hospital business managers involved in administrative “chronic disease treatment” related tasks. The objective was to understand their vision, constraints, needs, goals, and behaviours.

There was a positive overall attitude towards the concept. Most interviewees found the solution useful and adequate for long-term treatment of chronic disease. They addressed the need for mobility, thus we implemented the user interaction in a PDA that is both mobile and can used via touch screen.

Although this system provides patients with heart failure a sense of security and confidence, issues remain: the system requires user interaction with a technical device, thus reducing the number of people who could be incorporated to the program, necessitating a user-centered design.

This system forces the users to follow a fixed routine that is potentially a burden in their lifestyles. Thus the system should incorporate a higher modularity, offering different solutions to a diverse range of users.

Once all of the interviews were finalized, the multidisciplinary team studied the results in bringing about the HFM product.

Once we completed the conceptualization, the Implementation Phase first refined both domain and other user models, taking results from the previous phase as input. Domain models included workflow diagrams among multiple people, environments and artifacts. User models (“Personas”) represent patterns in user behavior, attitudes, aptitudes, goals, environments, and challenges [6].

The generic user (“persona”) of HFM is Carlos Gómez, 72 years old. He is retired and has heart failure. His awareness of his heart condition leads him to be proactive in his health. He can use an electronic device following an intuitive system. He requires no special needs regarding accessibility (e.g. blind people).

His chief goals are self-assurance and self-confidence when performing his daily routine. He must feel unperturbed and lose his fear of a sudden death. He also aims to control his own health evolution by self-managing his health.

He wishes to live normally, thus making it crucial to give him a system that is non-intrusive that invisible from public view while under treatment. Namely, the system must adapt to his daily routine.

The team creates stories about ideal user experiences, describes how the system fits into the personas’ life and their environment, and helps them achieve their goals. We based the method on the description of scenarios or contexts of daily use.

In the HFM context, the end users are prompted to follow a daily routine consisting of a set of activities (i.e. symptoms questionnaires, measurements using wearable garments and portable devices). The vital signs assessed are ECG, heart rate, and respiration. The portable devices are a blood pressure cuff for systolic and diastolic blood pressure and weight scale. All devices and garments have communication capability (i.e. Bluetooth). Moreover, the user can perform a light exercise of 5-6 minutes, several days a week to improve their health. This routine varies for every patient but must follow some rules for medical reason (e.g. blood pressure must be taken every morning). The routine can be personalized for each patient despite the light constraints.

There were two scenarios detected within the system: indoors and outdoors. The former contains a set of measurements, using the wearable garments and portable devices at home. The user answers two questionnaires defined by the medical team. The later contains an exercise scenario (e.g. a short walk) that promotes a healthy lifestyle and improves cardiovascular capability. The professional checks the status of all patients via portal.

Adaptation to personal routines is the most important user requirement. Specifically, each user will have a different daily health schedule according to particular health status, preferences, mental status and recommended medical protocol. Furthermore, the user application must be intuitive, user-friendly, and must allow natural interaction. The PDA with a touch-screen allows these requirements.

Adaptability to user preferences and routines within HFM is achieved via dynamic workflow execution (which depends on the context information). First, we defined taxonomy: a session is a day using HFM, a day is divided in contexts (morning, exercise, evening, and night). Each context comprises a set of activities requiring user participation at the same temporary term (i.e. a task or activity is the measurement of blood pressure). It is done while measuring the subject’s weight and the morning questionnaire. Thus, we have the morning context. Each context is defined by a beginning and ending time that sets the validity period, restricts the context execution, sets activity performances, and describes the current context state. The state can be inactive, active, performed, aborted and incomplete. Following this scheme, after the application is turned off, all contexts are inactive. Figure 2 shows the flow interaction model based on contexts.

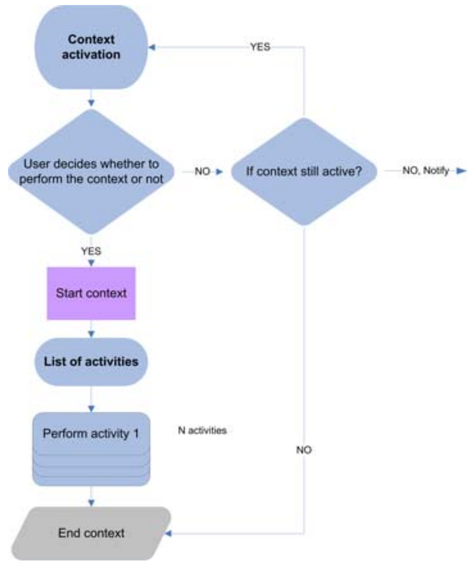

Fig. 2 Basic flow patient system interaction model based on contexts.

Different rules govern context activation (i.e. they are performed between starting and ending time). They also have restrictions in the medical protocol (i.e. exercise must be finished two hours after medication).

Following context activation, the alarm is launched and executed with the user acknowledgement. The context execution equates the activity execution in the list. Each manager controls each activity, thus allowing modularity. The manager invokes all necessary SW and HW modules (e.g. sensors).

Restrictions are events-based occurring in real time. They are triggered either by the user via direct interaction (user voluntarily stops an activity) or by the system. The system launches events coupled to the health status from the study of vital information or the environmental status (patient location, etc.).

The activities execution dynamically occurs depending on the current context: period status, user dialogue, and the health status together with other contextual information.

All gathered data, raw processed raw signals, notifications are sent to the Back-end for further processing and management.

The professionals access all data via the portal. The first available information is an outline of every user highlighting crucial events. The professionals can also consult and edit the information for specific uses. Thus, professionals close the loop and enhance their relationship and interaction with patients.

III. Resulted System

Taking as input all information from the models, we implemented a solution based on a context workflow engine.

The resulted distributed system is composed of a patient interaction which comprises all necessary sensors and interaction device (i.e. a PDA) and the Back-end with all servers, databases and a portal to allow the professional interaction.

The final user platform is a modular architecture running on Microsoft's .NET Framework [8] [9]. The Session Context Engine is the core element that provides flexibility in the protocol that users follow. We based it on the workflow engine that invokes the tasks the user performs according to a workflow that varies with every patient. The varied tasks are organized in contexts.

Figure 3 illustrates the user platform's architecture whose modules are further explained below.

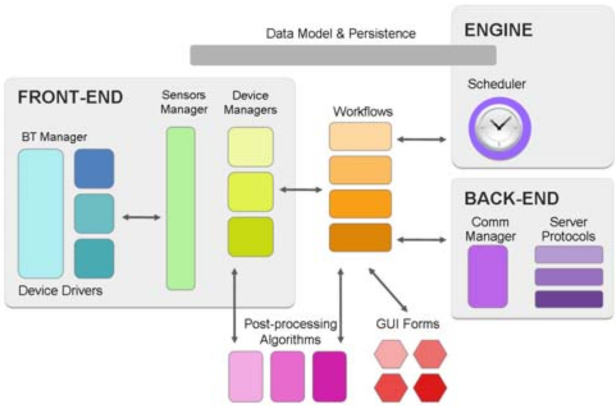

Fig 3. Modular architecture of the user platform

The architecture is divided into 4 main areas: a) the Front-end module, b) the Workflows, c) the Engine and d) the Back-end module. The PDA is also composed of Post-Processing Algorithms, a set of programming Tools and GUI Forms that allow user interaction.

The Front End module provides a standard interface to the sensors. This module isolates the complexity of the communication protocols towards the different sensors. The sensors are a blood pressure monitor, a weight scale and wearable on body sensors to take information from electrocardiogram, respiration and activity.

Workflows define the user interaction via displayed messages and actions taken when the user presses the button. Events from the scheduler trigger the workflows when a context requires performance; the related workflow starts showing the correct user interface. Activity workflow communicates with the device manager and receives the measured data plus events relating to activity status during the activity's execution. The workflows use the graphical user interface via opening and closing formularies, and setting their text fields. The workflows use a Localization module that gathers the local language's textual information from an .xml file to provide internationalization into the application.

The engine module covers a) the application data meaning and storage, b) a scheduler, c) some modules for the application configuration and d) an error management module. This engine implements and manages the Session/Context/Activity model. The application runtime information is stored on Tabloid, a data structure. A tabloid implements the table containing the list of actions the application performed and will perform during the day.

A scheduler persistently updates the tabloid. The scheduler checks the system clock and decides the actions the user performs. It manages contexts, sends information, and launches events warning the user of pending action. Figure 4 sketches the scheduler.

Thus, two programming threads work within the scheduler: the scheduler thread updates tabloids and main forms thread handles the events that activate the GUI.

Context execution is managed on the tabloid. Each context is defined via starting and ending time that sets the validity period, a set of restrictions constraining the context situation, a set of activities the user will be performing, and a variable describing the current context state.

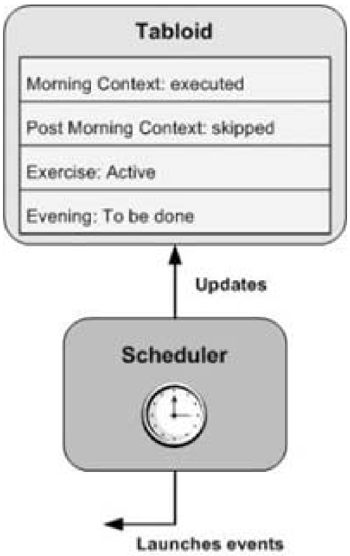

Fig 4. The Scheduler updates the Tabloid and launches events

Some possible states are described in table I:

TABLE I. THE POSSIBLES STATES OF A CONTEXT

State	Description
INACTIVE	when a context has not begun yet
ACTIVE	when a context can be performed and is waiting for an event to be started
PERFORMED	when a context has been completed correctly
ABORTED	if the context execution has been aborted by the user
UNCOMPLETE	when the context has been executed, but not finished

Following this scheme, when the users' application sets off, all contexts are inactive.

Context activation follows the following rules:

1. Each context can be performed between its starting and an ending time.
2. If a context has no restrictions, only the time is checked to know when to activate the context.
3. If the context has restrictions, all of them must be matched.

An alarm is launched and executed via user acknowledgement once a context is activated. The context execution means the execution of activities included in the list. Activity managers control each activity: a questionnaire activity manager supervises the questionnaire's extraction from a configuration file, fills the questionnaire data structure and manages the answers.

Graphical user interaction is provided as .Net formularies (forms). Each form represents an application screen, with static, graphic elements (text/pictures) and dynamic and interactive elements like buttons and slides. User interaction and workflows manage the forms via events.

We designed the GUIs according to Heuristic rules for usability [10] [11]. We carefully performed and validated the design for patients aged 65, experts, and final users in various development stages.

Figure 5 illustrates some of these interfaces.

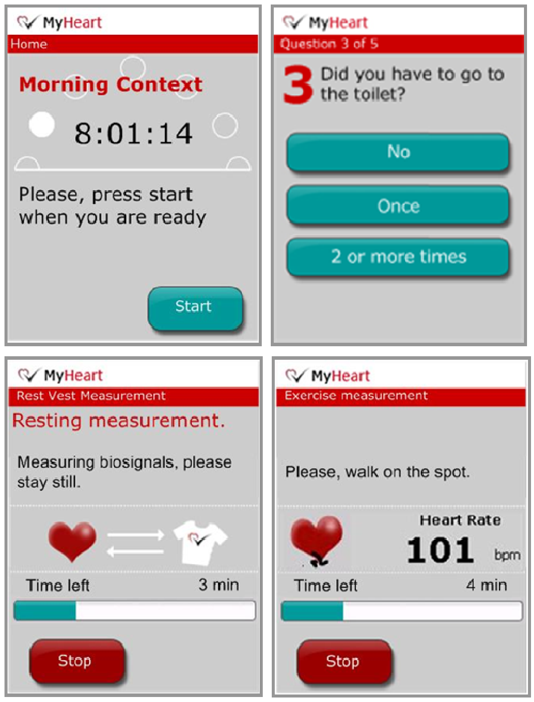

Fig 5. Different screen of the graphical user interface running on the PDA

IV. VALIDATION

This carefully performed research involved the stakeholders in all three phases. Different actors took part in the validation, depending on their needs, throughout the three phases [12][13].

Table II summarizes all testing along the process:

TABLE II. VALIDATION ALONG THE WHOLE PROCESS

Process phase	Validation	N
Conceptualization	Conceptual	26
Implementation	Experts – Heuristics	4
	Usability tests with patients	5
	Field tests with patients	4
Deployment	Field tests with patients	37
Total		76

The conceptual validation occurred in the first semester 2005 in Spain [14].

The heuristic evaluation involved 4 experts in user interaction and people research took place in Eindhoven, The Netherlands, in November 2006. This validation detected an immoderation during the entire routine. We implemented the skip functionality plus more help functionalities, clarifying information for users.

In November 2006, we interviewed 5 users in Eindhoven. We performed this validation in 2 rounds with 3 users each time.

We held the field test during the implementation stage with Medgate in Basel throughout July 2007 with 4 old ladies. The study's primary objective was to validate the global system for Heart Failure's assessment in a real environment with real users who will use the system in their homes. We tested version 1 of the system [15].

Patients performed all tasks until technical problems occurred. Only one patient, whose PDA malfunctioned from the third day, didn't complain.

We started the field text at home and the day they returned all devices. We prompted all patients to fill in a user-experience questionnaire.

The patients initially felt intimidated by the device. After the pilot, they felt more positive although they were still unsure how it will fit into their daily routines.

We fixed all technical bugs detected during the field test. The worst was an inconsistency in data when a context was unfinished (which is solved). Next, another complete system was deployed in Madrid, Spain end of December. This improved system was more stable with integrated sensors and devices. This system was validated with 37 patients in Madrid together with Hospital Clínico. No usability problem appeared and the system resulted robust and stable (see Fig. 6.).

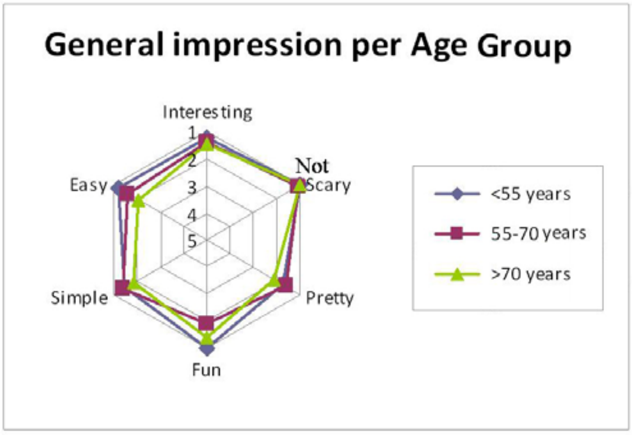

Fig. 6. General impression of the system per age in the field test in Madrid.

V. Conclusions

The results show promising in terms of the interaction modality implemented. However, a detailed analysis in order to enhance individuals experience and incorporate this system into their routine is still lacking. This entails an in depth study of diverse behavior components towards e-health in order to create a tailored communication framework that boosts motivation of patients to use such systems and truly incorporate them to their daily activities. A framework to be followed would consider the analysis of different variables.

Finally, in the new paradigm of Ambient Intelligence, we strongly believe that in the future this kind of systems will represent an important part of the daily activity of this sort of patients, supporting a better quality of life and helping to prevent and to treat chronic diseases.

Acknowledgments

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