MONITORING PHYSICAL AND PSYCHOLOGICAL STATE

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HeartMan is a three-year project funded by the Horizon 2020 programme of the European Commission, developing a personal health system for management of congestive heart failure.

Congestive Heart Failure

Congestive heart failure (CHF) is an incurable disease in which the heart fails to pump enough blood to properly supply the body with oxygen and nutrients. In most developed countries, one senior out of every 15 on average suffers from CHF. Moreover, CHF is the most common reason seniors have to visit the hospital. The main symptom of the disease is the inability to be physically active. CHF patients have to take various medications, they are supposed to monitor their weight, they are advised to exercise, they need to watch what they eat and drink, and they have to make other changes to their lifestyle. This makes CHF management very difficult.

Self-Management Support by HeartMan

In the HeartMan project, we supplement regular care for CHF patients with the HeartMan technology: it is always at hand to provide accurate advice on disease management adapted to each patient, in a friendly and supportive fashion. The HeartMan personal health system consists of a mobile application, a sensing wristband, and a backend in the cloud where patient data is managed in a secure and standard-compliant way. The mobile application for patients provides personalised advice on exercise, healthy diet, medications, weight monitoring, and on other aspects of lifestyle and treatment. In addition, it provides elements of cognitive behavioural therapy to help users change life-long habits to better adhere to HeartMan recommendations. It consists of personalised messages and mental exercises that can change one’s mindset.
The core of the HeartMan project is the mobile application developed for patients. The application helps CHF patients - and their informal caregivers - to manage their physical activity, nutritional needs, mental state, and medication. It does so by using the data collected from sensors in the wristband, manual input, and the decision support system. Notifications remind patients to do specific tasks, such as to engage in a specific physical activity, to play a mindfulness game, to take their medication, etc.

The patients’ progress and status are displayed in a series of dashboards on their mobile phones. Furthermore, patients can also use the application to manage other disease-related information, such as doctors’ appointments. The HeartMan system uses the patients’ measurements to offer personalized advice. These measurements are made with a sensing wristband, connected to the smartphone using Bluetooth. This device offers optic heart rate monitoring, activity monitoring with an accelerometer, and measurements of skin conductivity and temperature. The measurements registered by the wristband are sent to the smartphone for further analysis: for instance, the activity monitoring provides accurate data about the patients’ movements, and the patient’s heart rate offers crucial information for tracking the patients’ health during exercise.

A Web Portal for Healthcare Professionals

Healthcare professionals have a key role in the HeartMan system: the system includes a web portal designed specifically for professionals. This portal has two main aims: to provide fast access to patient data from multiple sources, and to simplify the interpretation of patient information to improve disease management.

The portal offers healthcare professionals the information they need to follow up on their patient: they can monitor their patients’ health status, adherence to medication, nutrition or exercise plan, etc. Furthermore, professionals can follow their patients’ evolution by examining the dashboard that combines patient data from the HeartMan system with existing health records from hospital information systems.
Technology Used

Decision Support System

In order to analyze the patient’s data, a Decision Support System (DSS) has been developed, which is accessed through the mobile application. This DSS analyzes the patients’ data, and offers personalized advice. For instance, for physical activity, the DSS prepares an exercise plan each week, which depends on the patient’s physical condition, preferences and the physician’s input. On exercise days, the patients’ heart rate and blood pressure are checked to determine if it is safe for them to start exercising. Afterwards, the patients are provided with exercise instructions. During exercise, they are constantly monitored via the sensing wristband. Furthermore, the DSS provides nutrition support and education based on testing the patients’ knowledge of appropriate nutrition. The advice provided by the DSS is adapted not only to each patient’s physical needs, but also their psychological profile, and the system also supports the patients’ mental wellbeing. An increasing number of studies highlight the importance of psychological interventions to help patients to lead a fulfilling life after diagnosis of chronic diseases, and HeartMan is one of the first European projects that takes this into account in the management of CHF.
Psychological monitoring and support

The psychological profile is assessed with a model based on artificial intelligence. This model is able to process speech and physiological parameters that are monitored during a semi-structured phone interview between familiar caregiver and patient. Based on these parameters, the model can recognise the psychological profile. The overall psychological model assesses possible changes of psychological status week by week and provides an appropriate psychological intervention based on cognitive behavioural strategies (CBT). This approach is based on personalized messages which act on cognitive processes and unhealthy behaviors in order to improve adherence of medical prescriptions. Specifically, cognitive principles based on “Free choice”, “Effort justification”, “Cognitive consequences of forced compliance” have been adopted, aiming to restructure the patient’s belief for successful management of CHF. Furthermore, exercises of relaxation and mindfulness have been developed and integrated into the mobile application. These exercises are based on biofeedback games, mindful messages and experiential audio files to make the patients more aware of the present moment and to help them to see their illness in a new light, without allowing fear to consume them and drive unhealthy behaviors.

Continuous blood pressure estimation

Blood pressure is an important indicator of the health of CHF patients in general, and the patients need to check it before exercise for safety reasons. Because of this importance, it would be very useful to be able to measure the blood pressure continuously with the HeartMan wristband, rather than use a regular monitor with an inflatable cuff. However, estimating blood pressure using wristband sensors is a challenging research problem that has not yet been solved. In the HeartMan project, we developed a method that achieves accuracy close to what is required by standards for blood-pressure monitors, assuming it receives some reference measurements with a regular monitor for each user. While it is not reliable enough for pre-exercise safety checks, it does offer a valuable insight into the patients’ condition. The method first performs extensive cleaning of the PPG signal to deal with the noise inherent to wrist sensing, and then segments it into individual heartbeats. Afterwards, it computes both established and original features.
Predictive models

Machine learning is used to build a model that can predict the patients’ feeling of health based on the parameters captured with the sensors in the HeartMan system (in addition to the wristband, the HeartMan system features an ambient sensor that measures air temperature and humidity). The model was built from data collected in an earlier European project, Chiron, in which we telemonitored heart-failure patients as well as asked them about their feeling of health each day. It can predict good vs. bad feeling with roughly 80% accuracy on Chiron data. We also developed a method that determines the minimal change in a patient’s parameters that changes the feeling from bad to good. While not entirely adequate for a truly reliable model, we believe its advice regarding ambient temperature and humidity is useful, since this is a topic not addressed by established CHF self-management guidelines. Based on HeartMan trial data, the predictive models are currently being improved.

Health Data Management

In today’s healthcare systems, it is important that different technology systems and software applications are able to transfer and receive data, as well as effectively use them. Therefore, the HeartMan system collects, processes and normalizes data coming from various sources, such as clinical data coming from the Hospital Information System (HIS), Decision Support System (DSS) notifications, the wristband and other sensors, in order to send notifications to the patients to effectively manage their disease. The integration component implements Fast Health Interoperability Resources (FHIR), an improved standard framework created by the Health Level Seven International (HL7). FHIR solutions, built from modular components (called ‘resources’), can be used in many contexts and shared easily and securely.
To make sure the HeartMan system is designed to meet the patients’ needs, CHF patients have been involved in the project from the start. Based on a human-centered design philosophy, patients’ expectations and day-to-day problems have been researched, and they have been involved in creating the first HeartMan prototypes. In Belgium and in Italy, heart failure patients have participated in a diary and interview study. The purpose of this study was to understand the everyday context of heart failure patients as well as their problems, needs and wishes. The study revealed relevant insights into the lives of CHF patients, including how patients experience medical incidents - such as a heart attack or surgery - as traumatic events, and how patients manage their disease on a day-to-day basis, often supported by their partner or children. These insights were translated into user requirements, which, in turn, were the starting point for a first conceptual design of the HeartMan system. Based on that concept, several iterations of mockups were created, to gain more feedback on how patients perceive a self-management system, and to fine-tune the design of the HeartMan system to better meet the patients’ needs. Among other insights, the evaluation indicated which HeartMan features are most important to patients and caregivers, and should therefore be more prominent: these were medication reminders as well as easy-to-read insights into one's own physical and heart condition.

As a final test, the HeartMan system is being tested in a clinical trial. Starting from January (in Belgium) and June (in Italy) 2018, patients with heart failure were recruited to participate in the HeartMan trial. Following a baseline assessment, patients were either randomized into the control group and continued receiving standard care, while those in the intervention group were provided with the HeartMan equipment and instructions. In Belgium, a total of 39 patients were recruited in three Flemish hospitals, with 23 patients being allocated to the intervention group and using the system for at least twelve weeks. In Italy, as of mid February 2019, 27 patients were recruited in the Rieti General hospital, with 15 patients being allocated to the intervention group and they will be using the system for at least twelve weeks. At the end of the intervention, all patients underwent a final clinical examination, identical to the baseline assessment, to evaluate the effect of the HeartMan system on a variety of outcomes, including self-management, quality of life and exercise capacity.
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