pHealth 2020
B. Blobel et al. (Eds.)

doi:10.3233/SHTI200637

Evolution of SmartBEAT for Heart Failure Telemonitoring

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Abstract. The prevalence of Heart Failure is growing exponentially in the last decades, particularly amongst older adults. Heart Failure is a chronic cardiovascular disease that demands self-care management and substantial healthcare resources. For that reason, it is highly associated with hospital readmissions and mortality. Due to increased hospitalization costs, excessive waiting times and lack of specialized healthcare professionals to follow-up this growing population, telemedicine and telemonitoring technologies have become the best solutions to support health providers in the disease management tasks. Telemonitoring technologies offer better and more comfortable care because the elderly do not have to leave the comfort of their home to interact with the doctors, giving and receiving daily feedbacks trough these new applications, wearables, and health care platforms. This paper provides a comprehensive review covering the current progress of research in telemedicine and telemonitoring and their applications to Heart Failure Management services. It presents SmartBEAT, which demonstrated during a pilot phase, a user adherence of 97% for three months. Furthermore, SmartBEAT plus, an improved solution, is described, and the system usability a technology acceptance will be evaluated through a pilot with 40 Heart Failure Patients, involving nurses and cardiologists.

Keywords. Telemedicine, telemonitoring, telemonitoring systems, heart failure management, health information management, heart failure

Introduction

The elderly population in the world is increasing, therefore exists an urgent need to find solutions to extend the time people can live in their preferred environment by increasing their autonomy, self-confidence, and mobility. Chronic diseases are the leading causes of morbidity and mortality in Europe, accounting for more than 2/3 of all death cases and 75 % of the healthcare costs [1]. Thus, there is a high demand for health professionals and scientist to research new solutions and technologies for caring the elderly and chronic patients [2]. These new solutions must consider health information systems (HIS) since hospitals have adhered to these health information technologies to become more effective and efficient in the way health services are delivered to patients. Online information services have shifted traditional paradigms and opened unprecedented opportunities for organizations and citizens, not only in accessibility and availability but also in quantity and diversity [3].

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Heart Failure (HF) is one of the most prominent, prevalent and complex chronic conditions and is accompanied with multiple other chronic diseases [4]. For the context of cardiology, the information systems, together with the technology, allowed to gather conditions that could improve the quality of life of patients with cardiac disease, and consequently facilitate the work of the cardiologists.

Changing the approach of chronic disease management is of extreme social importance to control the cost associated with the continuous growth of HF patients. To address these problems, it is required the adoption of technology and changes how health care is provided [4]. Mainly, enhance the collaboration between all persons involved in the care of chronic diseases and improve the prediction of the results. The adoption of information and communication technologies and the advent of mobile internet resulted in improvements on the connectivity. A variety of data can be collected, such as lifestyle, sensor/biosensor, and health-related information. The analysis of these data empowers patients and the involved ecosystem actors improve healthcare delivery and facilitates the transformation of existing health services [5].

As a benefit of telemonitoring, patients do not need to make as many visits to the hospital since medical treatment can be prescribed remotely. These systems are more accessible and affordable, and patients' autonomy, self-confidence and mobility improve considerably [6]. This paper provides an overview of HF telemonitoring systems and compares them to the one developed in the project SmartBEAT [7]. Through this review, patients and health professionals feedback we specify SmartBEAT Plus an improved version of SmartBEAT that is presented further in Section 3. This paper is structured as follows in Section 1 is presented the SmartBEAT solution, followed by Section 2 that compares heart failure telemonitoring systems with SmartBEAT. Section 3 introduces the improved version of SmartBEAT, based on market solutions ideas, the so-called SmartBEAT plus. Finally, we present the conclusion in Section 4.

1. SMARTBEAT

The Smart System for Management of HF in Older Adults (SmartBEAT) [7] is an e-Health system composed by a mobile smartphone application to a patient diagnosed with HF to create conditions for autonomous monitoring and provision of feedback in time to caregivers and health professionals. SmartBEAT was designed to collect physiological information (weight, blood pressure, heart rate, medication intake, physical activity, SpO2) from the patient using a Vital Signs System (VSS) through a smartphone application the SmartBEAT Companion (SBC), which is integrated with a monitoring system, a medical inference unit (MIU), and a caregiver portal (CGP). The system enables three fast response loops to the patient: 1) automatic using the MIU component, 2) a conditional one through a nurse, and 3) an unconditioned by the cardiologist. In the architecture, each of these components is characterized by having several modules that are interrelated to transmit all relevant information between the SBC application and the caregiver's portal.

To guarantee maximum adherence to the technology from patients, SmartBEAT was subjected to iterative evaluation phases. First, to support the definition of requirements, target-users (patients, informal caregivers, nurses and cardiologists) were surveyed (incl. filling daily diaries) and involved in focus groups to understand better the disease, challenges and suggestions on ideal care. This process used context mapping techniques through several sessions [8]. Due to this phase, SmartBEAT changed its core

dramatically from a sensor-filled wearable harness to a kit of external medical devices. The 46 participating HF seniors considered the latter the most preferable because of comfort reasons. Afterwards, a heuristic evaluation was performed, followed by a pilot and a field trial. In each one, there were significant improvements in the system's reliability, stability, robustness, and the more importantly, in its usability.

Usability is the strongest point of the SmartBEAT system. The application's simplicity allowed for a user adherence of 97% for three months, with 10 HF senior patients – all having low technology literacy. Nevertheless, users still suggested changes and added features. The challenges that were identified during the final sessions of each trial also allowed for the definition of possible improvements. The main observations were: (1) patients felt the need to receive more feedback (either automatic or by healthcare professionals; (2) most patients do not know how to interpret the values of their vital signs; (3) patients have low HF literacy, which in turns affect their self-care; and (4) healthcare professionals feel that the portal still needs to be better adjusted to the usual care process (it adds burden to use multiple and differently conceived systems).

2. Heart Failure Telemonitoring Systems vs. SMARTBEAT

The patients suggested that SmartBEAT should be improved to include an integrated multidisciplinary intervention by adding behavioural and nutritional vectors. The set of variables that could be studied are physical activity, the number of meals per day and type of diet performed. Besides the users' feedback, it was studied which solutions were available in the market targeting heart failure telemonitoring. The solutions that were found are described next and summarized in Table 1.

Table 1. Applications vs incidence areas.

	Incident Area						
Applications	**Nutrition**	**Tech. Devices**	**Physical Activity**	**Family Accompaniment**	**Diabetes**	**Personal Control**	**Medical Check-up**
AHHS for Patients		X					X
AF Manager						X	
COOEY	X			X			X
Nokia Health			X			X	
Veta Health							X
SmartDiab					X		X

The AHHS for Patients system places the patient at the centre of a network of health-related information such as vital statistics, test results, payment information, and many other features. Moreover, through this application, the patient has general pharmacy access to be assisted in prescribing medication options, an appointment book to schedule all kinds of appointments, exams or events, data visualization for analysis and communication platforms [9]. AF Manager is an application developed by the European Society of Cardiology to be used by all professionals who are related to the patient, for example, cardiologists, general practitioners, and nursing staff. The "My AF app" is an educational resource and tool for Atrial Fibrillation patients, which aims to record symptoms and data regarding the patient's quality of life. This information can be shared with the healthcare team [10]. MY COOEY application allows health caregivers to manage patients, vital signs monitoring, manage events and social life, and manage the activities register. Furthermore, through a web portal, they have a perceptivity of all

activities, create care plans, manage caregivers, and connected devices. The informal caregiver has the MY COOEY KIN that allows to elder health remote monitoring; receive alerts in case of a fall or vital sign outside of the normal ranges [11]. The NOKIA Health – App Health Mate application is more focused on sports but serves as a reference for the permanent collection of a patient's lifestyle, for example. The analogue clock provides continuous and precise information about your daily progress in activity (number of steps, heartbeat, calories lost) [12][12]. Veta Health enables patients and caregivers to be partners, producing better health outcomes together. The right tools can empower patients to become active managers of their health, thereby reducing costs and improving the quality of care in an overloaded healthcare system. The patient-facing application collects health data through handheld devices. It is the medical responsibility to identify and manage patients at-risk through the doctor's portal. This App allows users to monitor their vital signs, care coordination, message exchange between patients and doctors, disease management and medication compliance [13]. SmartDiab is a platform designed to support the monitoring, management, and treatment of patients with type 1 diabetes. SmartDiab allows users to manage their diet, exercise, emotional well-being, control his health and medication, manage medical appointments, and visualize the statistics of his registered health values to better understand of his health evolution [14].

Based on the presented solutions, we specified the possible evolution for SmartBEAT. Next, we describe some new suggestions to enhance each component of SmartBEAT. For patient support, suggestions have been made about whether he or she may receive suggestions for controlling vital signs, using voice commands, creating a note section, communicating with formal caregivers, accessing appropriate information about the illness, and registering physical exercise. For the healthcare professionals' platform, it would be convenient to offer them a supportive system, that is, to create a treatment and medication prescriptions. For the informal caregiver's platform was thought about a more significant interaction of these in the care of their family member or friend. Finally, a few other monitoring devices have been added and suggested that it may be useful for controlling HF and other possible diseases, such as the glucometer for diabetes and the ophthalmoscope for diabetic retinopathy.

3. The Evolution of SMARTBEAT

To evolve SmartBEAT other systems and therapeutic areas were identified. In terms of architecture, the SmartBEAT Plus system will be divided into the same four structures VSS, SBC, MIU and CGP. This evolution will be more focused on the data obtained from the patient's clinical information, more precisely on vital signs, response to application questionnaires, physical and nutritional information.

3.1. Proposed Architecture

To characterize the evolution of SmartBEAT to SmartBEAT Plus system, we use the Use Case (UC) Diagrams of UML to represent the main functional requirements and the interactions between the actors and the system. The SmartBEAT Plus system consists of the Web Portal and Mobile Application. Figure 1 represents the more abstract level that generically describes the main functionalities of the SmartBEAT Plus system. In terms of evolution, the new functionalities include a Web App so that health professionals can receive and send messages to the patient with weekly feedbacks (U.C.6 and U.C.7,

respectively). In the Mobile App is possible to manage messages (U.C.13 and U.C.14), access to educational games and activities (U.C.15), read on HF education (U.C.16), record notes (U.C.17), and access external tools (U.C.18). These new implemented use cases improve the patients' proximity relationship with the application and the health professionals and access to external applications related to nutrition.

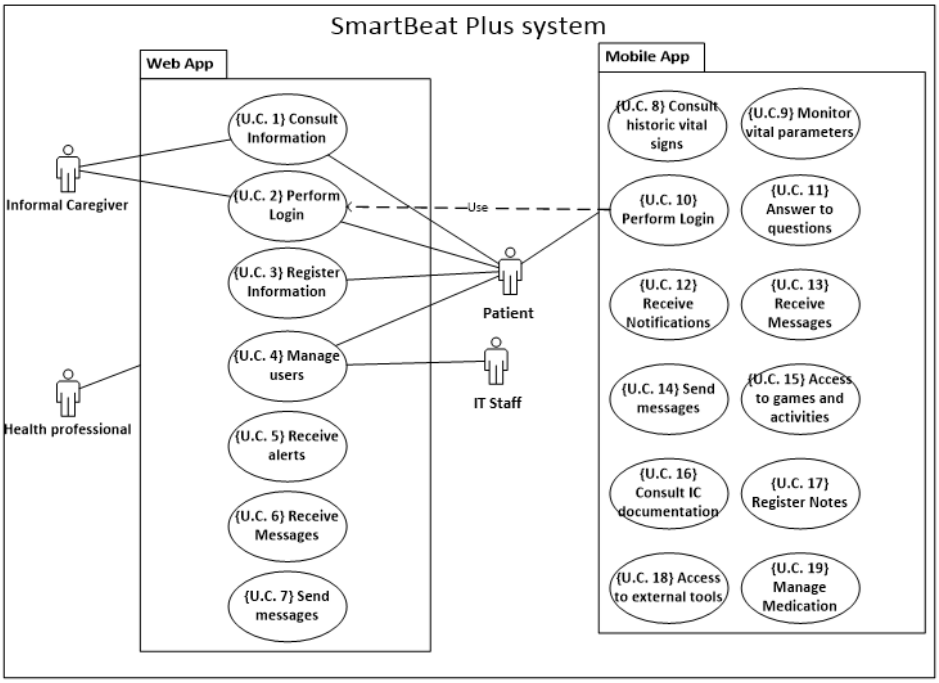

Figure 1. SmartBEAT Plus system use cases.

3.2. Implemented System

Considering the specifications depicted in the previous subsection, SmartBEAT Plus was implemented. The main menu is focused exclusively on the measurement of vital parameters weight, blood pressure, heart rate, physical activity, and SpO2 (U.C.9). In this menu, it is also possible to be notified of unread messages. It was also implemented new functionalities – namely, medication, messages, and the literacy menu. The literacy menu (U.C.16) is a simple, easy to navigate component. Its content was carefully created by SmartBEAT Plus's healthcare team, which included psychologists, psychiatrists, nutritionists, cardiologists, and nurses. The messages were grouped according to its nature: adherence, educational or nutrition-related; and they would have a different icon and colour. These messages were automatically generated. Therefore, the patient – through the mobile App could not send messages (U.C.7 e U.C.14). To manage medication, patients would have a list of their therapeutic plan. This plan would be inserted via the web app (U.C.3), with no required patient intervention. In this menu, patients would register their intake (U.C.19) and be notified at a pre-defined time (U.C.12). A nutritionist would generate a weekly meal plan (U.C.18). This plan would be readjusted every week, according to the feedback provided by the patient within the App.

4. Conclusions and Future Work

The future of healthcare demands the empowerment of patients in the management of their chronic diseases. By becoming responsible for their health and well-being, solutions to follow-up their disease throughout its life cycle become very important. In other words, they become the centre of care, which in turn will require health providers to become part of an Integrated Health System (IHS). In this paper, we described some telemonitoring systems that address these needs in terms of incidence areas. When compared to SmartBEAT Plus, we conclude that the proposed system outreaches them. First, by offering an integrated care solution (technology devices, nutrition, physical activity, personal control and medical-check-up); and second by proposing new ones – such as literacy and adherence strategies (motivational messages).

Several improvements are suggested do SmartBEAT like diabetes management, which affects HF prognosis. Identified functionalities such as note recording (U.C.17) and the possibility of sending messages (U.C.7) (U.C.14) is still yet to be implemented.

Finally, self-care personalization and simplification should be addressed more thoroughly, as they are the key for ideal patient engagement and adherence to therapeutics. In SmartBEAT Plus, we initiated that journey; but the team acknowledges that more can be done. In particular: customized interaction (incl. messages) with patients to keep motivation and adherence; a robust and reliable and a smart decision support system that facilitates the follow-up of multiple patients; and the integration of an e-Prescription service of medicines between the private platform and National Health Service for cardiovascular patients.

References

[1] Gemmill M. Research note: Chronic Disease Management in Europe. 2019.
[2] Leijdekkers P, Gay V, Lawrence E. Smart Homecare System for Health Tele-monitoring. Proceedings of the First International Conference on the Digital Society (ICDS'07), 2007, pp. 3–3.
[3] Santos LD, Amaral LM. Utilização efectiva de serviços de informação online pelos utilizadores. Proceedings of the 4º Congresso Luso-Moçambicano de Engenharia, 2005, pp. 1119–1126.
[4] Brunner-La Rocca H-P, et al. Challenges in personalized management of chronic diseases—heart failure as prominent example to advance the care process. EPMA J. 2016; 7,1: p. 2.
[5] Tripoliti EE, Karanasiou GS, Kalatzis FG, Naka KK, Fotiadis DI. The Evolution of mHealth Solutions for Heart Failure Management. In: Islam MS (Edr.) Heart Failure: From Research to Clinical Practice: Volume 3, 353–371. Cham: Springer International Publishing; 2018.
[6] Kirci P, Kurt G. Smartphones and health monitoring. Proceedings of the 4th International Conference on Future Generation Communication Technology, FGCT 2015, 2015.
[7] SmartBEAT - Project [Online]. Available: http://smartbeatproject.org. [Accessed: 20-Jul-2020].
[8] Visser FS, Stappers PJ, van der Lugt R, Sanders EB-N. Contextmapping: experiences from practice. CoDesign, Apr. 2005; 1,2: 119–149.
[9] All Hands Systems. [Online]. Available: http://allhandssystems.com/. [Accessed: 20-Jul-2020].
[10] Kotecha D, et al. European Society of Cardiology smartphone and tablet applications for patients with atrial fibrillation and their health care providers. EP Eur. Feb. 2018; 20,2: 225–233.
[11] Cooey Health - Empowering Providers with smart solutions. [Online]. Available: https://mycooey.com/. [Accessed: 20-Jul-2020].
[12] Health Mate - Total Health Tracking [Online]. Available: https://play.google.com/store/apps/details?id=com.withings.wiscale2. [Accessed: 20-Jul-2020].
[13] Veta Health - Veta Health. [Online]. Available: https://myvetahealth.com/. [Accessed: 20-Jul-2020].
[14] SmartDiab – Your Health is our Mission. [Online]. Available: http://www.smartdiab.com/. [Accessed: 20-Jul-2020].