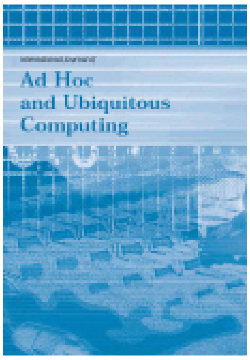


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Javier Navarro-Alaman, Raquel Lacuesta, Jose M. Jimenez, Jaime Lloret, Iván García-Magariño, Trinidad Serrano

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# Ubiquitous monitoring of liver transplantation patients


## Javier Navarro-Alaman* and Raquel Lacuesta

Escuela Politécnica Superior de Teruel,
Universidad de Zaragoza,
C/Ciudad Escolar s/n, 44003, Teruel, Spain
Email: jnavarroa@unizar.es
Email: lacuesta@unizar.es
*Corresponding author

## Jose M. Jimenez and Jaime Lloret

Instituto de Investigación para la Gestión Integrada de zonas Costeras,
Universitat Politècnica de València,
46730 Grau de Gandia, Spain
Email: jojiher@dcom.upv.es
Email: jlloret@dcom.upv.es

## Iván García-Magariño

Department of Software Engineering and Artificial Intelligence,
Complutense University of Madrid, Spain
Email: igarciam@ucm.es

## Trinidad Serrano

Instituto de Investigación Sanitaria Aragón (IISA),
Centro de Investigación Biomédica de Aragón (CIBA),
Avda. San Juan Bosco, 13, 50009, Zaragoza, Spain
Email: tserrano.aullo@gmail.com



**Abstract:** Currently, liver transplantation is the most effective treatment available for patients with end-stage liver disease. Patients, after being transplanted, require immunosuppressive treatment that must be monitored. mHealth systems reduce costs and increase the effectiveness of monitoring. Wireless body sensor networks are used to connect personal monitoring devices in the health environment. In this work, we present a system with a specific software application to monitor liver transplant patients remotely through the data gathered from a body sensor network. The main objective of the application is to carry out the out-of-hospital follow-up of patients who are receiving postoperative treatment. The application also provides a forum, frequently asked questions, and direct communication with health specialist personnel. We have observed that the degree of activity and the emotions of the patients are related to the information provided by the collected parameters through the devices of the body sensor network.



**Keywords:** mHealth; app; wearable devices; monitoring; liver; transplantation.

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**Biographical notes:** Javier Navarro-Alaman received his BS degree in Informatic Engineering from University of Zaragoza, Teruel, Spain, in 2017 and MS degree in Application Development for Mobile Devices from Universitat Oberta de Catalunya, Barcelona, Spain, in 2019. He is currently pursuing his PhD degree in Systems Engineering and Informatics at University of Zaragoza, Teruel, Spain. From February 2019 to October 2019, he was a Research Assistant with the University of Zaragoza, AffectiveLab Group, Teruel, Spain. Since November 2019, he is a Research Assistant with the Aragon Health Research Institute, Zaragoza, Spain.

Raquel Lacuesta received her degree in Computer Science Engineering and PhD degree (Dr.Ing.) in Computer Science Engineering from the Polytechnic University of Valencia, in 1999 and 2008, respectively. She has been a Lecturer of Computer Science with Zaragoza University. She

has authored or co-authored over 60 scientific papers published in national and international conferences; she also has had over 15 papers about education published in national and international conferences and more than 20 papers published in international journals with ISI Thomson JCR. She has been involved as an Organizer and Chair for several important program committees of international conferences.

Jose M. Jimenez received his degree in Computer Science Engineering in 1997 and University Master's degree in Digital Postproduction in 2013 and his PhD degree from the Polytechnic University of Valencia in 2018. He has authored more than 80 research papers published in national and international conferences, international journals (more than 30 with Clarivate Analytics JCR). He has been involved in several program committees and organisation of international conferences. Currently, he is a University Professor in the Polytechnic University of Valencia, in the Technical School of Telecommunications Engineering. Also, he participated in several European and national research projects.

Jaime Lloret received his BSc and MSc in Physics in 1997, his BSc and MSc in Electronic Engineering in 2003 and his PhD in Telecommunication Engineering (Dr. Ing.) in 2006. He is a Full Professor at the Polytechnic University of Valencia. He is the Chair of the Integrated Management Coastal Research Institute (IGIC) since January 2017. He has been Internet Technical Committee Chair (IEEE Communications Society and Internet Society) for the term 2013–2015. He has authored 15 books and has more than 800 research papers published in national and international conferences, international journals (more than 400 with Clarivate Analytics JCR).

Iván García-Magariño is a Lecturer and a contributor to the GRASIA research group at the Complutense University of Madrid. Prior to commencing this position in 2018, he was a PhD Assistant Professor in University of Zaragoza (2014–2018). He was awarded a PhD in Computer Science Engineering from the Complutense University of Madrid in 2009 and was a recipient of an FPI scholarship from 2006 to 2010. He has over 135 publications (over 60 in journals with ISI Thomson JCR). He is an editor in several journals and guest editor in several special issues in journals with impact factor.

Trinidad Serrano has an MD and PhD degree in Medicine. She is the Head of the Hepatology and Liver Transplant Unit of the Lozano Blesa University Hospital in Zaragoza and Associate Professor at the University of Zaragoza. She is an author and co-author of more than 60 scientific articles published in national and international indexed journals. Since May 2021, she coordinates the functionality of the Electronic Health Record of the Health System of Aragon, Spain.

## 1 Introduction

Information and telecommunications technologies (ICT) allow rapid, continuous, and innovative development of technologies in the health area, which improves people's quality of life and electronic services. World Health Organization defines eHealth as the cost-effective and secure use of information and communications technologies in support of health and health-related fields, including health-care services, health surveillance, health literature, and health education, knowledge and research. Starting from the general term eHealth, other terms have emerged that cover different concepts such as telemedicine, telehealth, mHealth, etc. Wearable devices for monitoring patients are a common type of wearable in the field of eHealth. The term mHealth refers to any medical practice that uses mobile devices such as smartphones, PDAs, or wireless devices in general, which improve the care of each patient.

In recent years, mHealth has become a very helpful tool, opening up great possibilities for improvement in the world of health. It is facilitates an important commitment by preventing diseases and self-care, and helps the sustainability of health systems as it increases their efficiency by reducing costs thanks to the remote monitoring of the patients. Moreover, it enables access to medical care, which can be provided by specialists, to people who live in areas of difficult access, which makes access to health systems more equitable for all people (Blumenthal and Tavenner, 2010).

Wireless body sensor networks (BSNs) are used for both health applications and other issues such as sport and wellbeing. When these networks are applied to the health environment, it is very important to transmit the monitored data properly and securely. When there is an emergency, data management can become a challenge. In addition, in order to make adequate diagnoses in patients with chronic diseases, the network should be reliable in terms of high packet data delivery and shorter network delay (Sangeetha and Bhanumathi, 2022). Yousefi et al. (2019) recommend clustering methods to improve wireless sensor networks and indicate that the IEEE 802.15 [wireless personal area networks (WPAN)] standard (IEEE 802.15 Working Group for WSN, 2018) becomes the most popular technology for these networks.

Currently, mobile devices and applications designed for the management of chronic patients are proliferating. In the field of liver diseases, there are recent studies (Stotts et al., 2019) carried out, mainly with cirrhotic and liver transplant patients, that show a decrease in the number of consultations and visits to the emergency room without reducing patient satisfaction. Recently, the first randomised trials have been published, which explore the role of remote monitoring, based on telemedicine, in newly transplanted patients, both liver and kidney (Levine et al., 2019; Lee et al., 2019), demonstrating the usefulness of these new technologies both in adherence to treatment and in the reduction of hospital readmissions.

Currently, patients who have developed liver disease and are in a terminal phase, have a greater chance of improvement if they undergo liver transplantation. It has very good short-term and long-term survival but requires lifelong monitoring of patients (Charlton et al., 2018). Patients require immunosuppressive treatment that must be monitored and, in addition to the specific complications of the transplant, they present an increased prevalence of cardiovascular diseases and cancer. For example, in Spain, from 1984 to December 2018, around 28,000 transplants were performed (Registro Español de Trasplante Hepático. Memoria de resultados, 2018). The high volume of patients, and their chronic control, supposes a significant consumption of health resources in addition to constant displacement for many patients with the inconvenience and difficulties that this entails.

Our working group has a large experience in the development and elaboration of computer applications, which can be installed on any smartphone. These apps allow health personnel to obtain patient data remotely. The data observed will be those related to the parameters that are considered most important and of reference, in terms of the patient's health status. In our work, we present a specific application for the remote control and monitoring of liver transplant patients. To carry out monitoring, we use wristbands compatible with the Google Fit platform. Bluetooth protocol is used to transfer the information from the bracelet to the smartphone. Using the FitKit, which is the Flutter plugin, the data from the bracelets is extracted. It has been developed following health guidelines demanded by specialists from the Hospital Clínico Universitario 'Lozano Blesa' de Zaragoza, and Instituto de Investigación Sanitaria Aragón. Among other aspects, the application collects information on mood, alarm control, and medication. It also takes vital signs, etc. In addition, a list of frequently asked questions, a forum for transplant patients, and a mailbox for direct communication with health personnel are provided. The main objective of the application is to carry out the out-of-hospital follow-up of liver transplant patients. Thus, patient care will be improved and the number of medical visits will be reduced, therefore helping to optimise health resources.

The rest of the paper is organised as follows. Section 2 presents the related work. Section 3 describes the proposed system. The experimental results are depicted in Section 4. Finally, the conclusion and future work are presented in Section 5.

## 2 Related work

In this section, we are going to introduce some studies on eHealth and mHealth that have been presented by different authors.

Some authors (Lloret et al., 2016; Guillén-Gámez et al., 2017; Machado et al., 2012) have presented studies and proposals for the general application of eHealth and mHealth. Lloret et al. (2016) proposed a new secure architecture and protocol between interconnected eHealth clouds. Thanks to their characteristics, they allowed the exchange of data, services, and, in general, all types of resources that could be found in eHealth clouds. A very important feature of the presented architecture was its high scalability, as it easily allowed the addition of both new nodes and eHealth clouds. They present the results obtained in a controlled test bench. Guillen-Gámez et al. (2017) present a software application that allows authenticated access for patients, doctors, or any actor involved, based on the analysis of the face through the cameras integrated into their devices. According to the authors, to achieve privacy in data access, it is necessary to have a software application to access the database. This access will be graded by sensitivity levels, applying algorithms to facial images. Machado et al. (2012) presented a system that was evaluated in a real scenario, using a mHealth application called SapoFit. Through such system, they enabled the cooperation of mHealth services and applications. His system was based on the reputation of web service-oriented architectures. On the other hand, authors like Otal et al. (2009) present a new medium access control (MAC) model in BSNs, specifically for healthcare scenarios. With their proposal they improve the performance of the networks, controlling the quality of service and energy consumption. Other authors such as Mekikis et al. (2017) present a study on wearables used in hospitals for patient monitoring, so that they have a reliable communication system and a long service life. The authors have provided an analytical model to understand the ability of wearables to rapidly inform to the medical services.

McKenzie et al. (2015) present a study that seeks to evaluate the impact of text messages sent to young patients who have received a liver transplant, to enhance their involvement in laboratory tests. Young people between the ages of 12 and 21 participated in the study. In their results, they demonstrated an enhancement of the involvement in tests from 58% to 78% ($p < 0.001$). As indicated, the participation rate in the controls of patients who did not use the messages was lower ($p = 0.003$). Demonstrating the acceptance and benefit of the use of technology in eHealth.

Other authors such as Abaza and Marschollek (2017) have studied previously published mHealth articles that identify the main diseases, areas, and mHealth technologies and services. These works were most widely applied in low-and middle-income countries. The authors identify seven types of technologies and eight areas of mHealth. Most of them were related to applications for mobile devices that allowed patient monitoring, and aspects related to the dissemination of information, through SMS messaging. Also, Kartsakli et al. (Marschollek) present a survey on M2M systems, which use wireless communications, applied to mHealth. They initially review wireless body area networks (WBANs) used by patients, continuing to present practical applications in mHealth.

Lopes et al. (2011) present a mobile health application designed for dietary monitoring and evaluation, called SapoFitness. Users of the application can obtain a personal health record (PHR), their diet, and the exercise they do daily. It allows continuous monitoring of the user and sends alerts/messages about their dietary program taking into account their physical activity. Its operation was verified on different Android mobile devices.

McGillicuddy et al. (2013) present a study for the prototype of a system where patients who have been kidney transplanted, and who suffer from uncontrolled hypertension, through the use of a smartphone, can perform self-management of medication administration, and also take blood pressure. Charrad et al. (2020) presented a system that allows monitoring patients suffering from heart disease. They propose to collect and analyse cardiac data during normal life, in settings such as home and work. To prevent heart attacks or other forms of heart problems, they use a device that sticks to the skin. Through an algorithm, they detect heart abnormalities in real-time. Through a platform, when an anomaly is detected, doctors can control the patient's activity. It allows an agile and fast treatment of the patient. The medical team can order take actions from a distance such as the application of electroshocks or other measures. In addition, it can even monitor the location of the patient to send help services. McElroy et al. (2016) presented a study to determine the benefit of using digital health kits (DHKs). The kits allowed access through web technology to patients who had been treated with cardiac surgery, to carry out controls on their lung activity and heart rate. The automatic sending of patient information daily was enabled. In addition, live video transmission with a specialist was allowed. Both patients and clinicians were very satisfied with the capacity of the kits. Le et al. (2019) evaluated whether doctor-patient relationships remained strong during post-liver transplant care using telemedicine. According to their results, 90% of the patients agreed to use telemedicine and were willing to use it again. The authors affirm that by using telemedicine, the relationship between doctor and patient is not compromised and, in addition, it serves to save time and money in clinical follow-up.

Other authors (Charrad et al., 2020; McElroy et al., 2016) have presented studies on some of the parameters that our application deals with, such as the emotions and activity of a patient. Setiawan et al. (2020) propose a framework that fuses physiological and facial cues to enhance the classification performance of fine-grained emotion recognition. Feature-level fusion (FLF) and decision-level fusion (DLF) techniques were investigated to recognise seven fine-grained emotions. They stated that multimodal fusion would improve overall accuracy compared to the unimodal system. An accuracy of 73.23% was reached for seven emotions. Sabri and Aloui (2019) propose the detection of a patient's activity in a smart home, using machine learning. Its objective is to evaluate the functional capacity to follow the routines in the patient's life. According to their experiments, they detected a great improvement in the employed time taken for learning.

Fleming et al. (2022) present a review that identifies mHealth applications that have been developed to be used by transplant patients to improve health outcomes. In addition, they help raise awareness about future needs in mHealth applications, which will be developed for patients who have undergone organ transplants.

Vizzini and Piazza (2014) have presented an evaluation study of a home monitoring system for patients after liver transplantation. Using mHealth, they managed to carry out an uninterrupted recovery at the patient's home, maintaining close contact with the medical teams. The system allowed health personnel to monitor and assist transplant patients from the hospital, verify their general condition, collect biometric data, manage their treatment, and finally, offer face-to-face appointments through videoconference.

The proposal of our group improves the previous proposals since it collects information on mood, alarm control and medication taking, vital signs, etc. and emotions. In addition, a list of frequently asked questions, a forum for transplant patients, and a mailbox for direct communication with health personnel are provided.

## 3 Proposed system

This section presents the system procedure that was agreed upon after several meetings with doctors from the Hospital Clínico Universitario Lozano Blesa, who was present throughout the design and development process. Their comments and feedback made the system for monitoring the evolution of transplanted liver patients very easy to use.

After transplantation, there is a decrease in bone density, and significant motor disturbances may occur. Maintaining good physical activity will help to prevent such disturbances. In addition, transplant patients require nutritional follow-up to assess the evolution of their nutritional status and detect, prevent, and treat the late alterations that frequently appear in these patients. Immunosuppressive treatment, through its side effects, contributes significantly to the development of nutritional problems after transplantation, as well as can affect the locomotor system. Therefore, the system will monitor the patients' basal and immunosuppressive medication, exercise, and diet.

Figure 1 shows the architecture of our system. A ubiquitous computing system for patient monitoring is shown. The wristbands, that are responsible for monitoring the patient, send the data from the body sensor network to the gateway (smartphone or tablet) using Bluetooth. The data is collected by the gateway through the developed application. From these devices and using a private wireless network such as WiFi (through their home router) or public networks such as 3G, 4G, and 5G networks, the information will reach the database located at the hospital. After performing the appropriate data processing, the doctors will be able to access the information of each patient.

**Figure 1** Proposed system (see online version for colours)

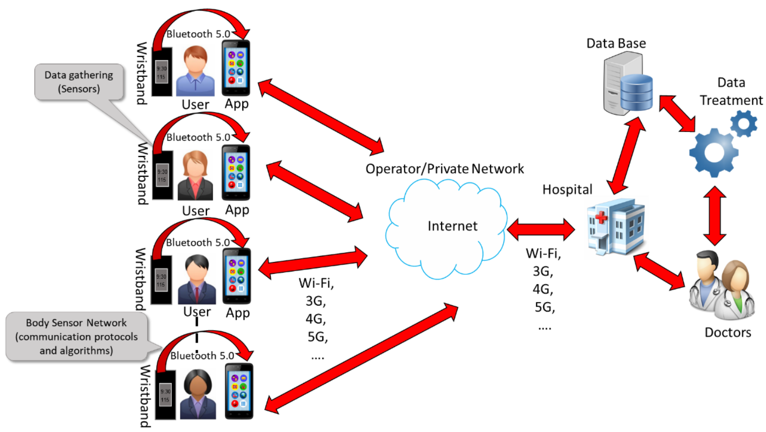



**Figure 2** Data collection process (see online version for colours)

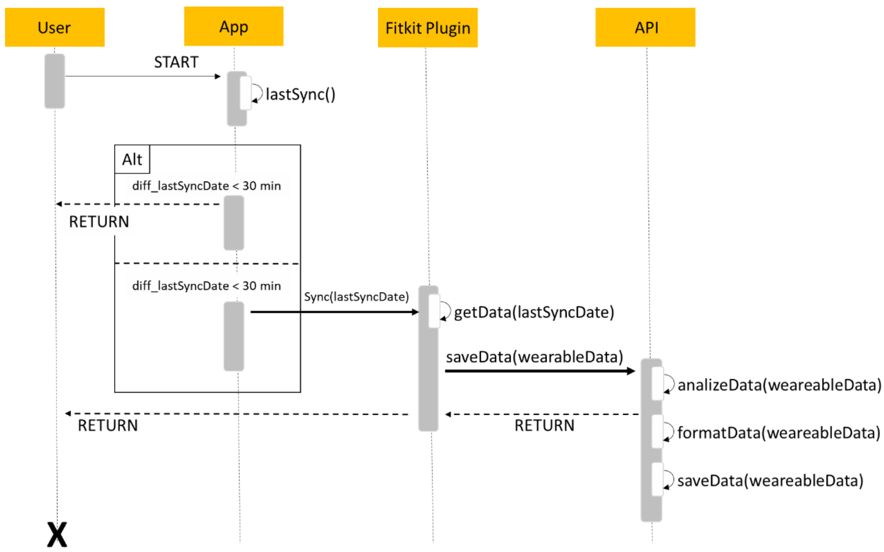



**Figure 3** Process algorithm (see online version for colours)

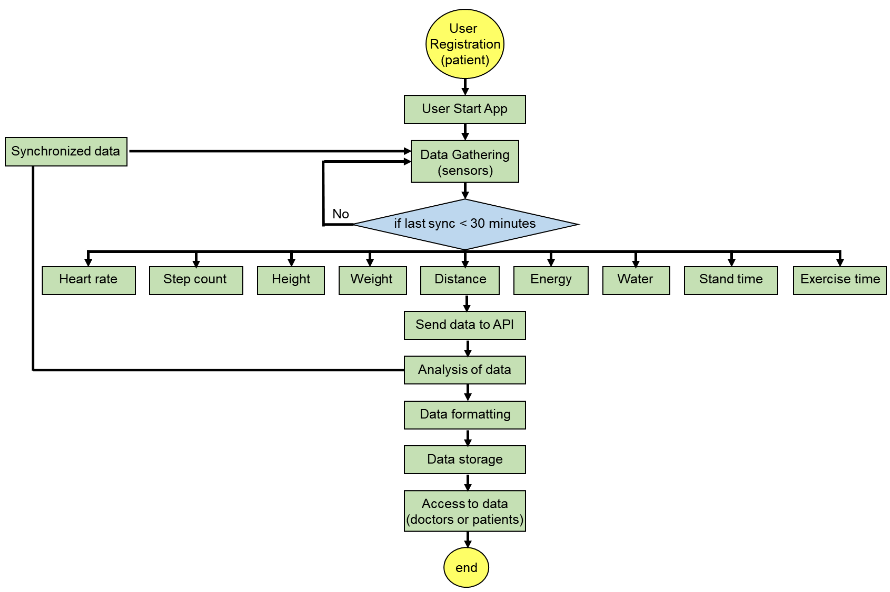
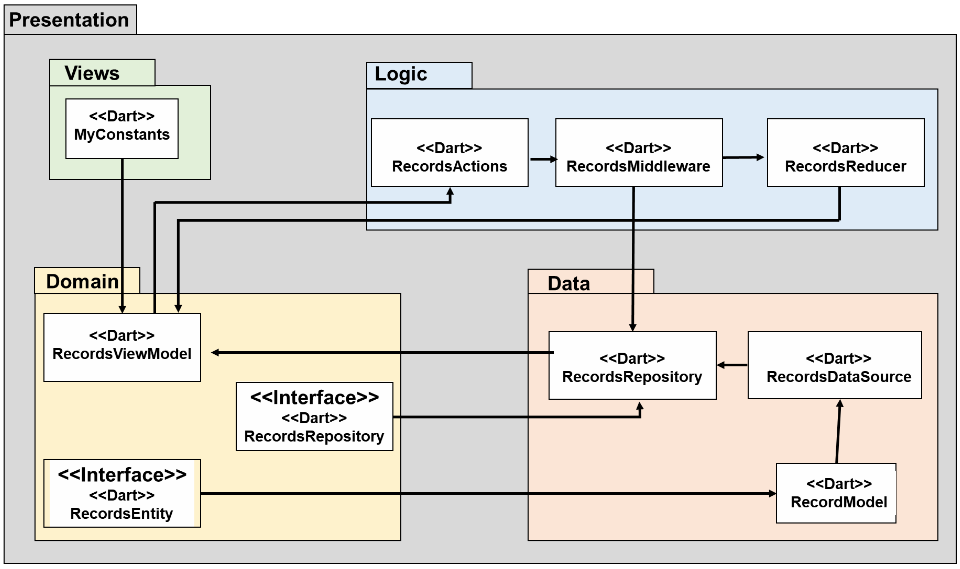


**Figure 4** Application design (see online version for colours)




To implement our system, we have developed an app. The followed methodology was an agile methodology in which doctors participated in all phases. Several versions were made along this process because we took into account the comments and improvements sent to us by the doctors. Although it was initially developed only for Android cell phones, the doctors asked patients who were willing to try the system, and a percentage of them could not use them because they had an iOS cell phone. So, as we started the development of the application in Flutter, Google's open-source framework for creating cross-platform applications compiled natively from a single code base, it was possible to make it multiplatform. To obtain the data from the wristbands, we used a plugin called FitKit, which allows us to connect the mobile phone with the wearables and was compatible with both platforms.

The monitoring process is done through an application connected to low-cost bracelets. As we have previously described, we use bracelets compatible with the Google Fit (2014) platform. We use Bluetooth Standard version 5.0 to transfer the information from the bracelet to the smartphone or device used by the patient. Using FitKit (2019), which is the Flutter (2017) plugin, the data from the bracelets is extracted. Bluetooth 5.0 is one of the latest specifications of the Bluetooth communication standard. By using this specification, higher speed, distance, and bandwidth can be achieved. Google Fit is an app on the Google AppStore and Play Store. It is an open system that allows health and wellness data to be uploaded to a central repository, where the user can access the data from different wearable devices or applications. The advantage of using Google Fit is that the data is associated with a Google account, and even if the patient changes the device, he/she will still be able to access the data.

The FitKit package provides data access in two different ways:

- access to a specific type of DataType
- access to all types of DataType as provided for a given platform.

The available data types are: HEART_RATE (count/min), STEP_COUNT (count), HEIGHT (metre), WEIGHT (kilogram), DISTANCE (meter), ENERGY (kilocalorie), WATER (litre), STAND_TIME (metre), EXERCISE_TIME (metre).

The system controls the patient's follow-up, with the data and surveys carried out in the application and the data obtained from the bracelets. In this way, the doctors can see how the patient evolves and how the different parameters are related to customise the treatment. The type of data collected from the wristband was decided by the doctors concerning what could be most beneficial for the specific monitoring of the liver patients (steps, heart rate and sleep).

Figure 2 shows how heart rate, sleep, steps, and physical activity data are collected in the app. This synchronisation check is done while the user is using the application ('synchronising...' appears at the top of the app). If the last synchronisation has been done less than 30 minutes ago, it displays the time since it was checked. If more than 30 minutes have passed, the system performs the synchronisation using the Fitkit plugin, passing it the last date and time of synchronisation. In this way, the system obtains the synchronisation data of the bracelet from the last date, thus avoiding repeated data and time so that it always collects the necessary data. Then, the system sends it to the API and that is where it parses all the data. Finally, the system sends a message to the user letting him know that the data has been synchronised. Meanwhile, the API formats the data and saves it into the database.

Figure 3 shows the algorithm of the general process. Initially, the user is registered in the application by the medical services. From that moment, the patient can install and activate the App. Patient monitoring will begin. If there have been no changes in the last 30 minutes, the process will wait to update the data. If the 30 minutes have passed, the current data are sent to the API, where they are analysed, and at the same time, a message is sent to the patient in order to notify him/her that the data has been updated. These data go through a formatting phase, so they can be stored later. Finally, both the staff of the accredited medical service, as well as the patients, will be able to access the stored data.

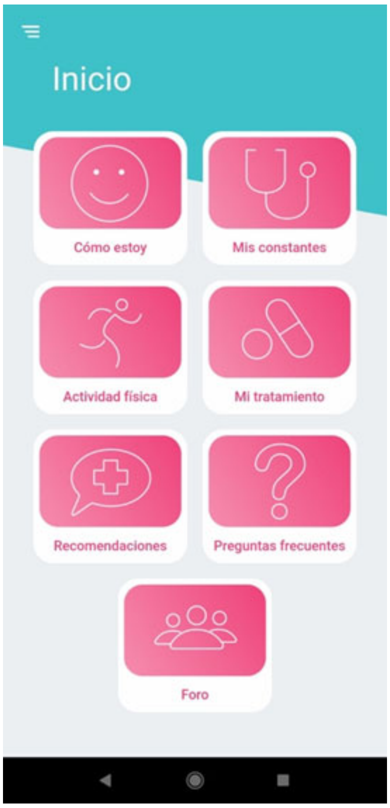
A clean architecture has been followed. We have isolated the layered coordinated code, which allows us to change those layers when necessary. Layering allows us to have innovative options and the way of collecting data from the wristbands at the edge of the application, where they can be changed, modified, or added depending on the changes we want to make in the future.

Figure 4 shows the classes that are responsible for data collection in the mobile application. *MyConstants* is connected through *RecordsViewModel* to the application logic through actions.

The logic of the application is made with redux and the *RecordsMiddleware* is responsible for connecting with the repository. It gets the data from the bracelet. Through *RecordsDataSource* the application sends the data to our API.

The *recordsReducer*, through the actions that will come from the middleware, will save in the state of the application valuable data such as the date of the last synchronisation or raw data of the bracelet to be able to analyse them.

**Figure 5** Application home screen (see online version for colours)




The application home screen is seen in Figure 5. From this initial screen, users can easily access the different categories: how am I, my constants, physical activity, my treatment, recommendations, frequently asked questions, and forum.

Figure 6 shows the screen of the user constants. The application collects information both manually and via wristbands. According to the order they appear on the screen, the system collects the following data:

- Manually: weight, blood pressure, and temperature.
- Using the bracelets: steps, heart rate, and sleep.

**Figure 6** Data collection phases, (a) synchronising (b) synchronised (c) when it is synchronised (see online version for colours)

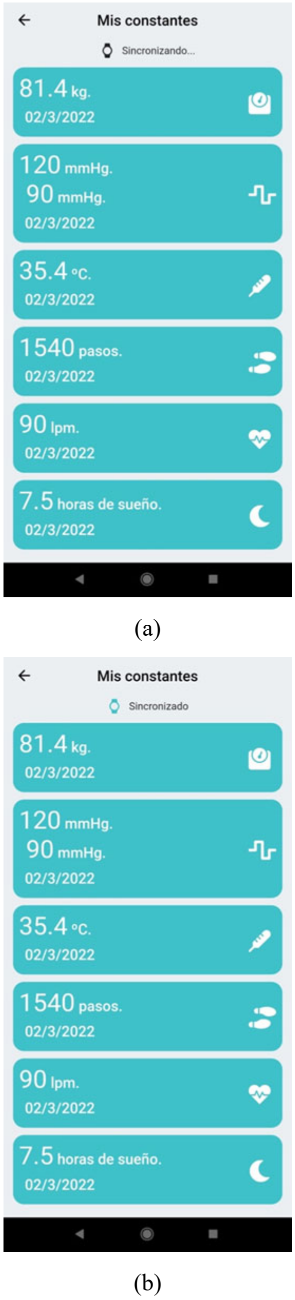
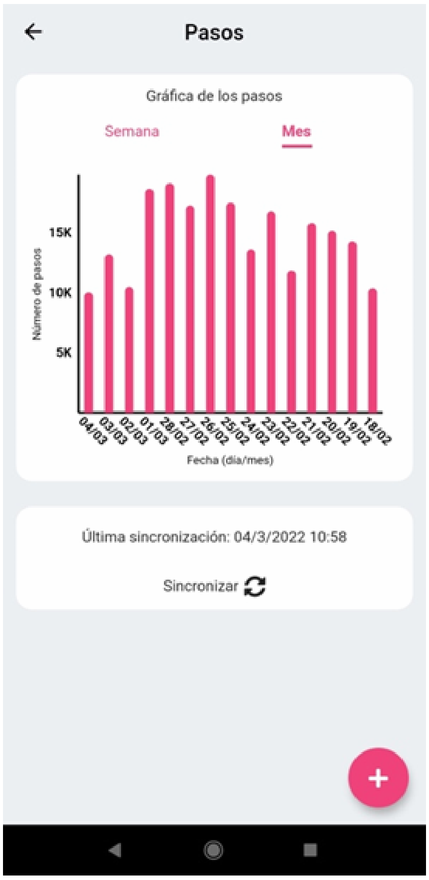


**Figure 6** Data collection phases, (a) synchronising (b) synchronised (c) when it is synchronised (continued) (see online version for colours)


(c)

It also gives the option that if the user does not have a wristband, everything can be included manually, to cover all possible cases.

**Figure 7** A number of steps and manual synchronisation (see online version for colours)



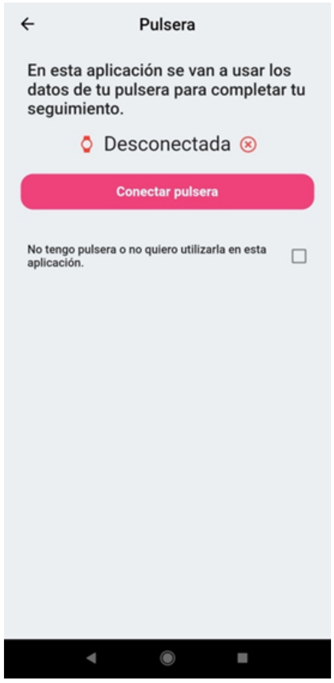

At the top of the screen, three data collection phases of the bracelet are shown:

a synchronising

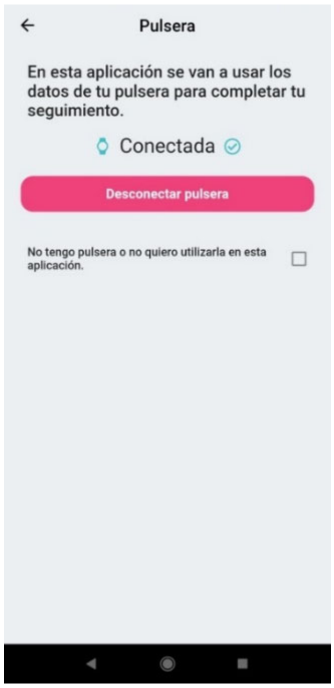
b synchronised

c when it is synchronised but the message is not shown to the user.

**Figure 8** (a) Connect or (b) Disconnect the bracelet (see online version for colours)




(a)




(b)

Figure 7 shows an example of the three constants collected with the bracelet. In this case, it shows in detail the user's steps and how the application can be synchronised with the bracelet manually. Also, it shows the last date of data collection.

In the profile section, the user can connect or disconnect the bracelet. A user can choose if he/she wants to use it or not (if not, the manual synchronisation button does not appear on the constant details screen). Figure 8 shows the screens to:

a connect

b disconnect the bracelet.

**Figure 9** User screen 'how am I' (see online version for colours)

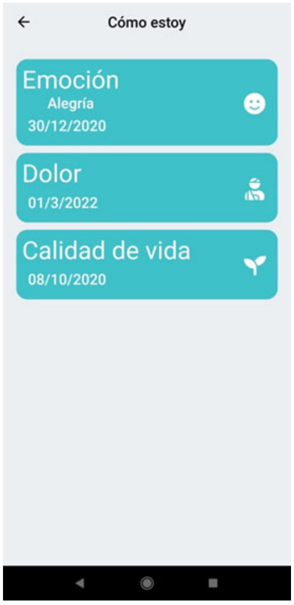
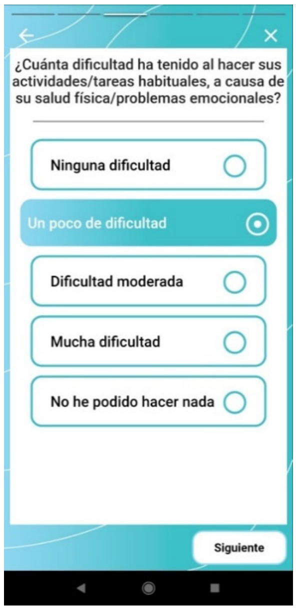



**Figure 10** Survey about, (a) most physical activity (b) difficulty usual activities/tasks (c) limit your social activities (see online version for colours)


(a)

**Figure 10** Survey about, (a) most physical activity (b) difficulty usual activities/tasks (c) limit your social activities (continued) (see online version for colours)




(b)


(c)

Figure 9 shows the screen 'How am I'. It details the information regarding its pain, emotion, and quality of life.

Figure 10 shows the survey carried out by those who wear the bracelet for three days. In it, they must answer the questions: What was the most physical activity you could do for at least two minutes? How much difficulty have you been doing your usual activities/tasks because of your physical health/emotional problems? Has your physical health and emotional state limited your social activities with family, friends, neighbours, or groups?

**Figure 11** Responses from users about the USE of the application (see online version for colours)

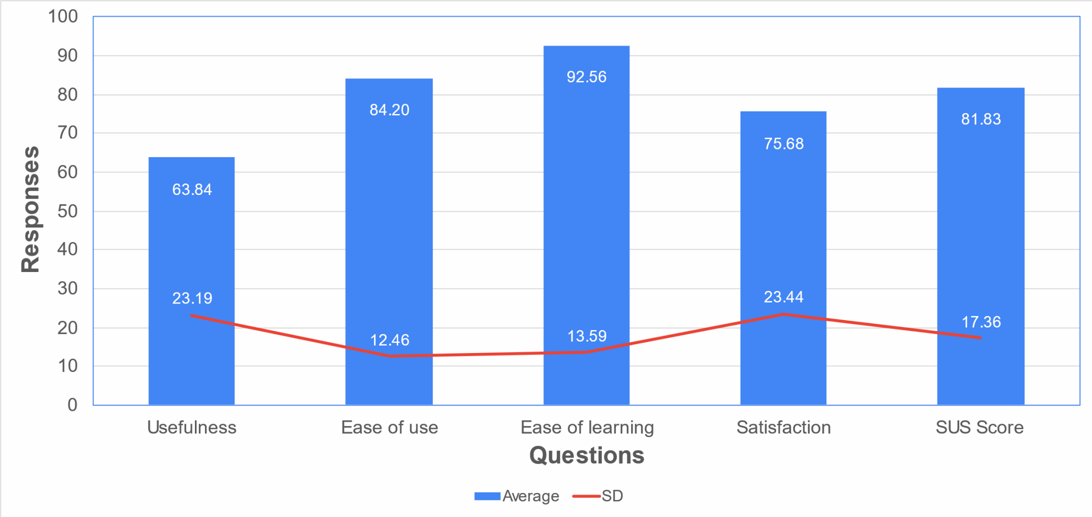
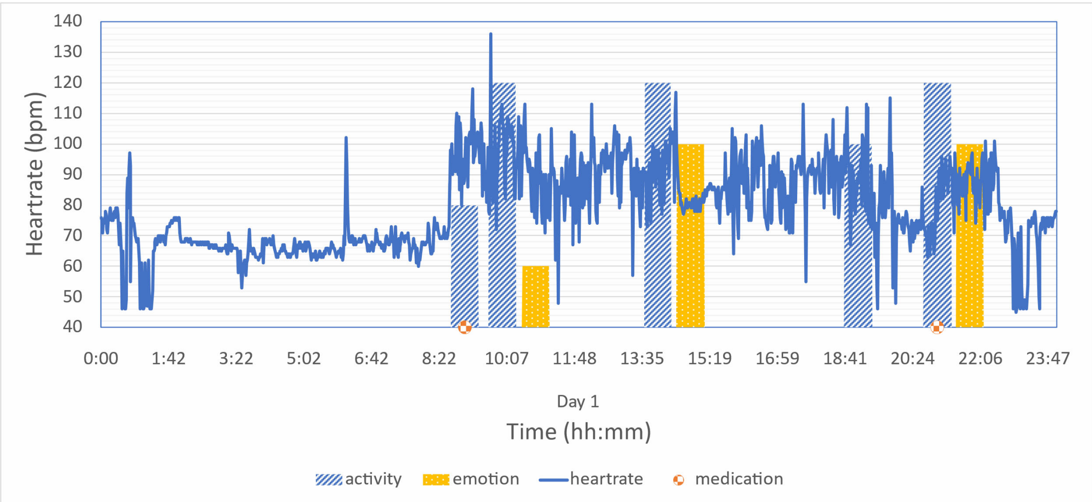
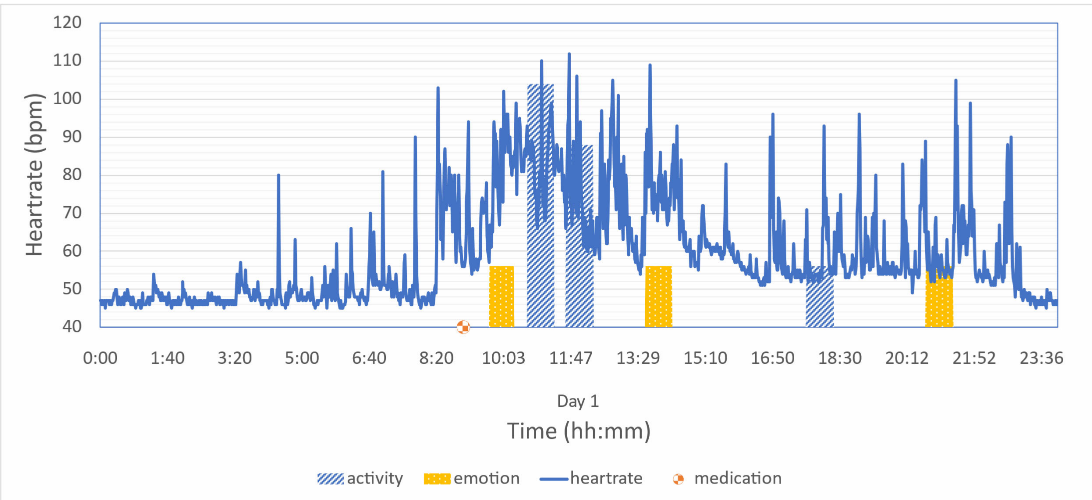



**Figure 12** Day 1 monitoring of users, (a) user 1, (b) user 2 (see online version for colours)

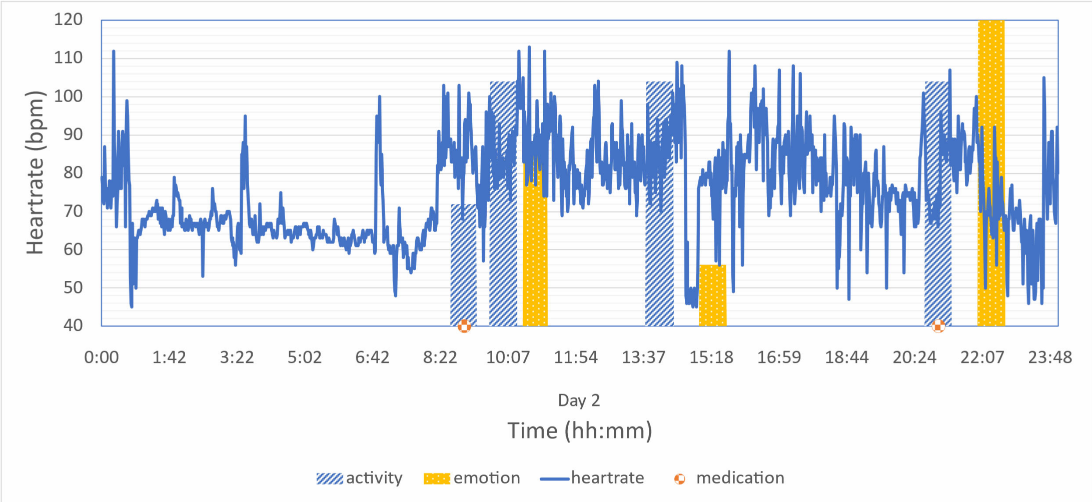



(a)

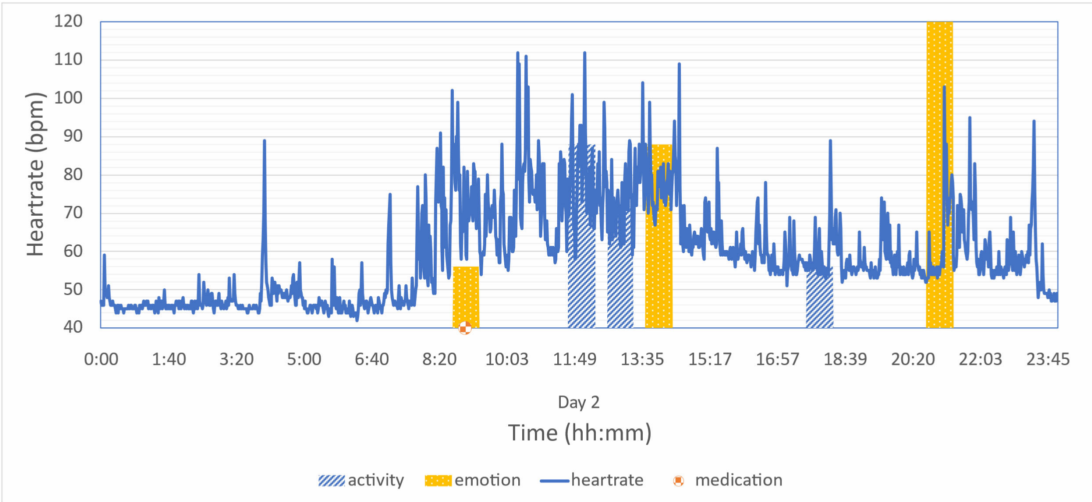



(b)

**Figure 13** Day 2 monitoring of users, (a) user 1 (b) user 2 (see online version for colours)

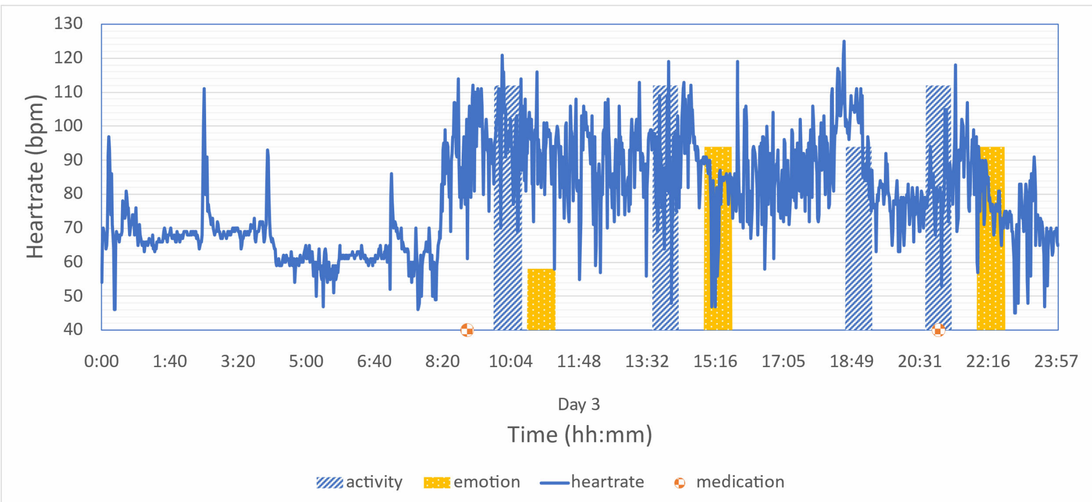



(a)



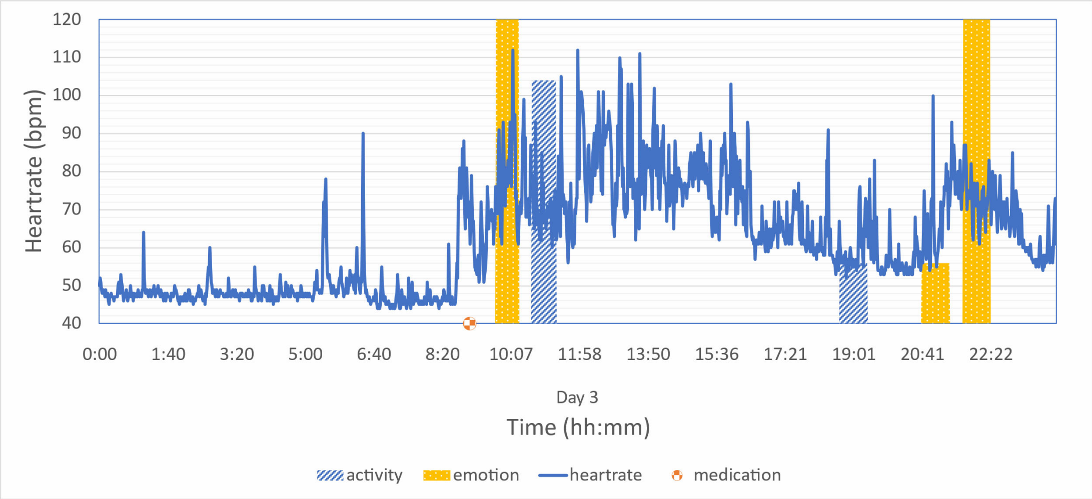

(b)

**Figure 14** Day 3 monitoring of users, (a) user 1 (b) user 2 (see online version for colours)



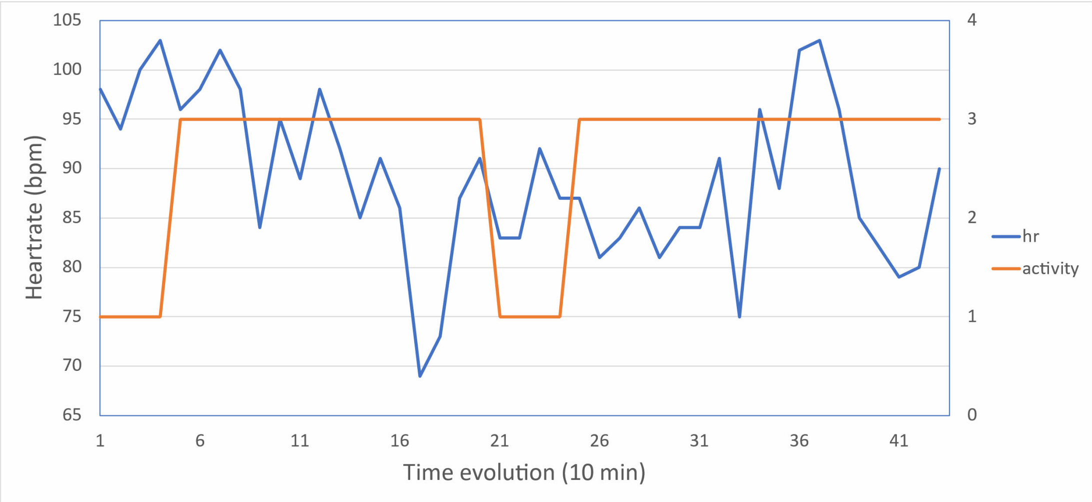

(a)

**Figure 14** Day 3 monitoring of users, (a) user 1 (b) user 2 (continued) (see online version for colours)

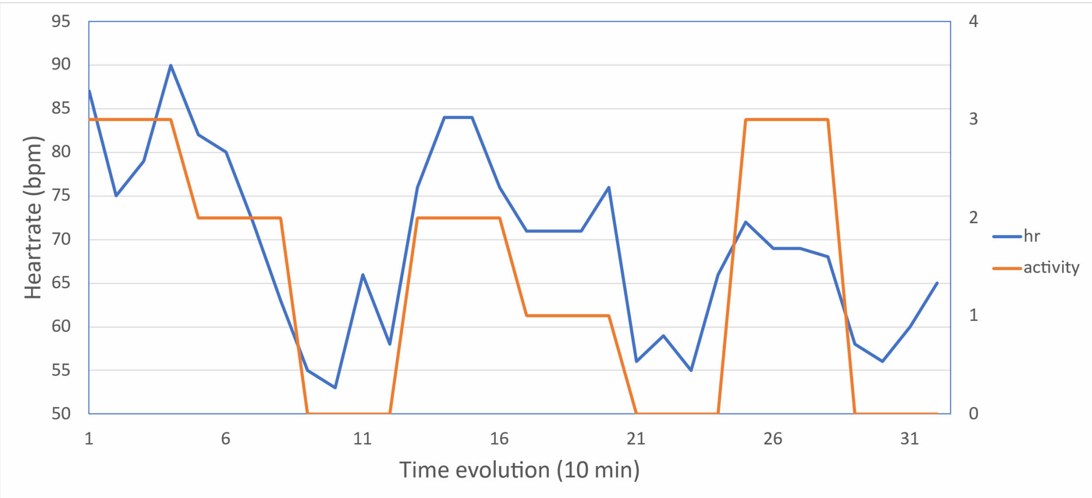



(b)

**Figure 15** Details of evolution regarding the activity, (a) user 1 (b) user 2 (see online version for colours)

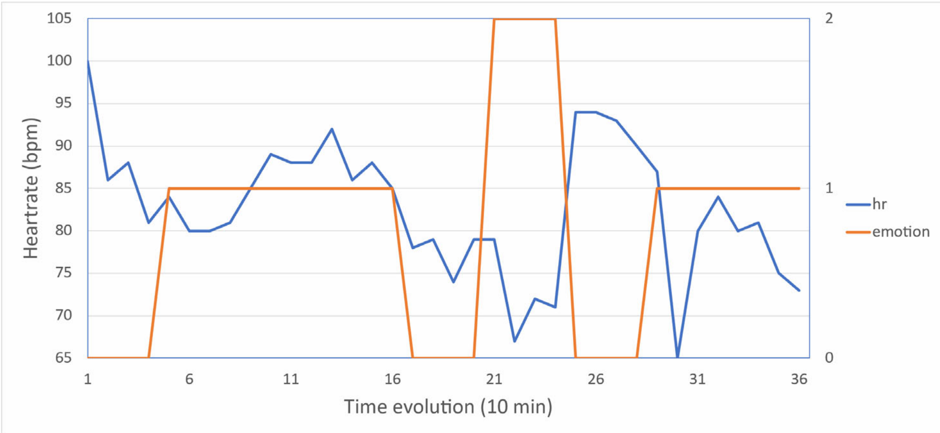



(a)

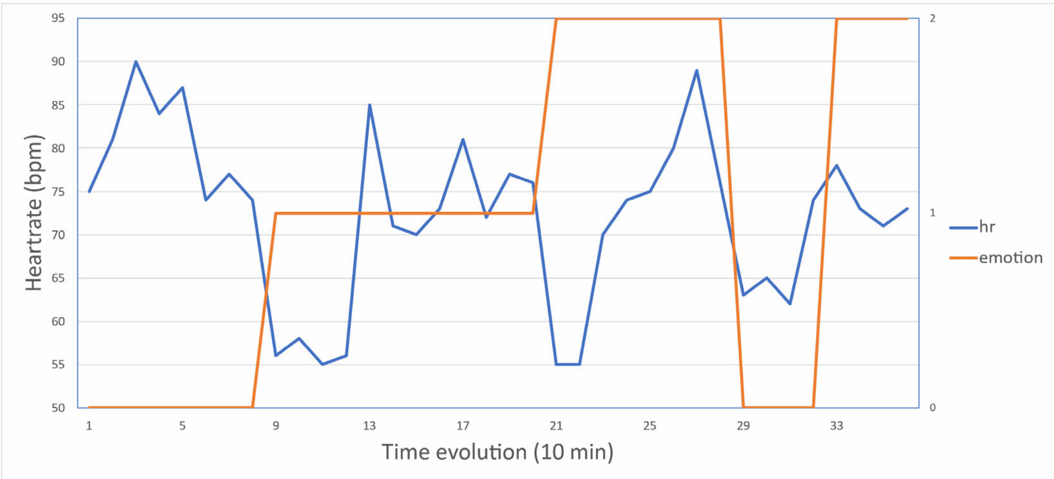



(b)

**Figure 16** Details of evolution regarding the emotions, (a) user 1 (b) user 2 (see online version for colours)




(a)




(b)

## 4 Results

In this section, we present two types of results. On the one hand, we initially present the answers to the questionnaires that have been completed by the users about the application. The first test has been carried out by common users (not liver transplantation users). On the other hand, the graphs of the data observed during monitoring periods are presented.

### *4.1 Usability data*

The average results of the system usability scale (SUS) were in the 1–5 range, and the average results of usefulness, satisfaction, and ease of use (USE) were in the 1–7 range. Therefore, we converted these results to the same range of 0–100 for the SUS and USE questionnaires to compare both results easily.

Regarding usability, the average result of the SUS test was 81.83 in the standard range of 0–100, and the standard deviation (SD) was 17.36. Hence, the average effect of the USE test was 79.07 in the standard range of 0–100, and the SD was 18.17. Figure 9 shows the responses of both questionnaires to compare the results of usability and the three dimensions of the USE questionnaire (ease of use dimension is separated into two factors, ease of learning and ease of use).

As can be seen in Figure 11, users have rated its usefulness at 63.84. The ease of use of the application has been rated at 84.20. Ease of learning has been the best-valued characteristic, with a 92.56. We can consider that 81.83 is an excellent score for our application, in which users can successfully achieve the objectives of the application, without much effort and it is a satisfactory experience for them.

In both SUS and USE questionnaires, values of standard deviation indicated that the participants' responses were highly consistent.

### *4.2 Bracelets data*

The following graphs show the data observed during the user's monitoring periods. Figures 12, 13, and 14 show the graphs obtained in an observation period of three consecutive days, for two users. The graphs show the periods in which the users developed an activity, marked with blue and white bars. When the users register an emotion, marked with an orange bar. A continuous blue line represents the heart rate value. Finally, when a user takes the medication, it is represented with a white and brown sphere. It is noticeable that every time user 1 takes the medication his heart rate goes up.

In Figure 12, if we compare the heart rate of user 1 with that of user 2, we observe that the heart rate of user 2 is more constant. In addition, it is observed that the activity and emotion parameters are lower in user 2.

In Figure 13, we observe that, as in Figure 10, if we compare the heart rate of user 1 with that of user 2, we observe that user 2's is more constant. Also, in Figure 13(a) we can see that for user 1 the last time an emotion is registered when it is positive the heart rate goes down but progressively in the following hour of heart rate taking, in the registration of negative emotion that same day we also observe how before that registration the heart rate is low and in the following hour it goes up.

We can see in that user 2 how the emotion affects in Figure 14(b) when at the end of the day he goes from a negative emotion to a positive one and we can see how the heart rate changes. In addition, it can be seen that, after taking medication and receiving a positive emotion, at 10:07 the heart rate also decreases. In Figure 13(a), in the monitoring of user 1, it is observed that when receiving positive emotions at 15:16, his heart rate decreases.

Figures 15 and 16 show details of observation periods, only when activity was performed or emotion was recorded. These details are for periods of ten minutes. With a continuous blue line, we represent the value of the heart rate. An orange line represents the activity or emotional state in the observed period. Figure 15 shows the details of the evolution regarding the activity of users 1 and 2. The intensity of user activity has been classified into five levels. Level 0 is associated with very light activity. Level 1 is associated with light activity. Level 2 is associated with moderate activity. Level 3 is associated with intense activity. Finally, level 4 is associated with very intense activity. Figure 15(b) shows how the activity affects the heart rate, the more intense the activity, the more the heart rate increases. However, Figure 15(a) shows how, when he/she faced with changes in activity, the user does not present associated symptoms in his/her heart rate.

Figure 16 shows details of evolution regarding the emotions of users 1 and 2. The intensity of emotions is classified from highest to lowest according to the level of emotion (negative, neutral, and positive). Negative emotions occur. As can be seen in the user 2 graph, they may vary depending on the type of negative emotion. As seen in Figure 16(b), negative emotion influences an increase in heart rate. The next moment you feel a negative emotion, the heart rate drops, it may be because it is between two positive ones or it is another type of negative emotion. The first can be nerves (increases heart rate) and the second frustration (decreases heart rate). It can be said that they do affect emotions and that the type of emotion should be studied in the future. In the same way, it can be seen in Figure 16(a), that when the user receives a positive emotion, it is associated with a drop in heart rate, while when he/she faced with negative emotions, an increase in heart rate occurs.

## 5 Conclusions and future work

In this paper, we presented an ad hoc system for monitoring the evolution of transplanted liver patients, capturing data from smart bracelets worn throughout the day, and compared it with the data collected by the application through low-cost smart bracelets.

Our contribution to improving the proposals studied in the literature is to present a system that collects all the data through low-cost bracelets and also to create a system that allows the patient to be in direct contact with the doctors. It offers a better solution for doctors, as they can analyse such data and improve the postoperative management of liver patients for out-of-hospital follow-up. This way, we improve the care given to patients and possible changes in their treatment, reducing face-to-face consultations.

We have been able to observe that the captures of emotions and activities are related to the data we collect with the bracelets. Focusing on the collection of the heartrate since it is what has given the best results. We have also been able to deduce that better data collection by emotion is necessary to draw better conclusions about the changes detected in the heart rate. In future work, the group will continue debugging and adding new parameters to the application, to improve its performance. A greater number of bracelets will be supplied to new patients to carry out a greater number of new patients monitored. In this way, patients can be classified according to different types, based on the responses observed during the monitoring periods, and based on the actions they were performing. The medical services will have a forecast of the evolution of the patients, based on the results obtained in the previous treatments applied to different types of patients and correlating all the variables collected. This could help to find new insights into the evolution of liver patients. In addition, the application will be adapted to be used in the monitoring of patients with other diseases. Depending on the requirements of the data to be observed, the control of parameters specific to the disease will be included.

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