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Better Health Tracking Experience

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Abstract

Nowadays a lot of people use wearables to keep track of interesting data, to compare between each other, and also monitor health data. Users analyse data such as steps, heart rate, burned calories, among others. However, only accessing this kind of information does not mean we are able to monitor health or to improve our health behaviours. It is essential to know the meaning of the data we are observing to understand our current health situation. If the knowledge of health indicators is weak, or is not well communicated, it becomes difficult for a person to change his behaviour by only displaying disparate values or seemingly meaningless, complex charts.

Although the wearables market reached shipments of 33.9 million units in the fourth quarter of 2016, growing 16.9% year over year [Cor17a], there has been decline on the target user's interest. People are acquiring wearables slower than expected, and this is also due to the changes that device vendors undergo to create smarter wearables. While vendors are trying to focus on smarter devices, they are neglecting the most impactful features of a wearable - the self-motivation that wearables can imbue to a person's health have evolved slowly. At present, wearables try to motivate users through achievements, notifications, goals, competitive comparison to other people, and by using dynamic interactions through social media integration. Despite all those motivational features, some users continue to display weak continued adoption, and they also fail to change their habits with these features alone. Furthermore, health tracking applications have small influence on helping users achieve this. Therefore wearables are not improving the health habits of users as well as they could. In this context, it is important to enhance the user experience and to evolve the methods of presenting data, in order to enable users to understand better what applications show them, to induce them in a change of habits, and consequentially to improve their health.

In this thesis there were two main goals. The first one was to create a application that presents the state of the art related to health sensor data, regardless of source being a phone or a wearable but as long as it is widely available. This included traits like steps, heart rate, periodic averages of them, among others. The second goal was intended to develop a proof-of-concept application. After a pilot project, practical results have been collected and analysed through user assessments (interviews and/or surveys), based on a sample.

Resumo

Nos dias de hoje é cada vez mais comum o uso de *wearables* para a recolha de dados fisiológicos interessantes, para a comparação entre outros utilizadores e também para monitorizar dados de saúde. Os utilizadores conseguem aferir, por exemplo, a contagem dos seus passos, ao seu ritmo cardíaco, calorias dispendidas, entre outros dados relevantes. No entanto, apenas ter acesso a este tipo de informação não se traduz na capacidade de monitorizar a saúde convenientemente, e numa consequente melhoria de hábitos. É por isso essencial perceber o impacto relativamente aos dados que são recolhidos e processados, de forma a se poder transparecer ao utilizador qual sua situação atual de saúde, no que respeita a atividade física no quotidiano. Quando o utilizador tem fraca percepção e conhecimento acerca deste tipo de indicadores, ou se estes não forem mostrados da melhor forma, torna-se difícil para essa pessoa alterar os seus hábitos de saúde, apenas pela apresentação valores díspares ou gráficos complexos e aparentemente sem grande significado.

Apesar do setor dos *wearables* ter atingido 33.9 milhões de unidades no mercado no quarto trimestre de 2016, com um crescimento de 16.9% ano após ano [Cor17a], tem havido uma diminuição no interesse dos potenciais utilizadores. As pessoas continuam a adquirir *wearables*, mas de forma mais lenta do que o esperado, e isto deve-se em grande parte ao facto de os vendedores destes dispositivos estarem ainda a afinar o propósito dos seus *wearables* de forma a incluírem funcionalidades do paradigma "*smart*". Ao focarem os seus produtos nesta tendência, estão a negligenciar algumas funcionalidades que têm mais impacto na saúde do utilizador – e por isso o fator de auto-motivação que os dispositivos podem incutir na saúde de uma pessoa está a evoluir lentamente. Alguns dos *wearables* disponíveis no mercado tentam motivar os seus utilizadores, através de conquistas, notificações, objetivos, competição entre utilizadores, e também através da integração com as redes sociais. Mas apesar destas funcionalidades de motivação, alguns utilizadores não conseguem atingir uma utilização continuada destes dispositivos, e com isso torna-se difícil uma modificação dos seus hábitos para mais saudáveis. Além disso, aplicações de *health tracking*, tanto do *wearable* como independentes de *hardware*, têm tido pouca influência na ajuda aos utilizadores que tentam alterar os seus hábitos. Assim sendo, os *wearables* não estão a conseguir melhorar os seus hábitos de saúde tanto nem tão bem quanto expectável com recurso a informação tão detalhada. É por isso importante evoluir estas aplicações de *health tracking*, permitindo que os seus utilizadores entendam os dados apresentados, conseguindo assim modificar os seus hábitos de saúde e consequentemente melhorar a sua saúde.

Esta tese passou por dois objetivos principais. O primeiro foi o de criar uma aplicação que fosse representativa do estado da arte na apresentação de dados de saúde baseados em sensores, independentemente de estes estarem num telemóvel ou terem recurso a *wearables* para a sua recolha, no contexto dos dados mais comuns e disponíveis abertamente para análise. Isto incluiu dados como passos, batimento cardíaco, médias periódicas destes dados, entre outros. O segundo objetivo passou pelo desenvolvimento uma aplicação protótipo para validação do conceito. Após um projeto piloto de utilização da aplicação, os resultados foram recolhidos através da avaliação de utilizadores (entrevistas e/ou inquéritos) com base numa amostra.

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Thanks to my mom and my brother that have always carried me on their arms and have never let me fall. And also a grateful thanks to my father, without whom this would never be possible.

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A big thanks to all my friends and family.

"Humans have always been emotional and have always reacted to the artifacts in their world."

Alan Cooper

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Abbreviations

app	Application
BeHTExApp	Better Health Tracking Experience Application
bpm	beats per minute
DAO	data access object
ECG	Electrocardiogram
GPS	Global Positioning System
HR	Heart Rate
IDC	International Data Corporation
KPI	Key Performance Indicator
KPIs	Key Performance Indicators
mins	minutes
MVVM	Model View ViewModel
PA	Physical Activity
PPG	Photoplethysmography
UI	User Interface
UX	User Experience
WHO	World Health Organization

Chapter 1

Introduction

Nowadays a lot of people use wearables[1] to keep track of interesting data, to compare between each other, and also to monitor health data. The sensory data - like steps, heart rate, burned calories, amongst others - is collected through these wearables that afterwards can be analysed in mobile applications that intend to assist the user in understanding his present health situation. Besides all those informational features, these apps also have complex and crucial mechanisms that intend to motivate users and help them improve health behaviours.

Users enjoy using activity trackers and monitor their health behaviours through applications. It is important to mention that not only users with knowledge on the field will use such apps, but there are users that cannot understand some aspects despite still using them. Nevertheless, the apps on the market do not seem to take that into consideration most of the times.

There are mainly two types of problems: the information passed through the apps is not well communicated, and the user does not have enough knowledge about the field to infer that his health behaviour is weak, strong, or has changed. This turns the process of creating a good user experience, on observing complex health data, a challenge. If the knowledge on health indicators is weak, or is not well communicated, it becomes difficult for a user to change his behaviour by only displaying disparate values or seemingly meaningless, complex charts. Thus, only having access to information, even if it is synthesised and clear information, it does not mean that the user is able to monitor his health and improve his health behaviours.

1.1 Motivation

The mobile apps that process sensory data gathered by smartphones embedded sensors and external activity trackers usually only display disparate numeric values or seemingly meaningless, complex charts. Most of the times, when observing the heart rate, a user with weak knowledge does not know if 100 bpm is good or bad, or even if sleeping specific periods of deep sleep is enough or too much. A study, published in BMC Public Health 2017, questioned participants

[1] Throughout this thesis the term wearable is used for a device that is a wrist-worn bracelet or smartwatch that tracks physical activity.

regarding the usefulness of a wearable [CJCS17] in order to explore users' experience of activity trackers. Most of the participants agreed that these trackers have various useful features. However, the study concluded that participants tended to use these wearables during a period, but do not use it in a continuous fashion. The main catalyst to that behaviour was found to be device breakage or loss, and technical difficulties with the device or companion software. This seems to indicate mostly that users, generally speaking, do not have enough knowledge to understand the information conveyed.

According to IDC, although wearables market reached shipments of 33.9 million units in the fourth quarter of 2016, growing 16.9% year over year[Cor17a], there was a decline on the target user's interest. People are acquiring wearables slower than expected, and this is also due to the changes that device vendors undergo to create smarter wearables. While vendors are trying to focus on smarter devices, they are neglecting the most impactful features of a wearable - the self-motivation that wearables can imbue to a person's health have evolved slowly. At present, wearables try to motivate users through achievements, notifications, goals, competitive comparison to other people, and also by integrating with social media integration.

Despite all those motivational features, some users continue to display weak continued adoption, and they also fail to change their habits with these features alone. Furthermore, health tracking apps have small influence on helping users achieve this. Therefore, wearables are not improving the health habits of users as well as they could.

In this context, it is important to enhance the user experience of these mobile apps that intend to help the user on observing complex health data, which, as we can conclude, need to take into consideration that not only users with knowledge on the field can access these applications.

1.2 Objectives and contributions

In the thesis work we aim to achieve two main goals. Our first concern was to create an application, presenting the state of the art regarding health sensor data, like steps, heart rate, periodic averages of them, amongst others. After that we intended to develop a proof-of-concept application. In order to verify that application we had a small pilot project, in which the results had been collected and analysed thought questionnaires and interviews, based on a small sample.

Also, as part of the thesis work, as a contribution, an analysis of the most relevant existing applications on the market was conducted, regarding health monitoring and activity trackers. Regarding UI/UX, has been identified patterns between applications, which makes possible to understand the current methods used by the industry players.

1.3 Report structure

In addition to this introduction, which includes the thesis context, motivation to help the reader to understand why it is important to solve the identified problem and the objectives that introduce the thesis main goals and contributions, there are four additional chapters. In chapter 2, we present an

overview regarding all subjects of the thesis background, supplying the reader introductory knowledge about the field. Section 2.4 presents the state of the art and related work, which includes an analysis of existing applications on the market and also a pattern identification regarding interfaces between them. Section 2.5 contains a description of the problem this thesis wants to help solving. After that, on chapter 3, we describe all the process taken to achieve the proposed solution, regarding the prototype, and the iterative process used for that. Chapter 4 presents the tests with users of the implemented application and an analyse through the obtained results. Finally chapter 5 concludes about the findings and deliberates about future work.

Chapter 2

Health monitoring through wearables: an overview

This section presents all the themes that have been discussed along with the thesis work, providing the reader with the knowledge about relevant fields.

Activity trackers are powerful devices that enable users the monitoring of their health data, which is based on the collection of data regarding their physical activity during the daily routine. To properly define the physical activity it is also essential to understand the concept of heart rate. Wearables enable the gathering of data, which can then be processed by internal algorithms, that consequently allow the user to assess relevant information in contextual fashion. On subsection *Wearable system overview*, the methods used by activity trackers to gather, process and display all the collected data are presented, and these will vary depending on device brand.

2.1 Physical activity

According to World Health Organisation (WHO), physical activity (PA) is considered as "any bodily movement produced by skeletal muscles that requires energy expenditure" [Org18]. Imagine that a person is simply walking very slowly - that is considered as a PA, even if it needs a tiny quantity of energy to move the body, as the process expends some of the person's energy to complete the action.

In 2010, about 23% of adults aged 18 years old and above, and also 81% of teenagers aged between 11 and 17 years old, were not physically active regularly. A person can become physically active through simple habits, and with it achieve the recommended activity goals. The WHO has defined recommended goals to improve health through physical activity depending on the age of the individual age (Table 2.1) [Org18]. To define these goals, WHO took into account a process involving multiple steps. First, they reviewed and compiled all scientific data for the age groups they created. Afterwards, they define a process which lead them to create these recommendations. This process involved a group that is not only expert in the field but also that works on policy development and implementation. On the subsequent step, the group had a meeting and an electronic

consultation of the guidelines, in order to prepare the recommendations' final draft. Eventually, the WHO Regional offices reviewed the recommendations, made them final and when they are approved by the WHO Guideline Review Committee, the translation, publication and dissemination were executed.

Table 2.1: Recommended physical activity by age [Org18]

Age		
5-17	**18-64**	**65+**
→ 60 mins of moderate to vigorous-intensity PA daily	→ 150 mins of moderate-intensity PA per week or 75 mins of vigorous-intensity PA per week or a combination of both	→ 150 mins of moderate-intensity PA per week or 75 mins of vigorous-intensity PA per week or a combination of both
→ Amounts superior to 60 mins daily provide additional health benefits	→ 300 mins of moderate-intensity PA provide additional health benefits	→ 300 mins of moderate-intensity PA provide additional health benefits
→ 3 times a week include muscle-strengthening activities	→ 2 or more times a week include muscle-strengthening activities	→ 2 or more times a week include muscle-strengthening activities
		→ 3 or more days per week of PA for people with poor mobility to enhance their balance and prevent falls

By achieving the goals mentioned on table 2.1 a person may improve his health in general, for instance the muscles, bones, cardiovascular system, and may further reduce the risk of developing diseases, like diabetes, various types of cancer and depression. For poor mobility persons, these goals are extremely import. Performing physical activities helps in reducing the risk of falls, as well as hip or vertebral fractures. People that cannot achieve this PA goals will present an increase of 20%-30% in the risk of death compared to persons that achieve the goals mentioned above.

Each specific person must have his own PA goal, but according to the WHO, the amounts in the table are at the threshold that produces best results. They not only mention the recommended duration, but also the types of physical activity. Those types are defined depending on the concept of **heart rate zones**, which will be described in the next section.

2.2 Heart Rate

Despite physical activity definitions not comprising specific heart rates, in fact it is an important aspect when defining the PA levels such as moderate, vigorous or low intensity of PA.

A persons' heart rate can be described as the number of times the heart beats per minute, and just as it reads, the measurement unit is in **bpm** (beats per minute). The appropriate heart rate values for PA can be different from person to person, but the age and gender are important factors to take into account, since they can change the zones of each intensity level.

Activity trackers are normally used in body locations where the heart rate can be measured better. Obviously, this value does not depend solely on the part of the body the measurement takes place. It can be affected by other factors like air temperature, body position, emotions, body size, and the use of medication.

This work does not consider those facts, since it is hard to account for all of them, only with the accuracy obtained from using a wearable. The work has mostly took into consideration, if a person is performing an activity or not. We also classify those activities according to table 2.2, which enabled the understanding whereas a person is performing an activity with large energy expenditure, in the case of Aerobic, or if she is performing low energy expenditure PA, in case of Low Intensity.

Table 2.2: Physical activity types classification [kn:19]

Physical Activity Type	**Range of Average Maximum Heart Rate**
Low Intensity	50% - 60%
Weight Control	60% - 70%
Aerobic	70% - 85%

This classification depends on the Average Maximum Heart Rate, which can be calculated with equation 2.1. For example, consider that a person is in Low Intensity activity - that classification means that his heart rate is comprised between 50% to 60% of his average maximum heart rate. On this work, this value was used as the threshold limit a person could achieve during activity, regardless of PA type.

$$Average\ Maximum\ Heart\ Rate = 220 - Age \tag{2.1}$$

The classification system was based on the values defined by American Heart Association, which also proposes that, a normal heart rate, on a relaxed ambient, and when the subject is in good health, should be between 60 bpm to 100 bpm. [Ass15] So, in this thesis the heart rate during activity only depends on the user age, according to the formula mentioned above. Regarding rest heart rate, we arbitrated that the maximum a subject can achieve is 100 bpm, but on the other hand the minimum was not limited, since a lower value means the subject health condition is, usually, better.

2.3 Wearable system overview

Wearables are getting more and more common nowadays, moreover, companies are evolving them with different sensors and technology to make these devices even more accurate.

These devices contain a variety of sensors that provide the ability to collect data, regarding the everyday PA of individual, for instance his acceleration, angular velocity, orientation, and others. One of the main objectives of wearables is to allow users to self-monitor their PA in a

way that they can improve their health habits. However, the data collected by sensors is raw data, which needs to be processed by an algorithm to transform it into understandable output metrics. Afterwards, the processed output information is submitted to mobile apps which makes a similar process comparing to wearables. Generally, the mobile apps take as input data, the output metrics given by a wearable, that subsequently are processed by an algorithm, returning human readable information. In order to process data, wearable sensors and mobile apps, apply an algorithm to input data (raw or not) that results in understandable information.

2.3.1 Sensors

A sensor is a device that collects physical stimulus, for instance light, pressure, magnetism and particular movements. Afterwards, it transmits a response with the obtained impulse. Thus, the work of a sensor is quite similar to a measurement.

Since there is a panoply of different types of sensors, we only present the best-known wearable brands including the top worldwide 5 wearable device vendors according to IDC in 2017 - *Garmin*, *Samsung*, *Apple*, *Fitbit*, and *Xiaomi* [Cor17b]. In table 2.3, we present a list of sensors included into different wearables, grouped by brand, regardless of the model. As a header we have different types of sensors, only the most common ones and for each row we have the information regarding a wearable brand.

Table 2.3: Different types of sensors in wearables, grouped by brand

	Accelerometer	**Gyroscope**	**Barometer**	**Heart Rate**	**GPS**	**Compass**
Garmin	✓	✓	✓	✓	✓	✓
Samsung	✓	✓	✓	✓	✓	
Apple	✓	✓	✓	✓	✓	
Fitbit	✓	✓	✓	✓	✓	
Amazfit	✓		✓	✓	✓	✓
Huawei	✓	✓	✓	✓		✓
Tomtom	✓	✓		✓	✓	
Polar	✓	✓	✓	✓	✓	
Xiaomi Mi Band	✓			✓		
Mobvoi	✓	✓		✓	✓	✓

In order to be more accurate in the most used sensors, it is also considered the sensors presented in the most released devices until 2017, as shown in the chart presented [AMZ+18] in figure 2.1. In the chart PPG means the photoplethysmography, which is the sensor that enables to measure the heart rate.

That allow us to choose the most common sensors in the wearables world, in order to select the ones we pretend to describe. So compass, Barometer, Accelerometer, Gyroscope, PPG (Heart Rate) and GPS were the selected sensors.

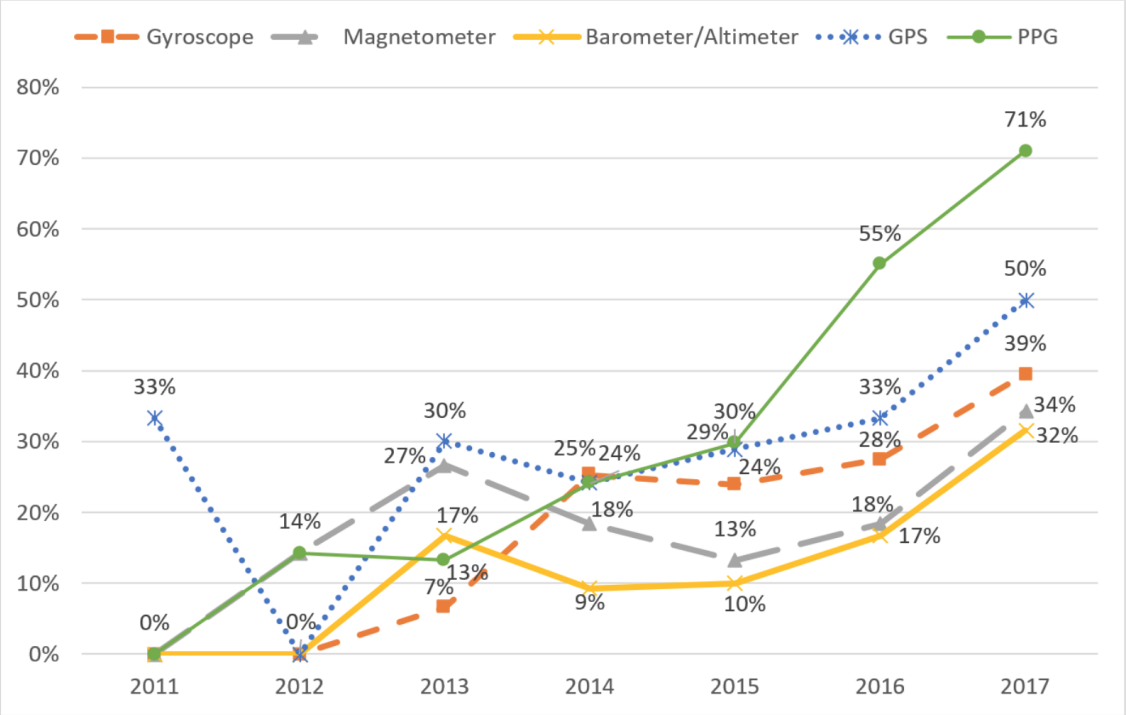


Figure 2.1: Percentage of devices released each year until 2017, supporting each sensor

2.3.1.1 Compass

A compass is a low-cost sensor that allows to measure the wearer orientation. It collects the magnetic field strength on the axis x, y and z. [HAM10] And with that it is possible to define the wearer orientation.

2.3.1.2 Gyroscope

A gyroscope is a sensor that allows to measure the rotation that a wearer is taking. It measures the angular velocity of the individual regarding each of the axis, for instance x, y and z [NAL+17]. The use of this kind of sensor makes the sense of movement more accurate.

2.3.1.3 Accelerometer

An accelerometer is a sensor that allows to measure movement related to PA. Acceleration is the change between initial and final velocity that enables these sensors to calculate the movement intensity. [YR05]

Acceleration is a most valuable information to obtain, because as it is defined by the velocity change with respect to time (m/s^2), it is also possible to obtain the velocity and the distance by calculating the integration with respect to time (Equations 2.2 and 2.3). If a wearer has an

acceleration of zero although there is no change on the velocity it does not mean the user is motionless. This information only tells that the velocity is constant, as shown in figure 2.2.

$$Velocity = \int Acceleration\ dTime \tag{2.2}$$

$$Distance = \int Velocity\ dTime \tag{2.3}$$

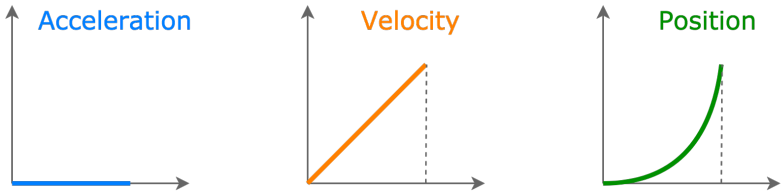


Figure 2.2: Graphic representation of velocity and position when acceleration is zero

The majority of wearables contain a 3-axis accelerometer, this means that the acceleration measurement is done in a 3-dimension ambient: x component, y component, and z component. However, some wearables contain more than 3-axis, if it contains, for instance 6-axis it means the wearable contain, not only a 3-axis accelerometer, but also a gyroscope to be even more accurate. In this case, in addition to the 3 dimensions it also includes the rotation into a specific axis. There are other wearables that contain more than 6-axis. Those, do not only contain 3-axis accelerometer plus a gyroscope, but also a compass, as shown in figure 2.3. This last sensor will provide an even more accurate measure. It not only provides the position and the rotation, but also includes the orientation of the wearer.

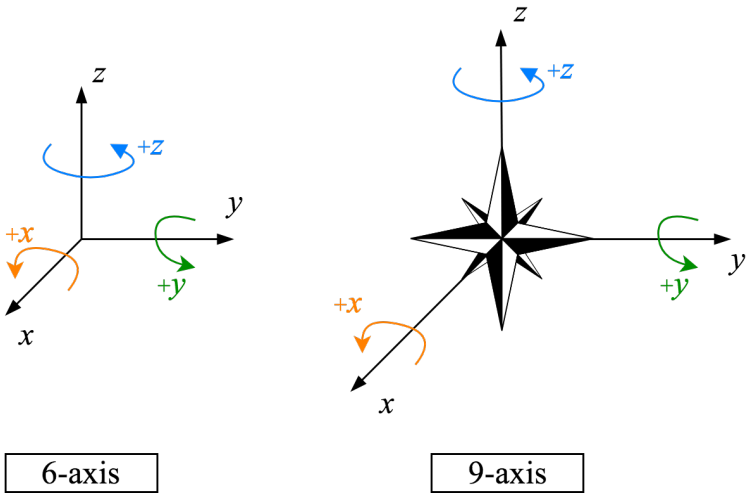


Figure 2.3: Representation of 6-axis accelerometer and 9-axis accelerometer

Therefore, with an accelerometer, it is possible to collect data regarding the wearer velocity

and acceleration. Therefore, this type of sensor enables the measurement of body movement that could be used to estimate intensity of PA overtime.

2.3.1.4 Barometer

A barometer is a sensor that measures the atmospheric pressure. For wearables to calculate accurately the burned calories it is needed to measure, for instance the stairs climbed, which can be obtained by the variations of atmospheric pressure given by this kind of sensor.

2.3.1.5 Photoplethysmography (Heart Rate)

A photoplethysmography (PPG) is a low-cost sensor, an optical one. It simply detects the blood volume variations in the skin surface. The optic-electronic components required in this sensor are a light source to illuminate the skin and a photodetector to measure the light intensity variations.

This kind of method to measure the heart rate is commonly used since it is non-evasive, the sensor only uses the light to detect the wearer heartbeat.

The measurements obtained with the use of a PPG can be compared to the correspondent measurement in an electrocardiogram (ECG). As shown in figure 2.4 the small intensity variations of light are detected as a heartbeat[J.07].

Figure 2.4: Comparison between ECG to the corresponding PPG

2.3.1.6 Global Positioning System

A Global Positioning System (GPS) is a sensor that determines the exact location of the wearer. The Hearth contains a set of geostationary satellites which enables these sensors to determine the user location, velocity, direction and also altitude. The device communicates through radio signal with the satellites, which needs at least four to be in range. To calculate the position, it takes into account the time taken for a signal to hit the wearable, that is considered as the distance between the user and the satellite. The sensor transforms this time into the exact coordinates of the wearer. This type of sensors allows a wearable to collect data regarding the route taken by a user.

2.4 Health monitoring applications

Wearables collect data using their sensors, as explained before in section 2.3. After that, the raw data needs to be processed into readable information, so that the user can understand it and, consequently, infer something about his health situation. Therefore, the most famous mobile apps are crucial to execute this process. In case this process is not well performed, the aim of passing readable information, understandable for the users, could not be achieved.

Nowadays exists a lot of mobile apps that allows users to monitor their health, activity and to understand their current health behaviours. They process the data collected by a wearable, showing important information like heart rate, number of steps, number of floors, calories, amongst others in a user friendly way.

This section presents some of the most popular mobile applications that allows to monitor the physical activity and some health values. This analysis is independent of the operating system, since the objective is to have a wide range of features that have been used so far, and to understand how the data is presented to the user. Also, with this analysis, we have identified some of the apps patterns, regarding the user interface (UI) and user experience (UX). Section 2.4.1.5 presents information through a table, which aims to make a deep analysis trough the methods actually used to present data. Also it presents a comparison through the current used applications, which leads us to identify some of the key resources used to improve the user experience.

2.4.1 User Experience through health monitoring applications

2.4.1.1 Samsung Health

Samsung Health is an Android mobile app, with more than 500.000.000 installations [SEC19], where its users can keep track of their physical activity and also some health information like nutrition and sleep. When the user opens the app, he comes across a bottom menu that enables him to navigate through the app. This menu has three different options, Home, Together and Discover.

Firstly, the home screen presents an overview of the user data during the day itself. As shown in Figure 2.5, this screen has different blocks, each one of them representing a distinct feature.

The first item, for instance, presents the number of steps already taken in the day. It displays this information using, not only a circular chart, but also a bar chart. Both presenting the user number of steps, but the difference between them is that the circular chart also has the user steps objective and the bar chart has the number of steps in each hour of the day. This allows the user to have a perspective of his general performance, on the circular chart, and also a view of his progress during the day.

The two items that follow are about physical activity. Active time shows, similarly to the one above, the time spent on activity in comparison to the user objective per day. In addition it has also the calories burned and the distance taken. The other item displays, not only the time spent

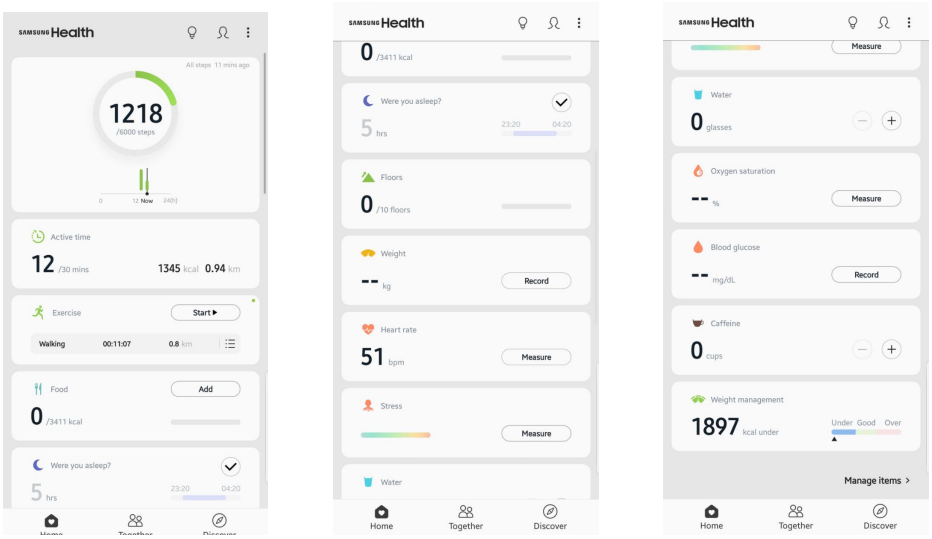


Figure 2.5: Samsung Health Main Screen

and calories burned, but also values regarding the type of activity. Besides that, the user can tap the start button to record a new physical activity.

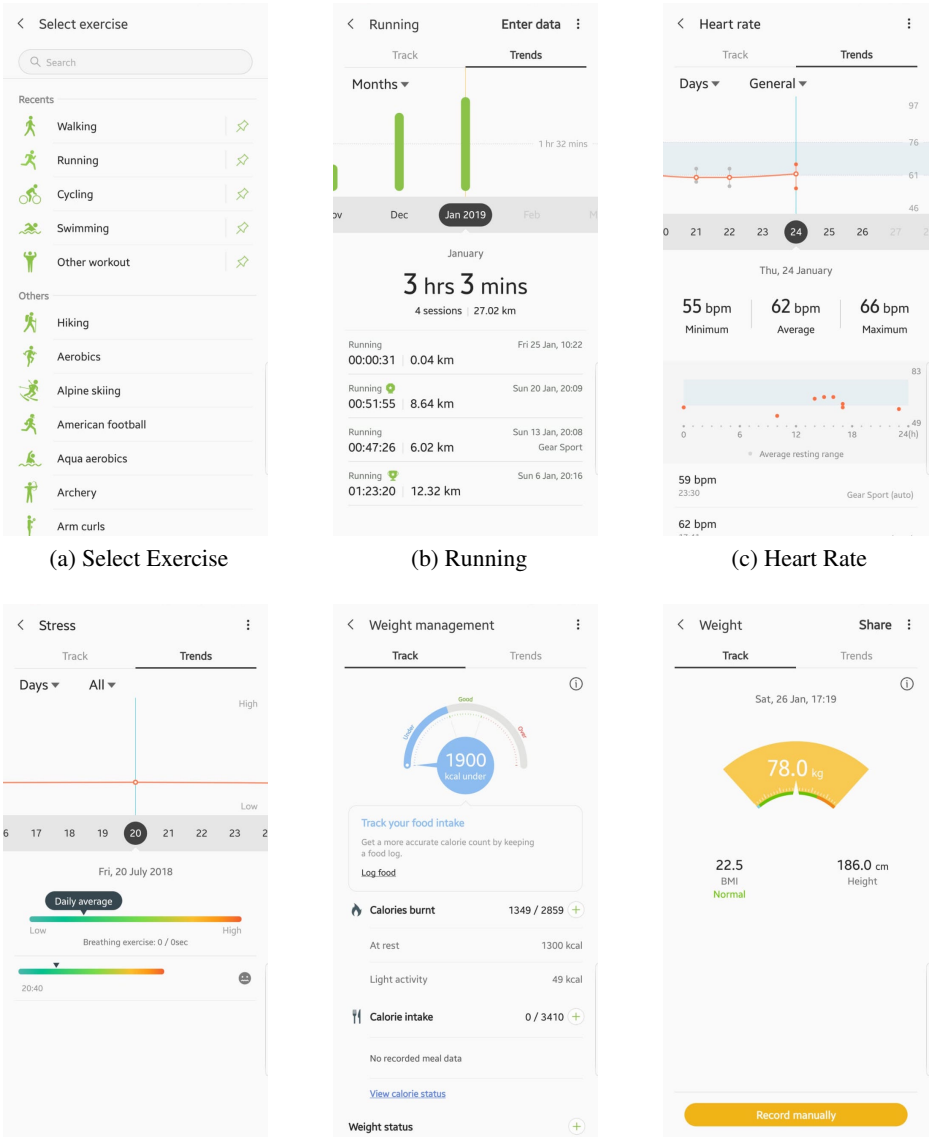
Food and Floors blocks represent their data in a similar way, by displaying the value of the day itself in comparison with the day objective. Additionally, both of them have a bar to indicate the above mentioned, but this time it represents the data in a more visual way, to be easier to have an overview about that metric.

Next to Food there is Sleep, showing to the user his number of hours slept, and similarly to the above features it makes use of a bar to represent the slept time, including the beginning and ending hour. And once again it intends to make a more visual way to displaying the data, since it is an easier to the user to understand his current situation.

Each of these features also has their own screen, as shown in Figure 2.6. These screen has always two tabs. One to represent the actual state of the user, called "Track" label, and the other one, "Trends", which displays the user progress. For instance, in Figure 2.6 (b), which is the running screen, the user can compare his progress during each month and also his general progress over the year. The only feature that stands out from the other features is the select exercise, which displays the information in a list view, as long as the user only needs to pick the activity to be performed, and since the objective is not to infer something about it.

There are a lot more items that the user can configure to have in his home screen. By clicking on the Manage Item (Figure 2.5) feature it is possible to configure all of them. This allows the user to have a full control on what really matters to him or not. With it Samsung Health enables the user to have a total customisable experience regarding the Key Performance Indicators (KPIs) shown on the main page of the application.

Apart from the home screen features, it contains also two other menu options, "Together" and "Discover" (Figure 2.7). Both of them intend to motivate the user to improve his physical activity. For that they use a method that is based on the competition between the application users.



(a) Select Exercise (b) Running (c) Heart Rate

(d) Stress (e) Weight Management (f) Weight

Figure 2.6: Screens of different features on Samsung Health Home page

The "Together" screen is an important motivational feature, since this could lead the user to get even better than the others, for instance, as shown in the image 2.7 it is possible to compare the user steps with the other application users. This app also contains programmes as presented on the "Discover" screen, in which a user is able to join a program in a specific physical activity.

2.4.1.2 Apple Health

Apple Health is a pre-installed iOS mobile application, that not only presents data collected through iPhone and Apple Watch, but also through third-party applications that the users' phone has. Besides that, it also helps on the process of finding more apps that could help the user to improve the displayed data.

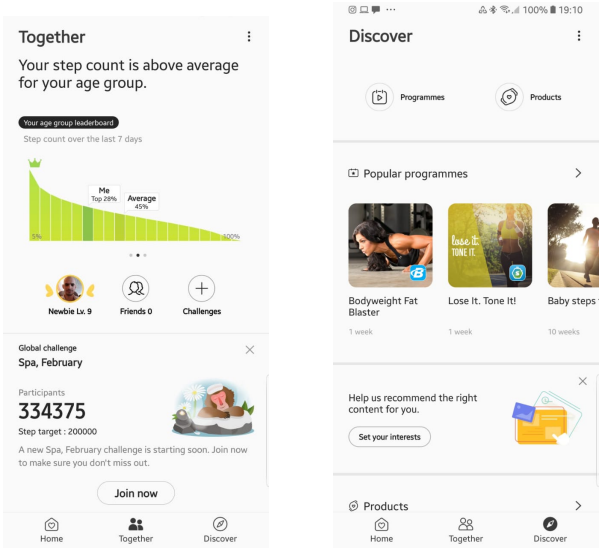


Figure 2.7: Samsung Health "Together" and "Discover" menu options

Just like Samsung Health, Apple Health has a bottom menu, in which the user can navigate through the application, as shown in figure 2.8. This menu contains four distinct options, "Today" and "Health Data" regarding the user actual health behaviours, and also "Sources" and "Medical ID". As long as the app collects data from different kinds of sources, it needs to list to the user where does this data come from. That is why they need to offer the user a menu option called "Sources". But, not only that one is different from Samsung Health, "Medical ID" is also a menu option that does not belong to the previous application structure. This option contains all the user personal information, for instance, his birthday and age, blood type, weight, height and an interesting one, which is the user emergency contacts. Once set, these contacts are notified when the user makes a call to emergency SOS.

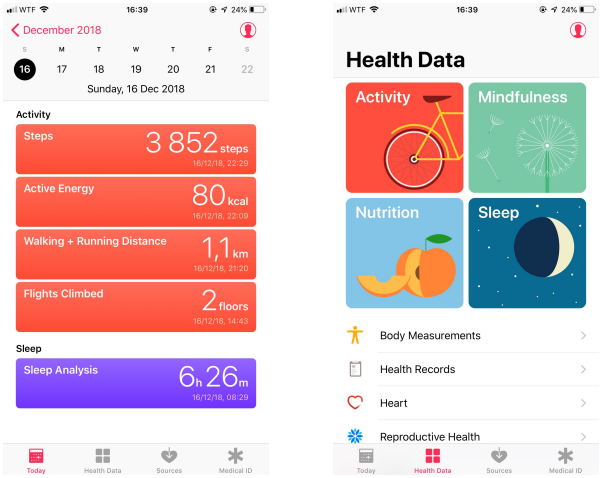


Figure 2.8: Apple Health "Today" and "Health Data" screens

The "Today" screen has also a characteristic that Samsung Health has, which is the fact that

(a) Steps (b) Active Energy (c) Distance

(d) Flights Climbed (e) Sleep

Figure 2.9: Apple Health screens after choosing an item of "Today" screen

each item of this menu option takes his user to another screen, i.e. if the user tap the item "Steps", for instance, the app takes him to a new screen, which contains all the information about his progress of steps during the day. Also the user can get that information regarding each of the other items as shown in figure 2.9. Each of these screens always contain a bar chart that displays the user progress during the day, hour after hour. This is important so that it is possible to have an overview of the progress during the day. The sleep screen is a bit distinct from the others, since the chart contains only one bar where they distinguish between "In bed" or "Asleep" with two colours, purple and pink, correspondingly. It is also presented the corresponding times regarding time asleep, in bed hour and also the hour in bed until the user get up.

With the same logic of the "Today" items, in the screen "Health Data" the user can, once again, tap on each of the four different items to navigate through his correspondent screen, as shown in figure 2.10. Besides that, Apple Health has a particular feature, which recommends the user to use some other apps to improve the data gathering.

So, Apple Health mainly distinguishes itself from others in terms of two features, the fact that the user can define emergency contacts to notify them if an emergency occurs, and also recom-

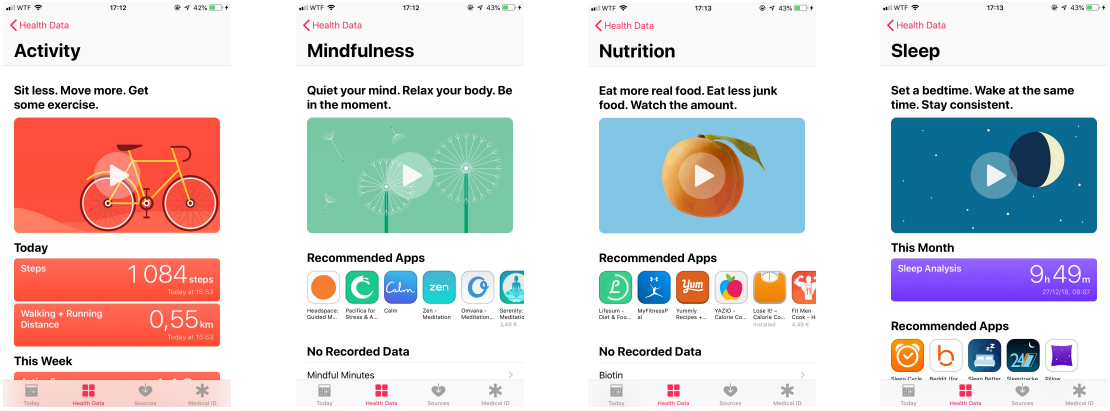


Figure 2.10: Apple Health screens regarding each item on the "Health Data"

mending new applications to the user so that the data presented can be more accurate and can contain more details about user health habits.

2.4.1.3 Garmin Connect

Garmin Connect is a mobile application, with more than 10.000.000 installations [Gar19], available both for Android and for iOS, that aims to give users not only access to physical activity and health monitoring systems. This app also has motivation engines that intend to drive the users to overtake their previous results.

Unlike other applications, Garmin Connect allows users to navigate through the app, not only with a bottom navigation menu, but also with a navigation bar collapsed in the top left side of the screen. This normally happens when the application contains a lot of menu options, which is not possible to include in a bottom navigation bar. And that is what occurs in the Garmin app, when the Hamburger icon is tapped (Figure 2.11) they display a group of options like Activities, Health Stats, Performance Stats, Settings amongst others. Each of the above mention items, that have a row down button, opens a new set of options on that menu. This means they have a big group of screens through which the user can navigate.

Despite that, the user can also navigate through the bottom menu in five different options (Figure 2.12), "My Day", "Challenges", "Calendar", "News Feed" and also "Notifications". Just like Samsung Health main screen, Garmin Connect "My Day" contains a day overview regarding the user actual health and activity behaviours. Besides that, it is also possible to edit the items shown on the screen by tapping the button "Edit My Day", which, once again, makes the UX totally customisable. With this feature, it is the user responsibility to decide the items that have more importance for his lifestyle.

The first item of "My Day" screen is the Heart Rate, in which they make use of a line chart to present the user progress in the last four hours. Displaying the data according to this method allows them to make use of colours to indicate whether the values measured are too high or not. With it the user has a perception regarding his actual health situation. Besides that, they also present the rest value and the highest value.

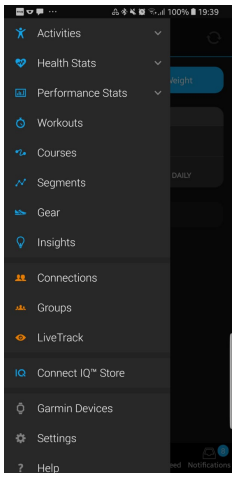


Figure 2.11: Garmin navigation bar collapsed opened

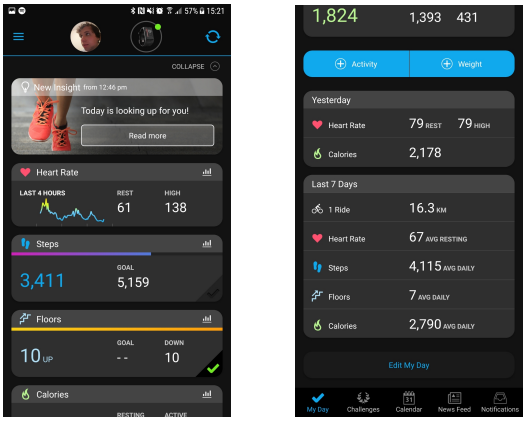


Figure 2.12: Garmin Connect main screen

Steps and Floors, works in a similar way, they use a coloured line bar to represent the user progress. As shown in the picture, when the user is near to the beginning of the bar, it has a colour, and if it is in the other side has another colour, since the user completed his goal. With this method they enable the user to have a more visual experience, inferring more easily his actual state.

In addition to the items about the user day itself, it is also possible to have items that have information regarding the last days. For instance, in Figure 2.12, the user has chosen the item about yesterday collected data and also an item regarding the last 7 days collected data.

The next option of the bottom navigation menu is the "Challenge" screen (first picture of Figure 2.13), which offers the user, the ability to join weekly predefined challenges and also to create challenges with his own friends. Garmin Connect, has another type of navigation through the screen, with a tab menu on the top. For instance, in this screen, the user can navigate through "My Challenges" and "Connections". This last one is a panel that shows the user friends that are also app users.

The "Calendar" menu option (second screen in Figure 2.13), contains, as its name suggests, a grid with a calendar enabling the user to check his events, and also to check the days with physical

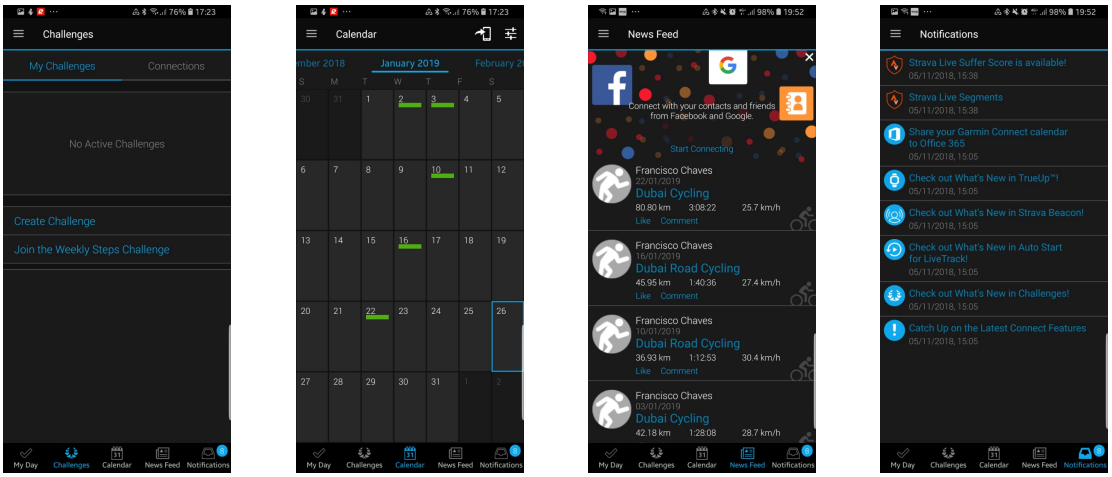


Figure 2.13: Garmin Connect "Challenge", "Calendar", "News Feed" and "Notifications" screens

activity, represented by a coloured bar. Similarly to "Challenge" screen, there is a tab menu, that allows the user to navigate in time. Once again, they have a visual display method with colours, making the task of identifying the days with activity or challenges a lot easier.

Unlike the other applications, Garmin Connect has two different options on the bottom navigation menu, "News Feed" and "Notifications". The first one is a list containing the users' friends last activities, as shown in the third screen in Figure 2.13. For instance, if the user has a connection with a friend, if his friend does some activity it will appear in his news feed. This system works as a motivation engine, since if the users do not exercise, then his friends will not receive that in the feed and will notice about it. Also, when a user checks his "News Feed" and realise that his friends are doing a lot of activities, that could trigger his will to do some exercise too. The "Notifications" screen, as the name suggests is a system to notify his users about new things, for instance in the fourth picture of Figure 2.13 the user is being notified so that he could notice that new things have appear on distinct devices.

Despite Garmin Connect has distinct navigation systems available on the app, they also have the same way of displaying data compared with the other applications.

2.4.1.4 Mi Fit

Mi Fit is a mobile application, available both for Android (more than 10.000.000 installations [AHITC19b]) and for iOS (number 16^{th} on Health & Fitness top charts of Apple Store [AHITC19a]), that allows users to monitor their activities, sleep and heart rate. Just like the previous apps, Mi Fit contains a bottom navigation menu that enables the navigation through the app with three different options, "Status", "Activity" and "Profile", as shown in Figure 2.14.

"Status" is the main screen of the app, and intended to display, like the other apps home page, the actual state of the user. Firstly, it displays his total number of steps, number of minutes taken and the calories burn during the day itself. These values are embraced with a circular form that aims to give the user a feedback regarding the progress of steps taken comparing to his goal. Once

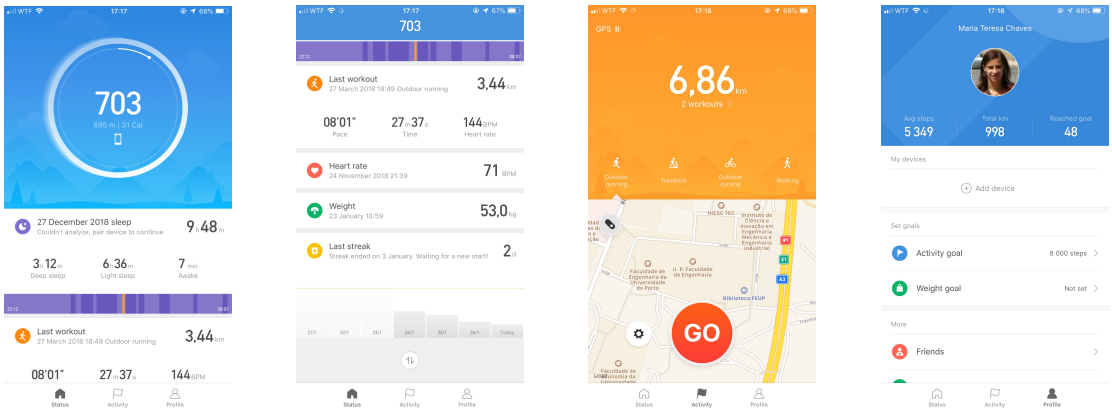


Figure 2.14: Mi Fit "Home", "Activity" and "Profile" screens

again, this application, like the others, displays the information in a visual way to be easier to infer if his goal has or not been achieved.

The next block in the main screen is about the sleep data. On it, there is a information regarding the time spend sleeping in global, the time in deep sleep, light sleep and the time spend awake during the sleep. All this data is presented in a text form, but it is followed by a bar containing three different colours, light purple, dark purple and yellow. They intend with it to display the sleep progress, with one colour for each of the sleep type, deep, light and awake.

There is also a block for the activity that contain the time spent during that activity, the heart rate and also the distance, all of them given in text form.

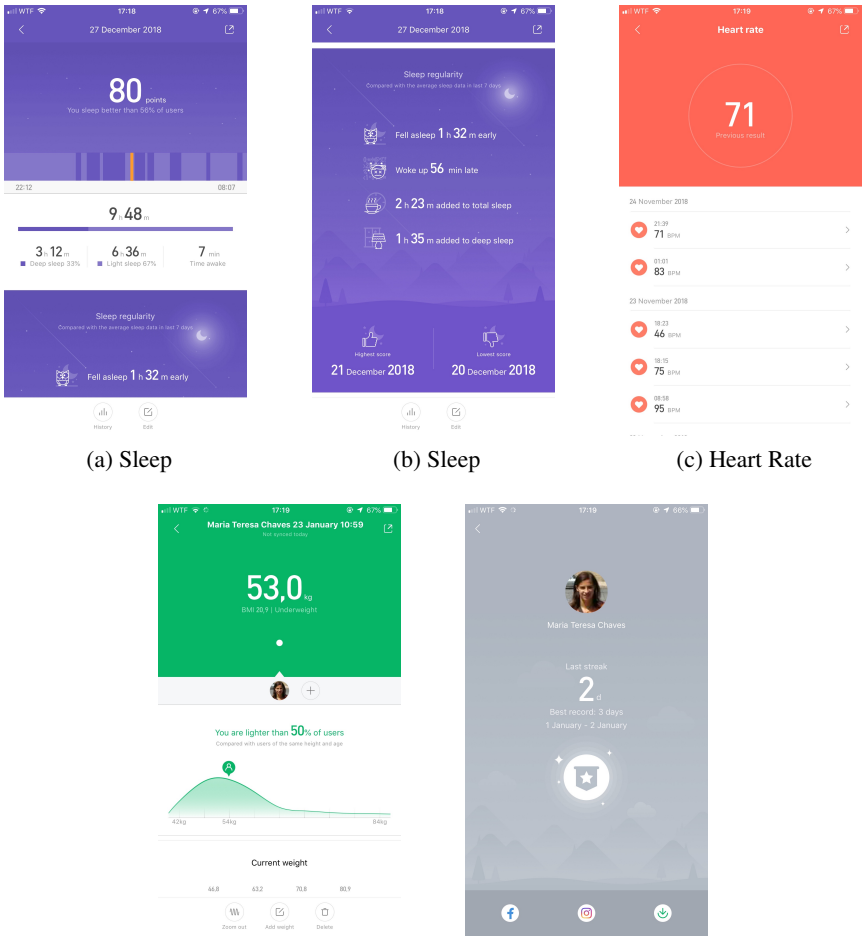
Heart rate is the next item in the list that displays the last measured heart rate, displayed also in a text form. Weight is displayed in a similar way, showing only the last registered weight.

Lastly, this screen has a block called Last Streak, that aims to motivate the user. For that it uses the number of steps taken in each day, for instance if the user number of steps reach his goal in sequential days, then it is considered a streak.

Like the other applications each of those items in the main screen can be tapped and takes the user to its corresponding screen. For instance, as shown in Figure 2.15, when the user tap the sleep block goes to a screen containing all the user information regarding his sleep. This app has a different interesting system, that makes use of a point system to tell the user how good his sleep was, and also gives information regarding the percentage of users that have slept worse than him. This feature is an important key to the user motivation, since this leads to a daily check to compete and be better than the others. Also in this screen some other information, regarding the user sleep to motivate the user.

If the user click on Heart Rate item on the main page, he goes to the Heart Rate screen which has only a list of the measured heart rates. The Weight screen can be achieved by clicking on the home Weight block. This screen presents a line chart that positions the user on the community weight, being motivated by the fact that his weight is lighter than a percentage of the users. It is also possible on this screen to remove or add a new weight. Lastly, the user can navigate to the last streak page that shows his last number of streak days and his best record. Also, in this screen

there's a curious way of motivating the user, there's the possibility to post on the social networks that a streak has been reached.



(a) Sleep (b) Sleep (c) Heart Rate

(d) Weight (e) Last Streak

Figure 2.15: Mi Fit different screens when home page item is tapped

Besides that features, the user has a screen called "Activity", in which it is possible to start an activity, as shown on the third picture of Figure 2.14. Mi Fit makes use of a tab menu where the user selects the type of activity that is going to occur. It also presents the number of workouts performed depending on the type of activity selected, in order to motivate the user.

Finally the last bottom navigation menu option is the "Profile", that has all users' information and also his goals. In addition, the user can edit those objectives and is also possible to connect devices through the button "Add Device".

Mainly, this application works like the others. However, it has a differentiating factor that is the points system, which works as a classification system, telling the goodness of the habit inferred by the collected information.

Nowadays, although people are buying more and more wearables, there is a lack of interest after a period of time, as shown further in chapter 2.5. Companies try to counter this problem by including some motivational features into their apps, and also with the use of charts and visual

items. All of them contain objectives, in which the user sets a goal that will try to achieve during a day, and they also include a reward system that enables the user to get medals by achieving some goals.

However, as will be discuss in chapter 2.5, regardless of all these motivational features already developed and used by all the companies, and also despite all the information passed to the user, it is not enough to make the users motivated or even informed about their physical activity and health behaviours. Even if the user can read his heart rate, he could not understand the meaning of that value. Probably a doctor or a person with knowledge on the field knows well these indicators and can conclude something about it, however a normal user, that has no knowledge in this field, may need some extra information like the normal limits, or even a simple colour, to understand if the measurement result is a normal value or not.

2.4.1.5 Applications UI/UX patterns

This section presents our analysis through different applications UI/UX, in which we compared them between each other, in order to identify patterns. That allowed us to have a better view of the main patterns applied in the apps to present the data and also the patterns used to navigate through them.

First of all, it is important to explain each of the labels used in Table 2.4 to describe each pattern we discovered in the analysed apps. The first pattern was "Main screen split through item blocks", which intends to describe the fact that apps have on their main page the information split through boxes, each of them containing only information regarding one metric.

Other pattern identified was "Main screen with clickable blocks", which means that the apps has on their main page not only boxes, but when they are tapped takes the user to his own screen, containing only information regarding that item.

The pattern "Main screen customisable items" aims to describe that each block that appears on the main screen can be removed or even the user can add another items.

Since all applications have a bottom navigation bar, as expected, it is also a pattern described by the label "Bottom navigation menu". But as long as some apps use the navigation menu collapsed there is a space for that pattern called "Navigation menu collapsed".

Regarding the data presentation there are the "Charts to show user progress" which intends to describe that some apps show the user progress regarding a specific metric making use of charts. Another data presentation pattern identified was the "Colour association to item type" that refers to the fact that some apps has a colour for each metric, i.e., for instance, all data regarding health is red, all data regarding activity is green, all data regarding sleep is blue, amongst others. The last pattern related to data presentations is "Circular chart for steps", since most of the applications use a circular chart to represent the number of steps taken in comparison with the defined goal.

Only one application shows an interesting pattern, in which they recommend other applications to the user in order to improve the information displayed to him, and we called it "Suggestion of other apps".

As long as the motivation is also an important feature we included some patterns about it. The first one is "Comparison between other users" that describes the feature of comparing the user results with other application users, in order to work as a motivational system. Another one is "Reward system", as the name implies, is about the app rewarding the user when he completes some kind of activity or goal.

Table 2.4: Applications UI/UX Patterns

Pattern Description	Samsung Health	Apple Health	Garmin Connect	Mi Fit
Main screen split through item blocks	✓	✓	✓	✓
Main screen with clickable blocks	✓	✓	✓	✓
Main screen customisable items	✓		✓	
Bottom navigation menu	✓	✓	✓	✓
Navigation menu collapsed			✓	
Charts to show user progress	✓	✓	✓	✓
Colour association to item type	✓	✓	✓	✓
Circular chart for steps	✓			✓
Suggestion of other apps			✓	
Comparison between other users	✓		✓	✓
Reward system	✓			✓

2.5 Users' reasons to stop wearing wearables

Although the worldwide number of sold wearables is growing 16.9% year after year, according to IDC [Cor17a], users are still showing reasons to drop the use of wearables. They keep on buying those devices, albeit more slowly than expected. Nevertheless, companies are trying to evolve their activity trackers in order to include some features of the smart paradigm and some features that work as part of a motivational engine, as shown in section 2.4.1.

Despite all motivational features that companies already included into their devices, according to the study published in BMC Public Health 2017 [CJCS17], based on an online survey, there are still various reasons that lead users to drop the use of wearables after a period of time. As shown in table 2.5, the most answered reason was "I learnt everything I could", in which could be concluded that the user does not understand the wearable objective. This kind of devices intend to daily guide the wearer regarding his health behaviours. Users could learn which behaviours are healthier, but some of the measurements taken into account for the behaviour analysis depend of external factors that could not be controlled by a person. Regarding the answers "Broken tracker", "Forgot to charge it", "Forgot to put it back on after taking it off" and "Band continuously came undone" they are related with technical failures, which are not possible to control. There are also some answers of personal opinion of wearables. "Intrusive", "Did not like it", "Inconvenient", "Work", "Annoying to charge", "Became too dependent" or even "Limited functionality" are reasons that

depend on a persons' mind, in these cases are also not possible to control. But the most important answers in the scope of this thesis are the ones regarding the user experience with wearables. With the answers "It was not helping achieve goals" and "Negative psychological impact" it is possible to conclude that the actual user experience could be improved in order to fulfil these problems experienced by these users. The other important answers were "Technical difficulties", "Got lost", "Difficult to understand" and "Information was not important", which also leads to conclude that the experience of the user with wearables really needs to be improved.

Table 2.5: Users' reasons to drop the use of wearables according to "Users'experiences of wearable activity trackers: a cross-sectional study" [CJCS17]

Reasons to stop wearing tracker	Users (%)
"I learnt everything I could"	29.7%
Broken tracker	21.6%
It was not helping achieve goals	13.5%
Technical difficulties	10.8%
Got lost	10.8%
Forgot to charge it	10.8%
Experiencing negative psychological impact	8.1%
Intrusive	8.1%
Difficult to understand	5.4%
Did not like it	5.4%
Inconvenient	5.4%
Forgot to put it back on after taking it off	5.4%
Information was not important	5.4%
Work	5.4%
Annoying to charge	2.7%
Became too dependent	2.7%
Band continuously came undone	2.7%
Limited function	2.7%

Note: Participants were allowed to select multiple responses, and percentages reflect the number of participants who selected each response option as a portion of all participants in that subgroup.

The problems experienced by these users are a key component to understand the actual problems they face, regarding wearables. With this thesis we intended to improve the user experience, regarding the mobile apps, realise the users' reasons to abandon the use of wearables is our strait point. Actually, users have access to a panoply of data, in KPI format or even in charts, however

as shown before only accessing this kind of information does not mean that our user is able to monitor his health.

Our proposal application, enable the user to have a perceptible view of all the important information, making use of the traffic lights colours that aims to cause a sensation of weak result in red colour, good result in green colour and a so-so result with yellow colour. Besides that, we have also included the famous KPIs and charts to display the collected data. As shown in section 2.4.1.5 we have identified a group of UI/UX patterns that helped in the development of a good solution, taking into account the user familiarity to those components.

With an application capable of passing the correct information in accordance with the UI/UX designed, we believe it is possible to improve the user experience, making also possible that users keep on improving their health habits, since they could not only observe some values regarding his health but also inferring if its a good or bad value. This application has been tested in a pilot project with 11 real users, in a period of one week. The testers have been submitted to a survey, which have been afterwards analysed in order to systematise their feedback.

Chapter 3

Solution Design

The scope of this thesis aims to improve the user experience on health monitoring applications, so, in that context, we needed a process that takes that into consideration. To create a solution for our problem we have used a famous process called Design Thinking, that, according to Interaction Design Foundation, is an iterative process that allows to understand the user, challenge assumptions, and redefine problems in order to identify distinct strategies and solutions to work on the problem, providing an approach based on a solution to solve the problem. [Fou18]

3.1 Design Thinking Process

This method has five distinct phases through which we have passed. As presented in Figure 3.1, it starts with the step Empathise, in which we get in touch with users. After that we enter on the Define phase, defining the user needs, problems and insights. Ideate is the next phase, that aims to, create ideas that lead us to an innovative solution. Next is the Prototype phase where we start creating a real solution for the problem we are facing. Lastly, we have the Testing phase, which aims to check whether or not our prototype is valid for the user. With it, we could learn even more about our users, so that we could go back to the beginning of the process, or just go back to the Ideate phase, making possible to iterate our prototype according to the information passed through users on the tests.

3.2 Our strategy to build a solution

Making use of this process we started by empathise with the users' needs. Most of the times, as shown in Table 2.5, users have difficulties on understanding the information presented and also since their is an interface that may not help the users to complete their tasks without the unnecessary effort.

After that we created a low-fidelity representation (wireframe) of our main ideas; we define as a big priority the fact that our users may not understand the displayed information to infer something about. Some of the users may not have the knowledge on the field, which could lead to

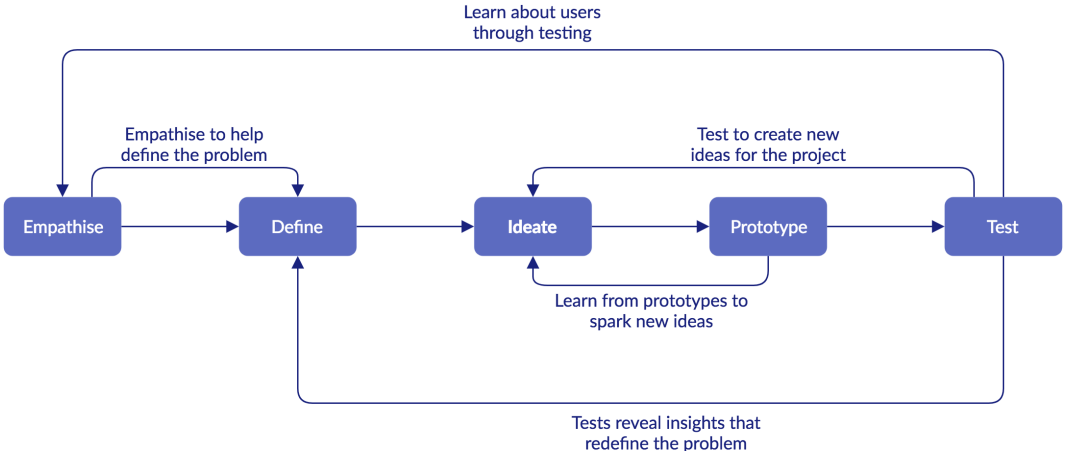


Figure 3.1: Design Thinking Non-linear process

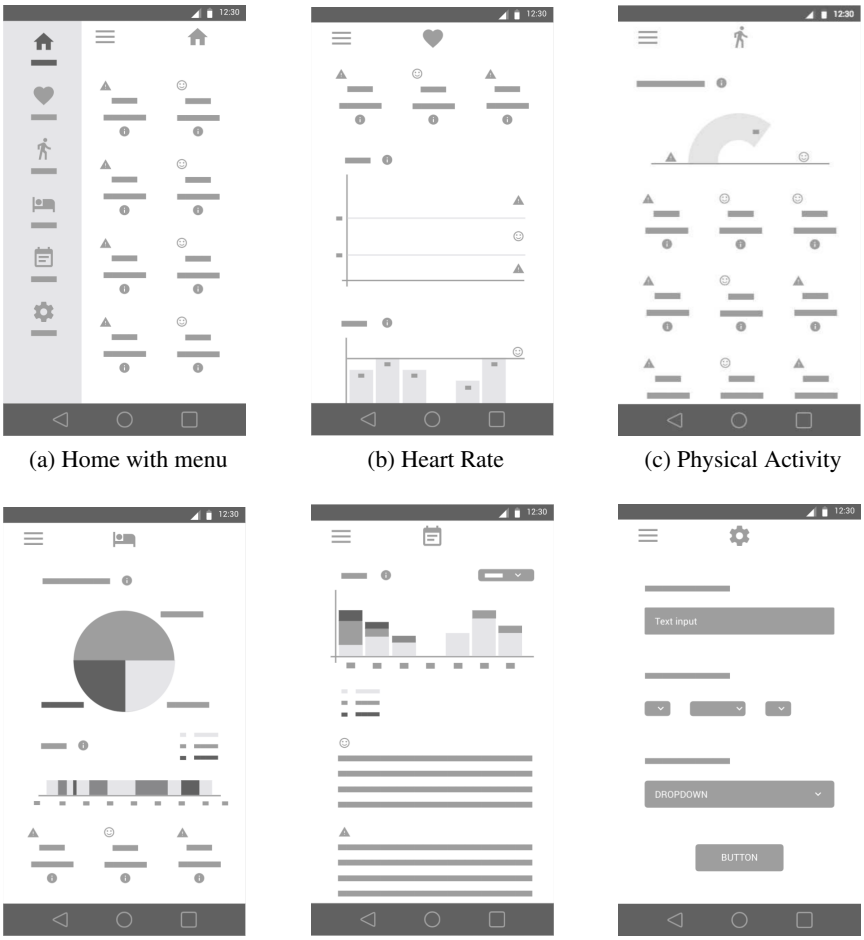
have more difficulties on infer something through the information presented by applications, and that is our main concern. But this process of defining the user needs was not closed in this phase, we get back to it later in the development of a solution. After that we created an high-fidelity representation, called prototype, so that we could implement our ideas, spark new ideas and also in order to have a model to test with our users. After the tests with users, we returned to our Ideate phase to take into consideration the feedback given by them and to recreate the representation according to their needs.

3.2.1 Low-fidelity representation - wireframes

Despite the Design Thinking process does not contemplate that, our first ideas resulted in a low-fidelity representation (wireframe), and afterwards we created a prototype, exactly as defined on the method (Appendix A). That has allowed to draw the ideas and to structure the app we aim to do, as a solution for our problem. To create the wireframes we used an online framework called *Fluidui*.

So, our first step was to identify some patterns on the already used applications, as mentioned on section 2.4.1.5. That is important to take into consideration, since our users already know very well some of these patterns. First of all, we defined that our application should contain six screens each of them focused in one theme. The Home page should contain a little about each of the other screens, divided into items, just like the other apps on the market, a page that only contains elements about the Heart Rate, another one that should present only items regarding physical activity, one about sleep data, another one that could be a monitoring through the use of machine learning (future work) and lastly the settings screen (Figure 3.2). Also it was idealised, that as long as our user needs to navigate through our application he will need a menu so, for that reason, we created, as shown on the first wireframe (a), a top left navigation collapsible menu.

We intended that our KPIs have the value and a corresponding title, but our user does not need only that information, so we created an icon that represented a warning state, characterised by a alert triangle. Also, in case of a good value we displayed a smile icon. That was our first idea to



(a) Home with menu (b) Heart Rate (c) Physical Activity

(d) Sleep (e) Monitoring (f) Settings

Figure 3.2: Wireframes regarding each of the idealised screens

make our user understand if the value is "okay" or not. Making use of that, we included that icons on all captions, charts, KPIs and Information passed through text.

Also, on this stage, was defined that the app will display a line chart for representing the heart rate progress during the day, a circular chart to display the number of steps taken in comparison with the user goal, a circular chart to display all sleep types duration during the night, a continuous bar that shows the user progress regarding his sleep and also a bar chart to display the encountered patterns along the week regarding physical activity.

Besides that, the settings screen also has been design, which contains a set of options, with a drop-down and some text inputs.

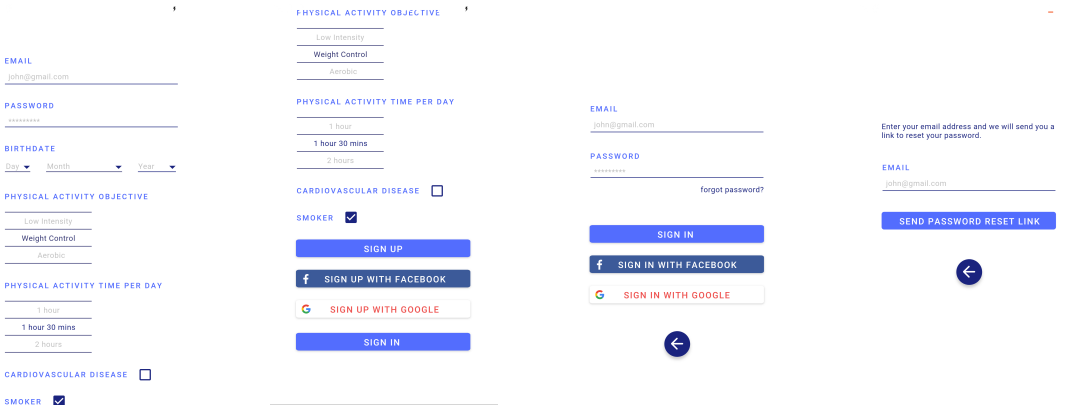
The first proposal was therefore defined, but obviously, since this process is iterative, we did not close this phase on the first take, it was edited later in the solution design development.

3.2.2 Prototype

After structuring the main ideas, our next step was to start creating our solution through a prototype (Appendix B). For that, we used a tool, called Adobe XD, that allowed us to create a high-fidelity representation of our ideas, and to test it with users, making use of a mobile phone. Our first step was to create a representation of what we defined on the wireframes. But, as our process definition tells us, when creating the prototype we come up with some great new ideas, which makes our first prototype a bit different from the defined structure.

3.2.2.1 Session Screens

Since our application must save the user information, we designed a session system, in which the user could associate his data to an account. So, the first screen of the application is the sign up screen, as shown in Figure 3.3. We consider that, since a person that install applications typically has never used it before. But, it could happen that a user already has used the app. So, for cases like that we display always the sign in option.



(a) Sign Up (b) Sign Up (c) Sign In (d) Forgot Password

Figure 3.3: First prototype session screens

In order to facilitate, we give the possibility of logging in and signing up with the user Facebook or Google account. With it, the user does not have to fill the email and password field.

3.2.2.2 Home screen

On the prototyping process, we found that our previous method of displaying whether a value was good or bad with icons, could evolve to a new concept, the traffic light colour schema. In which, only by using a simple colour, we make our users perceive if a value was good or not. So, we defined our concept as an association of the colour red for weak, yellow for so-so and green for good values, as shown on Table 3.1.

As long as Samsung Health, Apple Health and Garmin have a UI pattern (Table 2.4) that uses, on the main screen, boxes to embrace the components, we defined we should also use it on our

Table 3.1: Traffic Light Colours Concept

Colour	Meaning
Green	good values
Yellow	so-so values
Red	weak values

prototype. For that reason, was defined that each item presented on the Home page would be embraced within a box split into two parts, one containing the title and the other containing his corresponding value.

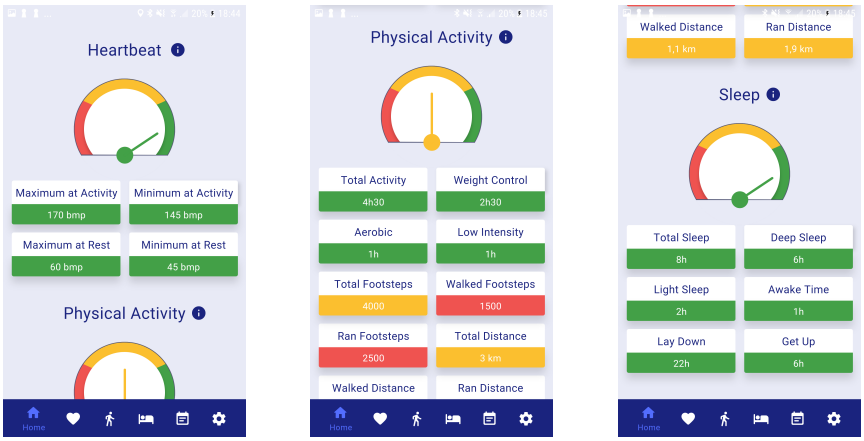


Figure 3.4: First prototype home screen

While creating a Home page sub-division into blocks of information, one for the Heart Rate, another one for the Physical Activity and a last one for the Sleep information, a new idea has appeared: the Barometer concept. With that we intended to give our users an overview of their actual state regarding each of the displayed groups. For instance on the Figure 3.4, the user Heart Rate, in general, has good values. However, in the Physical Activity block, the barometer is pointing to yellow, which means that user values are not as good as expected. It only points to a red value when the user has more reds than anything else.

However, as shown in Figure 3.5, we also introduced a modification regarding the navigation menu. That has happened, since we concluded, with the UI/UX pattern analysis, that the navigation menu collapse was not needed, mainly because of the fact that our app only has six option to navigate. So, we defined that our prototype should contain a bottom navigation menu instead of the collapsed one.

3.2.2.3 Heart Rate screen

For the other screens, we took the same line of though, and we split each theme in a box, containing all the information about it. For instance, on the Heart Rate screen we have a box dedicated to the HR during physical activity (Activity Heart Rate) and also another one for the HR while the user is

at rest (Rest Heart Rate). Here, we had another new concept idea, which was the fact that our user could want to navigate through time to compare values of different days. For that we introduced back and forward arrows. Also, the user needed to know the day of the displayed data, for that reason below the box title, we added a text, indicating the chart date.

Figure 3.5: First prototype Heart Rate screen

Besides that, as a mobile phone is not always as big as we wanted it to be, we need a way to inform our users about the values displayed on the chart. Therefore, similarly to Home screen, we created value boxes, a bottom rectangle that makes use of the traffic light colour system concept and that display the value tapped by the user on the chart.

Another detail that we introduced in the prototype, was a label system on the top of the box. With it we intended that the user could navigate through the information regarding a theme, without the need to scroll down the page. So, the main concept was to group all the information inside only one box. For that we created a label called Daily and a label called Weekly. On the last one, for instance, in the Heart Rate, we thought that could be of the user interest to split between minimum and maximum values of each day. Also, in that view, we do not show the value pointed by the user on our bottom sub-box, but we indicate the number of good or weak days. In case the user has all good days, then the corresponding colour is green, otherwise, if all days are weak, it appears with the red colour. However, if the user has a combination of good and bad days, it is presented with a yellow colour.

Regarding the charts presented on this screen, we used, for the daily period, a line chart, since it allows the user to have a perception of his progress during the day. On the weekly period we wanted to display, on the bottom sub-box, if the user has all good days or not. For that we displayed the information making use of a bar chart, giving the user a good perception of the week progress. In addition, there is a line on the chart that represents the maximum HR the user could reach.

3.2.2.4 Physical Activity screen

The Physical Activity screen contains, as the previous one, the information divided into blocks following the same concept. As shown in Figure 3.6, we created a block regarding the user physi-

cal activity, displayed by a circular chart, the time spent on each type. With different tones of blue we represent a bottom legend, so that the user can understand what is displayed in the chart. With this chart, it is possible to have a perception of the physical activity type in which has been spent more time. This first block, as explained before, gives the user the possibility to go back in time, in order to compare each day. The user not only can have a view of the physical activity in each day, but could also access the Weekly tab, that displays a bar chart containing, for a week, the time spent on physical activity, in general, per day. This tab, contains a bottom sub-box that aims to inform the user of his performance during the selected week. For instance, on the third screen of Figure 3.6, there were two days, in which the user completed his goal, so the label is yellow since his results were not all good or bad days.

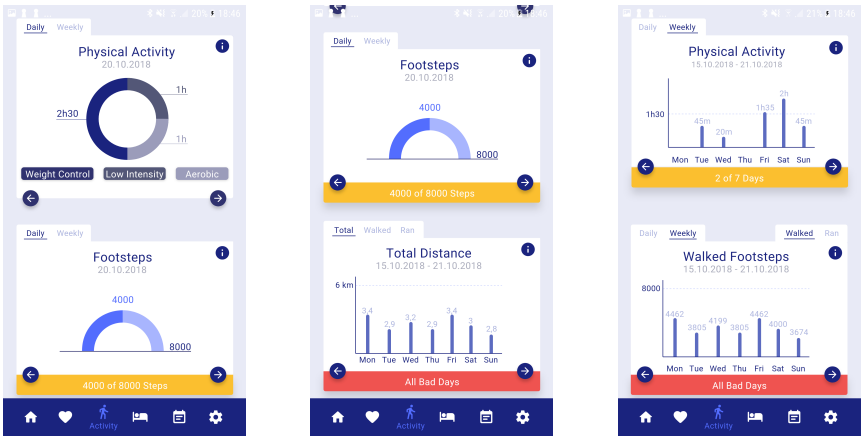


Figure 3.6: First prototype Physical Activity screen

Next to the Physical activity block, there is a block that contains information regarding the Footsteps. On this initial prototype we defined that a good way of passing the message for footsteps would be by displaying it with a semicircle. That aims to give the user a perception of his progress and what is left to achieve his goal. The concept of going back in time is also applied here since we wanted our user to compare his progress within different days. The tabs used here are similar to the previous box, but on this box, when the Weekly tab was clicked we wanted the user to have two kinds of perspectives, one regarding his footsteps on a walking activity and also while running. This view required a chart where the user could take an overview of his progress during a week, so we used a bar chart. On the bottom of the box, similarly to the previous ones, we present a status bar. For instance, in the Total Distance block, the user had all bad days, which means that his goal was not reached in any day of the week, making his colour red. The Distance block is exactly the same structure as the Physical Activity, but regarding, as the name suggests, the distance covered.

3.2.2.5 Sleep screen

The Sleep screen contains, as the previous ones, its information split into blocks. As shown in Figure 3.7, our first block contains the Sleep, in which it was used a circular chart to display the different types of sleep our user had during the night. With three distinct tones of blue, we intend

to give the user a perception of the time percentage spent on each type. Furthermore, it is possible to infer if the user has a good or a bad sleeping night. Besides the colours on the chart, a legend is also presented to display for each type the corresponding colour. The user can navigate in time, in order to compare his sleep for different days. The tab Weekly, when tapped, displays a bar chart that contains for each day three possible types: Deep, Light and Awake. These presented type can be changed by clicking on the top right tabs. It also contains a bottom sub-box to display the status of the week. For instance, on the second screen of Figure 3.7, our user has not completed the goal in any day of the week, causing the box to be red, working as an alert to the user.

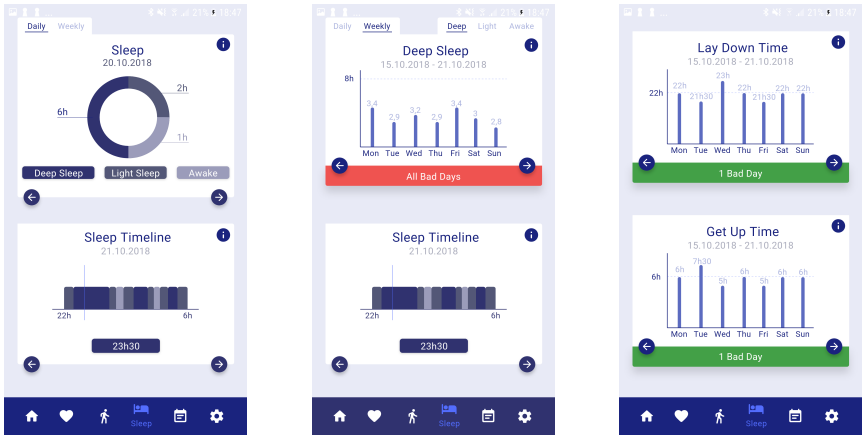


Figure 3.7: First prototype Sleep screen

For the next block we created a time-line regarding the sleep. For that we presented a bar starting on the lay down hour and ending on the get up hour, in which each block represents a period of time where the user has been in light, or deep sleep, or even awake. If a bar block is tapped, the app, displays a label containing the hour it has occurred, with the corresponding type colour.

Lastly, Lay Down Time and Get Up Time were designed with a very similar structure, containing a bar chart with the hour that the user lay down and got up, respectively. These blocks as also the bottom sub-block that aims to inform if the user has achieve his goals regarding the hour to lay down and get up. For instance, in the figure it is green since just one day of the week was bad. Each chart contains the concept of navigating through time, in order to let the user compare values.

3.2.2.6 Monitoring screen

Despite this screen being designed on our low-fidelity model, we did not take this idea further since it goes out of the thesis scope. This idea has been taken into consideration for our future work, which will be explained further in the document.

3.2.2.7 Settings screen

Our last bottom navigation menu option was the Settings screen that contains a list of parameters that the user may want to change. As shown in Figure 3.8, it is possible to change the birth date and the lay down time, making use of a drop down. The physical activity objective and the physical activity time per day can be edited through a scrolling list. It is also possible to change if the user is or not a smoker and if he has or not cardiovascular problems, using a check box.

Since we though of the possibility of using a session to save the user information, a log out button was needed, which is displayed to the user in the settings screen.

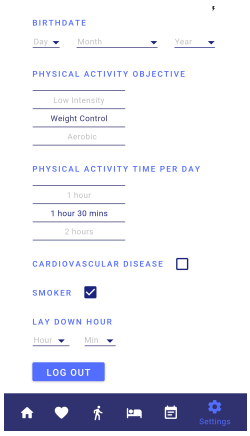


Figure 3.8: First prototype Settings screen

3.2.3 First prototype tests with users

Once the prototype was finished, our main concern was to test it with real users, in order to learn about the user needs and to evolve our first approach. In this phase we aimed to collect the users' opinion regarding the appearance of our future application. For this process we created a script, containing each step the user needed to perform on the prototype, which can be consulted on Appendix C.1.

Firstly we asked some questions regarding the user background, in order to understand if the tester was comfortable with technologies. In addition we asked if the user was a frequent user of wearables and the apps used. With that we intended to get information regarding the users' problems with wearables or apps, in order to do not make those mistakes on our application.

The results of user number 3 (Appendix C.4) did not unleash new ideas. Also, this tester did not have difficulties performing the asked instructions, taking us to think that the application did not have issues regarding the user experience.

However, the results of tester number 2 (Appendix C.3) were different, since there were some problems on performing the instructions. For instance, the operation "Navigate to the screen that contains only information about the heart rate.", was not performed with success since the user believed that we were referring to the information displayed on the home screen regarding Heart Rate. So, we concluded the issue was on the instruction and not in being able to execute it. The

same happened in the instruction "Get more information regarding deep sleep", where we should first tell the user to navigate to the deep sleep during the week and, just after that, ask to get more information regarding deep sleep. The tester answer to "What do you think it's needed for you to know your heart rate in a different hour of the day?" was "I would drag the bar", but our idea was that the user only needed to tap the value and not drag the bar. Lastly, on the operation "Imagine that you want to change the predefined hour regarding the lay down time. Where would you do", although the tester navigate to the settings to perform the operation, did not found the option to perform that.

The first tester (Appendix C.2) was the most interesting to interview, since his ideas was a great contribute to improve the first prototype. The opinion about barometer lead us to evolve the Home screen. We designed it thinking that would be a main concern to the user, but as we could conclude with the tester opinion it was not so important to them.

3.2.4 Prototype revision

After testing our prototype with users, we started the next phase, in which we improved our model according to testers results and new ideas that appeared during the process.

The barometer was a concern since the users think we should give less importance to it. So, we decided to refactor the home screen structure. While doing that, we devised a new idea, the concept of including illustrations about each block theme, and the barometer would still appear on the block but as an icon close to the theme title, as shown on home screen presented on Appendix D.

The concept was included also into the session screens. For instance, the Sign In screen includes a workout illustration, the sign up a form illustration and the forgot password screen contains a thinking illustration.

3.2.5 Android solution implementation

This phase was about the final prototype implementation into a real application. For that, was used the Model View ViewModel (MVVM) architectural pattern, which, according to Raffaele Garofalo [Raf11], one of the main objectives is to separate UI from the presentation logic to make the UI testable. That aims to establish a clear separation of responsibilities, which makes the process of maintenance easier.

In order to collect data through a wearable, we tested the prototype implementation using a Mi Band 2, which is a feature rich and widely available activity tracker. Besides that, since the application needs to display data collected through Mi Band 2, we created a database to save that information. For that, Room was used, an Android library that simplify the database implementation by creating an abstraction layer on top of SQLite, allowing a fluent access to the database while taking advantage of SQLite full power. [Dev19c] Figure 3.9 presents the work flow of this library, which has three main components: database, data access objects (DAO) and entities. Room has the database holder and works like an access point, DAO has the methods needed to access

the database and his entities serves as a table, just like in a normal database. The Room library allowed us to cache the most important information that we wanted to display, while the wearable synchronises the missing data with the app.

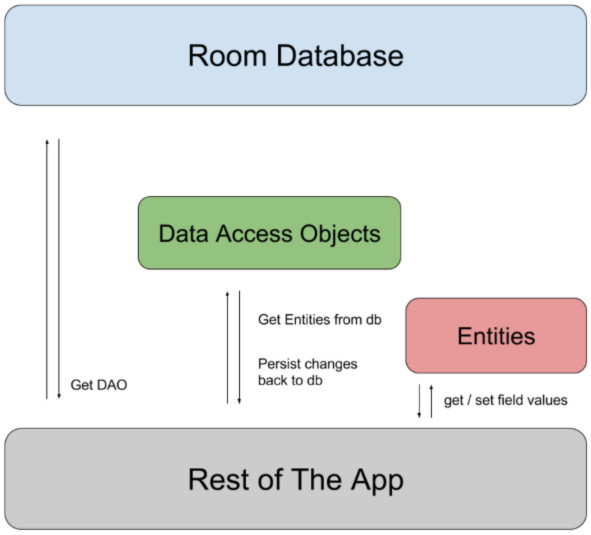


Figure 3.9: Room Android library work flow [Dev19c]

Additionally, as long as our displayed data is always changing, we included on our architecture the LiveData concept, which is an observable data holder class that notifies through an observer when data changes occur. This architecture component has some advantages, firstly it ensures that the UI matches our data state, since our LiveData observer is notified every time the data changes, and our UI is also updated. Another advantage is the fact that it prevents the app of having memory leaks, because it bounds the observer to the Lifecycle of the data objects and cleans up them after the observer cleans too when the Lifecycle is destroyed. With the use of LiveData we also prevent our app to crash due to stopped activities, if the observer Lifecycle is inactive, then it just does not receive any event. LiveData automatically manages all the Lifecycle handling, which is convenient, since we do not need to worry about them. Besides that LiveData recreates an activity or a fragment when a configuration changes. For example if the user turns the device, it immediately receives the most recent data. [Dev19b]

Taking that into account, we organise our implementation as shown in Figure 3.10, which explains the architecture used on the Home screen, since it contains all the application elements. BeHTExDatabase was our database that contained four different Entities (Figure 3.11): Heartbeat to save every data regarding heart rate values; Activity for all the physical activity information; Sleep, as the name implies, to save information regarding the user sleep; and, lastly, the User Entity, which contains the user information.

Our main activity structure, shown in Figure 3.12, was split into two sections, the bottom Navigation Menu and the fragment that could change depending on the menu option. An Android fragment is a piece of an application's UI or behaviour that can be placed in an Activity [Dev19a]. With that we could replace fragments instead of creating new Activities.

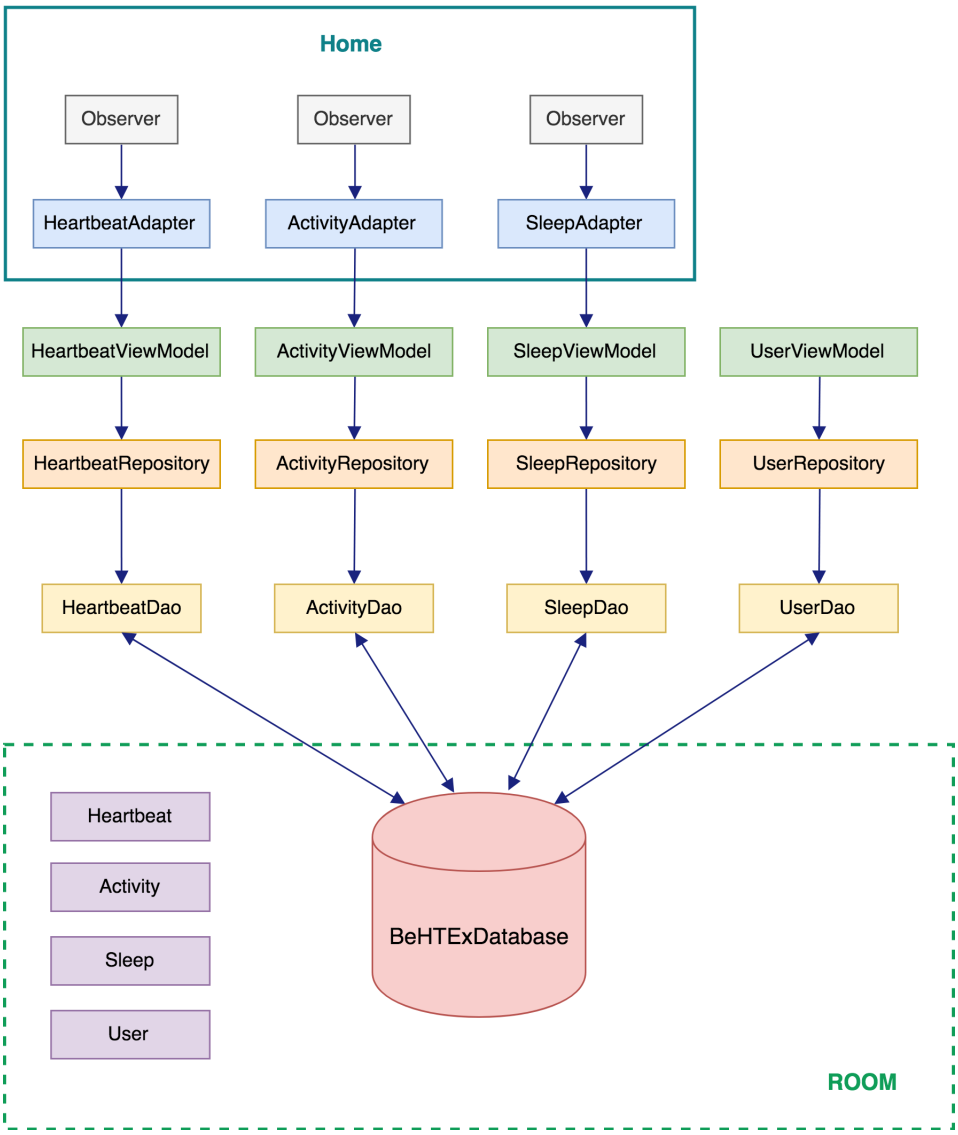


Figure 3.10: Android implementation architecture

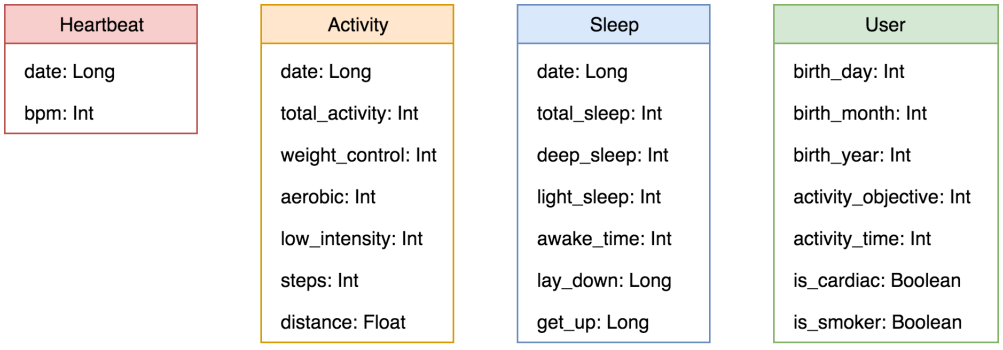


Figure 3.11: Database Entities for each of the collected activities (Heartbeat, Activity and Sleep) and the user inserted information (User)

Since, on fragments Home, Heartbeat, Activity and Sleep we wanted to use LiveData, the logic of those are different form Settings fragment. As shown in Figure 3.10, for each ViewModel that deals with LiveData there is an Observer, which will be vigilant on the data telling the Adapter when that data has changed. The ViewModel main function was to provide data to the UI, working as a communication channel between the Repository and the UI. Despite the User fragment not using LiveData, it needed also a ViewModel so that it was possible to have a communication channel between the Repository and the UI.

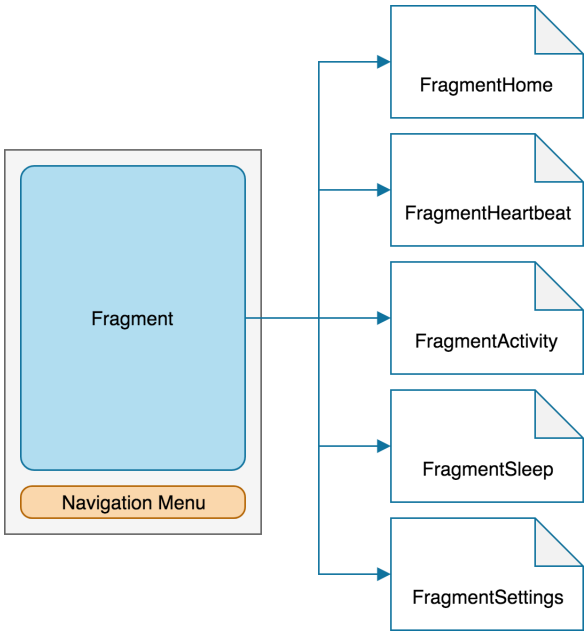


Figure 3.12: Main Activity Screen structure

Since Room Database does not allow, typically, to execute queries on the main thread, we created the Repository to manage those queries. However, the queries needed on LiveData run automatically on a background thread asynchronously. Those queries were defined on each DAO, which contained the needed methods to access the database.

Along with application structure, we defined the application requirements on a list, based on our prototype and on the users' needs. That allowed to prioritise the features so that in the end we could have a proof of concept application. The list, shown on Appendix E, has three different labels regarding the priority, High, Medium and Low. First we implemented the High priority features and after that the Medium ones. The features with Low priority would only be implemented if there is time left. To create this list we defined two types of users: new User and registered User. The first one is the person that opens the app for the first time, and the registered User is when the user personal information is already set, and it is not the first time the app is used.

It is important to mention that every features regarding Sleep were not implemented, since the data collected through Mi Band 2, seems to be inconsistent, and it was not good if we pass wrong information to the user. Also, the requirement R24 was not implemented, since it was a Low priority and only would be implemented if there was time.

On this phase, we redesigned the session concept, since it was only important that we get the user personal information. For that, we created the first screen presented to the user, as presented on Appendix F, that aims to collect the user personal information and his goals. The other features implemented can be consulted on the same Appendix.

Chapter 4

Tests with users

User Experience Questionnaire (UEQ) can be applied to products in order to test if they have a good user experience. And, as long as we are creating an interactive solution through an application we could use that to understand whether or not the proposed concept fulfils the general expectations regarding UX.

The questionnaire has 26 different questions, in which each item is composed by two opposite terms. Those items appear randomly on the form and half of the items has the negative answer on the left side and the positive answer on the right side and the other half items in the reverse order. Each of the items has seven answer options, from -3 to 3, in which 0 is the neutral option.

UEQ contains a six scale division for the 26 items. They classify a question in a scale as shown on Table 4.1, that defines the scales as Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty. This classification can be described as the tree in Figure 4.1. As the Attractiveness is the overall impression of the user it must be on the root of the tree. And it splits the classifications into two main groups, the Pragmatic Quality and the Hedonic Quality. The first one contains all quality aspects that are goal directed. In contrast Hedonic Quality is all the questions that are not goal directed. So the Efficiency, Perspicuity and Dependability belongs to the Pragmatic Quality group, while Stimulation and Novelty belongs to the Hedonic Quality.

To test the user experience with UEQ, firstly we gave our 11 testers a Mi Band 2, and the

Table 4.1: UEQ scale structure [AMJ18]

Scale	Description
Attractiveness	Overall impression of the product.
Perspicuity	Is it easy to learn? Is it easy to get familiar with?
Efficiency	Can users solve their tasks without unnecessary effort?
Dependability	Does the user fell in control of the interaction?
Stimulation	Is it motivating and exciting?
Novelty	Is it innovative? Does it catch the users interest?

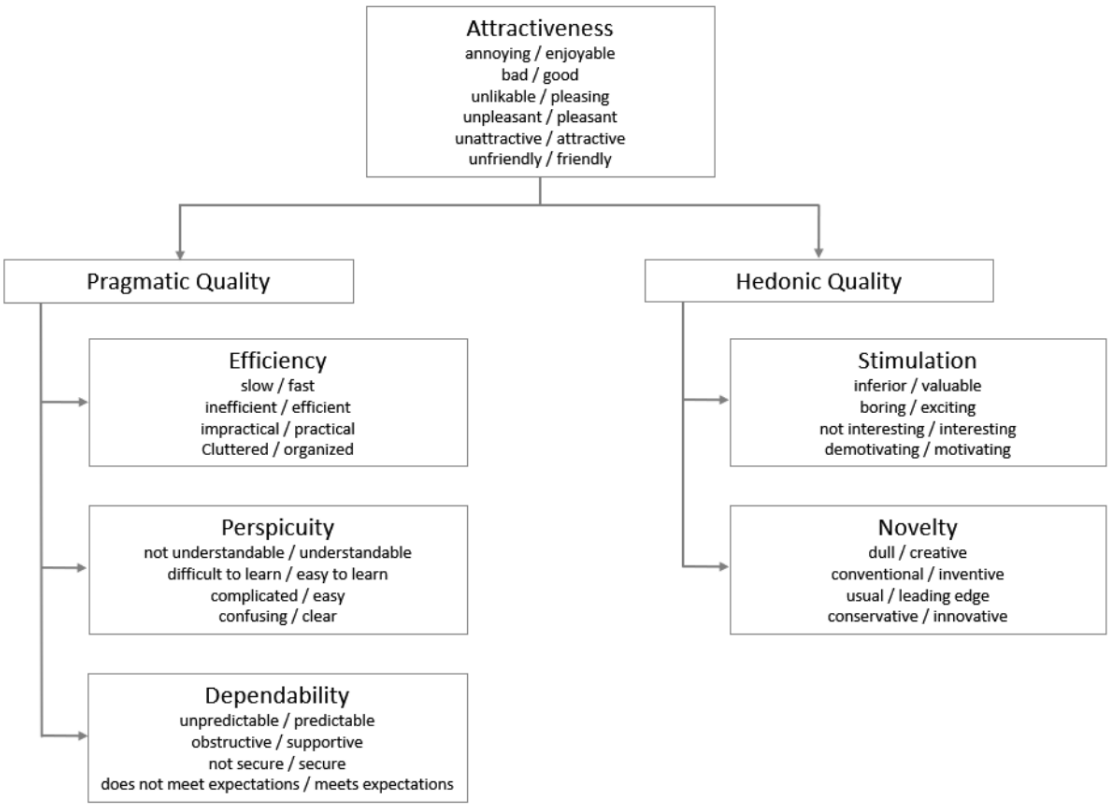


Figure 4.1: UEQ scale structure [AMJ18]

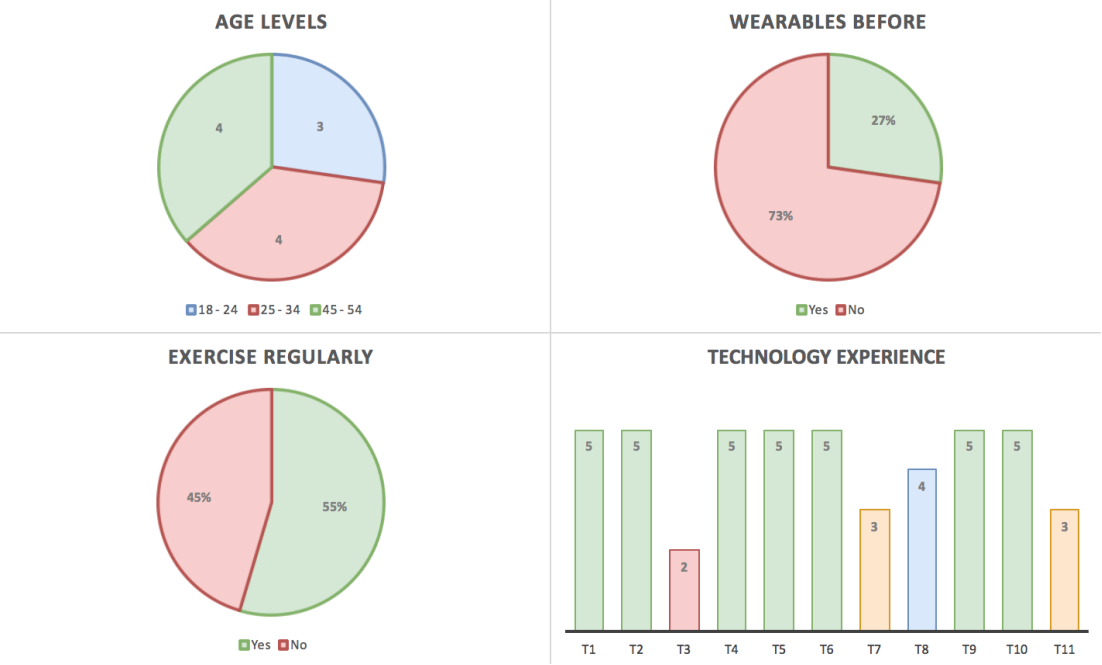


Figure 4.2: Testers initial information

implemented application and they tested it within a period of one week. Before the tests began, we inquired them about their personal information, about the experience they have with this kind of devices and applications and also the experience they have with technology. Appendix G presents their answers, in which we could conclude we had 3 users between 18-24 years, 4 users between 25-34 years and 4 users between 45-54 years. Regarding the use of wearables, only 27% of the testers had that experience before, as shown in Figure 4.2. Since the application contains elements about PA it was also important to know if the users practice PA regularly. As shown in Figure 4.2, 45% of the testers do not practice PA regularly and 55% do exercise regularly. Lastly, we wanted to take into account if the tester had or not experience with technologies, so we defined a scale from 1, no experience, to 5, a lot of experience. Figure 4.2 presents that 1 user had less experience on technology, 3 had the expected and the other ones had a lot of experience.

After the one week period, we had an interview with them to collect their feedback. To collect the user experience feed back we used the UEQ template, Appendix H.

Table 4.2 presents testers answers, and as we could observe in Figure 4.3 the distribution of those answers had been more green, i.e. more positive than neutral or negative. With that, in the first place, we could expect to have a positive feedback from the users regarding UX, since this questionnaire only consider that.

The UEQ data analysis tool provide charts like the Figure 4.3 with the questionnaires results (Appendix I). Our first analysis was regarding the results obtained grouped by UEQ scale. As presented in Figure 4.4 the Attractiveness mean value was around 2.333, which means that generally users' impression of the purposed solution was good. But also the Perspicuity, with a mean value of 2.455, showed a positive feedback, that leads us to conclude that the application is easy to get

Table 4.2: UEQ testers answers

	Item Nr.																								
Tester Nr.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**Mean Value / User**
1	2	3	2	3	2	3	2	2	0	2	2	3	3	3	-1	2	3	3	3	2	3	2	2	3	3	2	2.21
2	2	3	2	2	2	3	3	2	1	1	2	2	2	2	1	2	2	2	2	3	1	2	3	2	3	2	2.07
3	1	2	0	3	-1	2	2	2	3	1	1	2	3	3	0	2	0	2	2	3	2	2	3	3	3	2	1.84
4	2	2	1	2	1	0	2	3	0	-1	2	2	3	2	-1	1	2	0	1	2	2	1	2	1	0	0	1.31
5	3	3	2	3	3	1	2	3	1	0	3	3	3	3	2	3	3	0	3	1	3	3	3	3	3	1	2.35
6	2	3	2	3	2	3	3	3	1	2	2	3	3	3	2	3	3	1	1	3	2	3	3	3	3	2	2.47
7	1	2	2	3	2	2	2	2	1	1	1	2	3	2	2	2	3	2	2	-1	2	2	2	2	2	2	1.84
8	1	0	2	2	2	2	2	2	1	1	1	2	2	2	2	2	3	2	2	-1	2	2	2	2	2	1	1.62
9	3	2	2	3	2	2	2	2	3	1	2	2	2	3	1	2	3	3	3	2	2	3	3	3	2	2	2.30
10	3	2	2	2	2	2	2	2	3	1	1	2	2	2	1	2	3	3	3	2	3	3	3	3	2	2	2.24
11	2	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	2.93
Mean Value / Item	2.0	2.3	1.8	2.6	1.8	2.1	2.3	2.4	1.5	1.1	1.8	2.4	2.6	2.5	1.0	2.2	2.5	1.9	2.3	1.7	2.3	2.4	2.6	2.5	2.4	1.7	

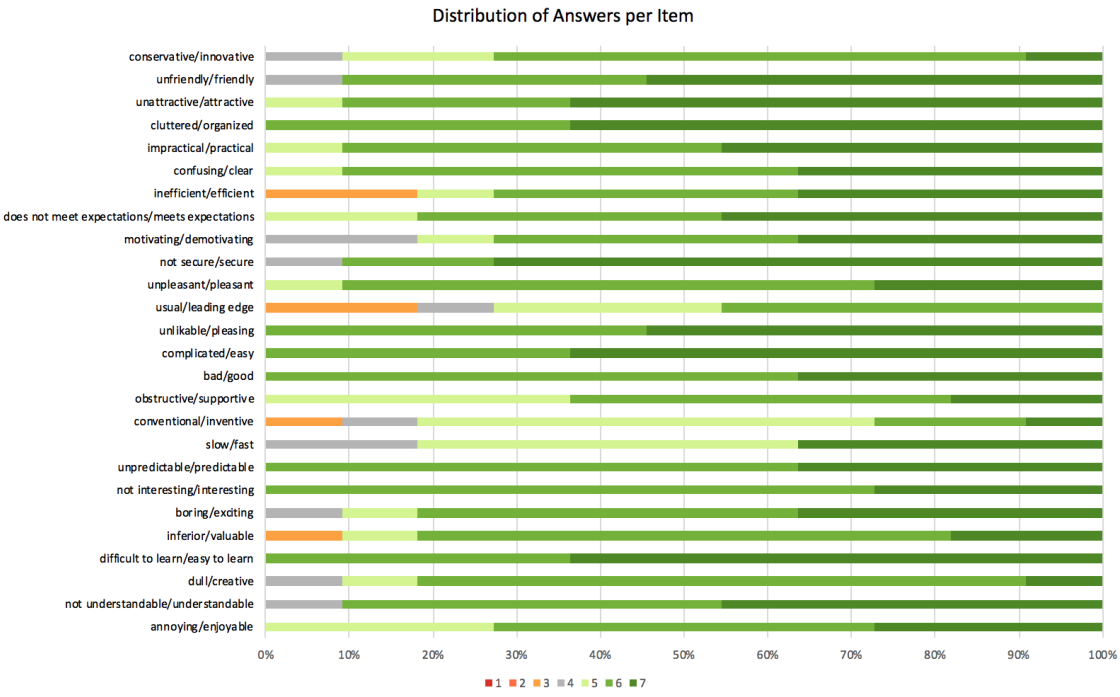


Figure 4.3: UEQ answers distribution

UEQ Scales (Mean and Variance)		
Attractiveness	2,333	0,26
Perspicuity	2,455	0,22
Efficiency	2,068	0,58
Dependability	2,250	0,25
Stimulation	2,023	0,41
Novelty	1,409	0,55

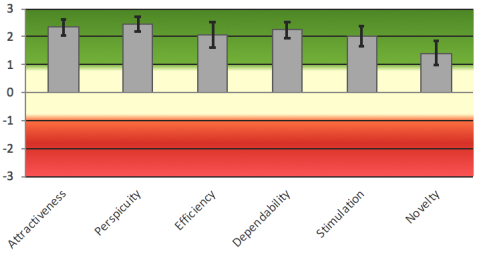


Figure 4.4: UEQ testers answers mean value divided by their scales

familiar with. Dependability, has a similar mean value (2.250) meaning that testers feel in control of the application interaction. The Efficiency and Stimulation had mean values of 2.068 and 2.023, which is a lower positive feedback, but the conclusion about those values is that the testers can perform their tasks without unnecessary effort and also that they feel excited and motivated to use the app. The Novelty mean value was the lowest value obtained which means we could improve the innovation of the implemented ideas.

So, generally, the proposed solution app has an extremely positive evaluation. But, in order to get more a precise view of the results we used the benchmark available by UEQ tool. That benchmark classifies the application into five different categories: Excelent; Good; Above Average; Below Average; and Bad. In the range of the 10% best results, they classify it as Excellent. If 10% of the results in the benchmark data set are better and 75% of the results are worse, than it is classified as Good. If 25% of the results in the benchmark are better than the result for the evaluated application, 50% of the results are worse, it is considered as Above Average. When 50% of the results in the benchmark are better than the result for the evaluated app, 25% of the results are worse, means a classification of Below Average. Lastly it is considered as Bad in the range of the 25% worst results. [AMJ18]

The benchmark results (Figure 4.5), showed, once again, that the application were on most of the scales considered Excellent regarding the user experience. However the Novelty items are on the Good level, which means there is space for an improvement.

In addition to those charts, this tool allowed us to understand if the user had give a random or not serious answer. They use a heuristic in which it is identified a difference between the best evaluation and the worst. If this value is greater than 3 it is considered it as an indicator for a problematic data pattern. However, it only makes sense to consider those situations if it happens on more than one scale, otherwise it can be ignored. On the case of our testers answers, there were no inconsistencies, so there were no problems on the results.

Besides the UEQ tool, testers have been inquired about their feedback regarding the application in general. All of them indicate that when they were trying to connect Mi Band 2 with the app, most of the times it took too long or did not connect. Testers number 1, 2 and 6 solved that problems with the use of an application, Gadgetbridge. They simply connect their Mi Band 2 with that application, and after that turn off the device on the app, close the app and finally open BeHTExApp. With that the application already could connect with the wearable, and collect the

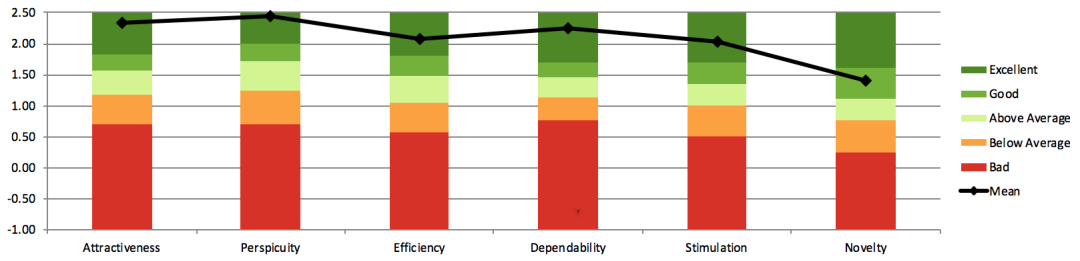


Figure 4.5: UEQ benchmark

missing data.

Tester number 9 also told us that he could not understand at first that the left arrow displayed on charts was to navigate in time, but when he clicked it aware that he could go back to previous days or weeks.

Tester number 10 expressed that he would like to have more features, besides the implemented ones, so that he could stay more impressed with the application. According to him there is novelty, but since the app had less features than other applications it looked less innovative.

The mobile phone of tester number 10 did not allow to present screens that contains charts, when trying to access to those screens the application simply crashed. That happens since the library used to draw the charts, MPAndroidChart, was not supported by the Android version his mobile phone has (Android 6.0). On this case, we asked the user to take his evaluation of the app only with the features available on his phone, which were the Home screen and the Settings screen.

Our testers were also inquired about their opinion regarding the use of traffic light colours to represent the state, to which, all the user thought it helped them to have a perception if it was a good or a bad value.

Chapter 5

Conclusion and Future Work

This chapter presents how we accomplished the thesis' objectives and what we have concluded with the developed work. We also describe some possible future work.

Our first task was to understand the concepts behind health monitoring through wearables. For that we explored the concepts of Physical Activity and Heart Rate. We also conducted an overview of the wearables system, explaining what each sensor brought into a wearable. After that it was important to take into consideration products regarding health monitoring. With that we could not only have an overview of what those applications offer at the moment but also identify some of UI/UX patterns used so far to present data. Our goal was to understand what industry players were using at the moment, regarding data visualisation, so that we could, afterwards, understand how we could improve.

To create the proposed solution we have used the Design Thinking Process, since we need to get in touch with the users' needs to define correctly our problem. After the problem definition, we created a low-fidelity representation of our possible solution. With that, with the use of Adobe XD we created a high-fidelity representation, so that we could test it with users. Those tests were a key point to find new ideas and improve our idea.

The second goal of the thesis was to develop a proof-of-concept application. For that we started by defining the structure of the Android app, including the architecture and which type of database to use since we wanted the application to display the data immediately. The development did not contemplate all the proposed features but the most important ones: sleep for instance, was not implemented, due to failures on the data gathered with Mi Band 2. With the solution implemented, to evaluate the concept we conducted tests with 11 users. We gave them a Mi Band 2, installed the application on their mobile phone, and after one week of testing we collected their feedback. We conducted those interviews using a UEQ template and also by recording the users' opinions regarding their experience during the tests.

The results proved that the implemented solution for those 11 users was an excellent user experience regarding Attractiveness, Perspicuity, Efficiency, Dependability and Stimulation. However, Novelty do not have high results, but still inside the "Good" level. We could conclude that our proposed application can help users understand the displayed values, i.e. if they are good or bad,

with the use of the traffic light colours. This concept was a contribution for the Novelty, with this new interface component the users' health values can be perceived with less effort. Also, by using that concept also on charts, users can not only understand each value presented, but also a set of values in a week regarding a specific metric.

For future work we would like to create a monitoring system that makes use of a machine learning engine to understand user patterns regarding physical activity. For instance, we could have a section, on monitoring screen, containing a chart that presents the number of days with activity and the number of days without. Additional textual information could make the user aware that our application detected a pattern on Mondays, for example. This way, the application could make the user understand that he only does physical activity on Mondays, which could be improved by doing more physical activity or by splitting it through the other days of the week. With that we motivate our user on his physical activity daily routine.

Also we would like to implement the feature R24 (Requirement List E), a button that aimed to show more information regarding a theme. This button aims to help the user understand even better the displayed values. For example only by telling him that the heart rate for his age should be between 60 and 100 bpm at rest, could lead him to understand the data and consequently to improve his health behaviours.

Finally, another improvement we would like to do on a future work is to test the application with a bigger number of testers so that we can further evaluate the application regarding the user experience.

References

[AHITC19a] Ltd. Anhui Huami Information Technology Co. Mi fit na app store. Available at https://itunes.apple.com/app/mi-fit/id938688461, January 2019.

[AHITC19b] Ltd. Anhui Huami Information Technology Co. Mi fit – aplicações no google play. Available at https://play.google.com/store/apps/details?id=com.xiaomi.hm.health, January 2019.

[AMJ18] Hinderks A., Schrepp M., and Thomaschewski J. User experience questionnaire (UEQ). Available at https://www.ueq-online.org/, 2018.

[AMZ+18] Henriksen A., Haugen Mikalsen M., Woldaregay A. Z., Muzny M., Hartvigsen G., Hopstock L. A., and Grimsgaard S. Using fitness trackers and smartwatches to measure physical activity in research: Analysis of consumer wrist-worn wearables. *Journal of Medical Internet Research*, March 2018.

[Ass15] American Heart Association. All about heart rate (pulse). Available at http://www.heart.org/en/health-topics/high-blood-pressure/the-facts-about-high-blood-pressure/all-about-heart-rate-pulse, Jully 2015.

[CJCS17] Maher C., Ryan J., Ambrosi C., and Edney S. Users' experiences of wearable activity trackers: a cross-sectional study. *BMC Public Health*, November 2017.

[Cor17a] International Data Corporation. Wearables aren't dead, they're just shifting focus as the market grows 16.9% in the fourth quarter, according to idc. Available at https://www.idc.com/getdoc.jsp?containerId=prUS42342317, March 2017.

[Cor17b] International Data Corporation. Xiaomi and apple tie for the top position as the wearables market swells 17.9% during the first quarter, according to idc. Available at https://www.idc.com/getdoc.jsp?containerId=prUS42707517, June 2017.

[Dev19a] Android Developers. Fragment. Available at https://developer.android.com/reference/android/app/Fragment, January 2019.

[Dev19b] Android Developers. Livedata overview. Available at https://developer.android.com/topic/libraries/architecture/livedata, January 2019.

[Dev19c] Android Developers. Save data in a local database using room. Available at https://developer.android.com/training/data-storage/room/, January 2019.

[Fou18] Interaction Design Foundation. *The Basics of User Experience Design*. Interaction Design Foundation, 2018.

[Gar19] Garmin. Garmin connect™– aplicações no google play. Available at https://play.google.com/store/apps/details?id=com.garmin.android.apps.connectmobile, February 2019.

[HAM10] Ketabdar H., Yüksel K. A., and Roshandel M. Magitact: Interaction with mobile devices based on compass (magnetic) sensor. *Proceedings of the 15th International Conference on Intelligent User Interfaces*, February 2010.

[J.07] Allen J. Photoplethysmography and its application in clinical physiological measurement. *Physiological Measurement*, March 2007.

[kn:19] Physical activity guidelines - health.gov. Available at https://health.gov/paguidelines/, 2019.

[NAL+17] Passaro V. M. N., Cuccovillo A., Vaiani L., Carlo M. D., and Campanella C. E. Gyroscope technology and applications: A review in the industrial perspective. *Sensors (Basel, Switzerland)*, October 2017.

[Org18] World Health Organization. Physical activity. Available at http://www.who.int/en/news-room/fact-sheets/detail/physical-activity, February 2018.

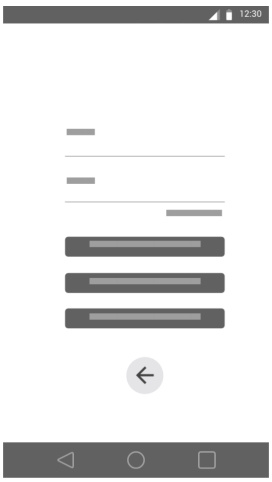
[Raf11] Garofalo Raffaele. *Building Enterprise Applications with Windows Presentation Foundation and the Model View ViewModel Pattern*. Microsoft Press, March 2011.

[SEC19] Ltd. Samsung Electronics Co. Samsung health – aplicações no google play. Available at https://play.google.com/store/apps/details?id=com.sec.android.app.shealth, January 2019.

[YR05] Chen K. Y. and Bassett D. R. The technology of accelerometry-based activity monitors: current and future. *Medicine and Science in Sports and Exercise*, November 2005.

Appendix A

Low-fidelity representation - Wireframes



Sign In

Sign Up

Menu Home

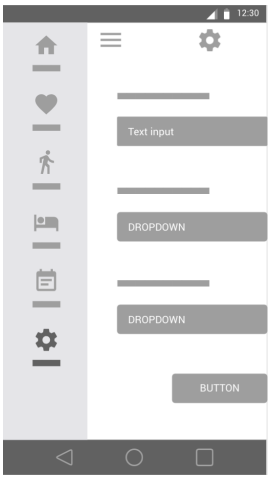
Menu Heart Rate

Menu Physical Activity

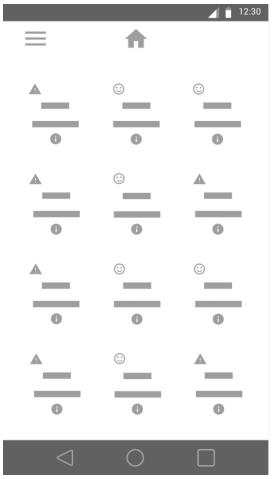
Menu Sleep

Low-fidelity representation - Wireframes

Menu Monitoring

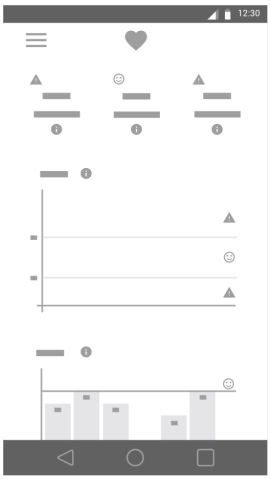


Menu Settings

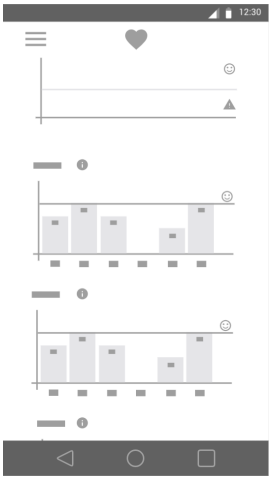


Home

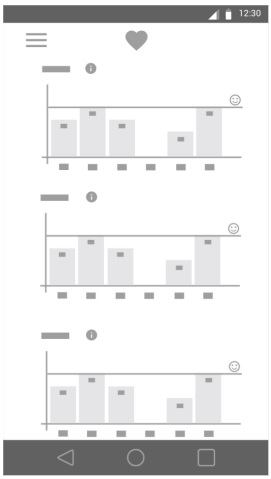
Heart Rate



Heart Rate



Heart Rate



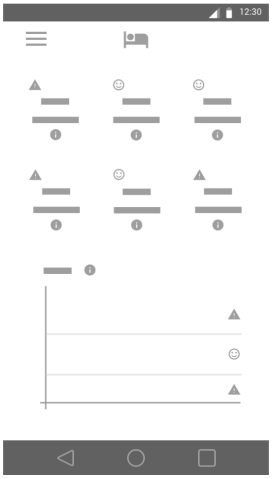
Heart Rate

Physical Activity

Physical Activity

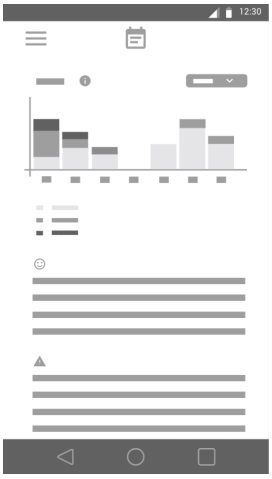
Low-fidelity representation - Wireframes

Sleep

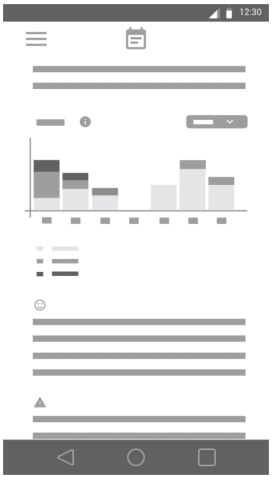


Sleep

Sleep



Monitoring



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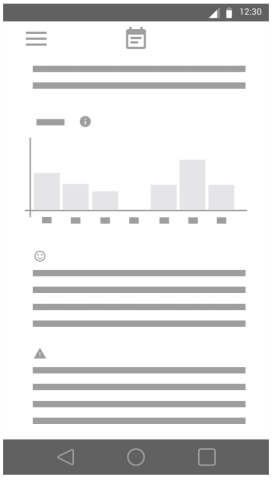

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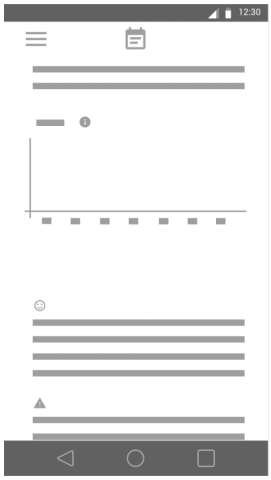

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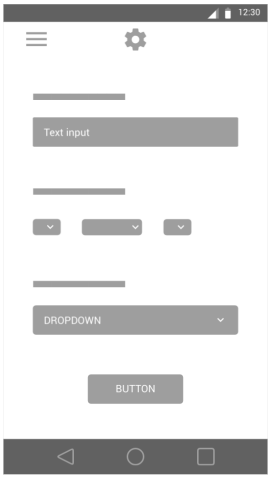
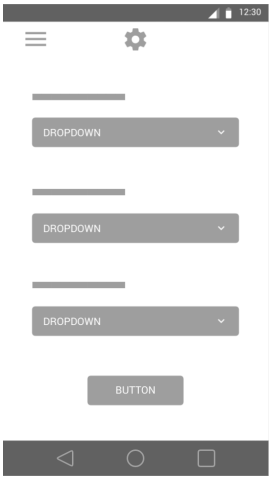


Settings

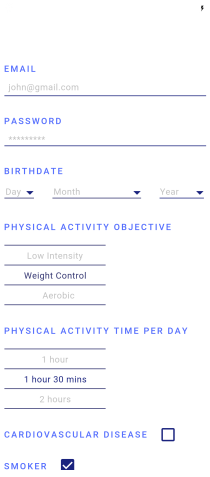


Settings

Low-fidelity representation - Wireframes

Appendix B

High-fidelity representation - First prototype



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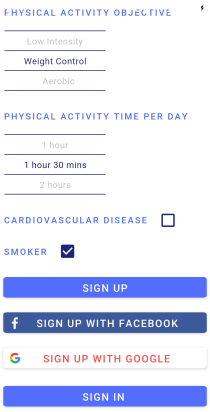

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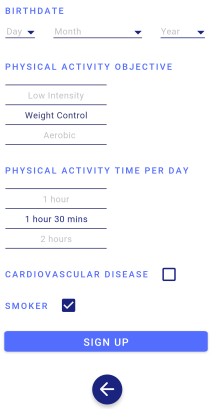
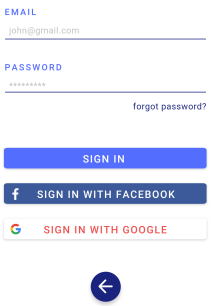
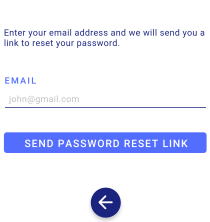


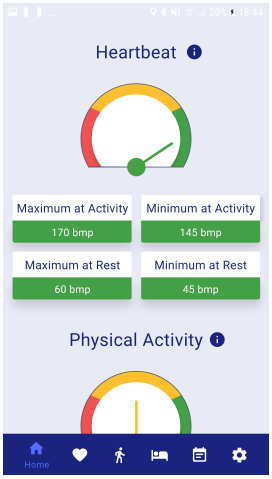
Sign Up With Google or Facebook



Sign In



Forgot Password



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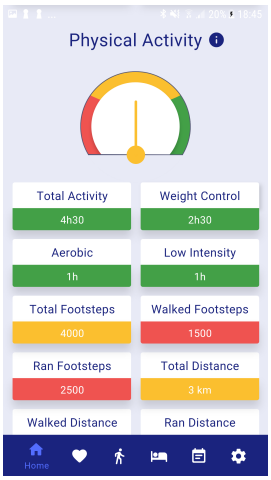

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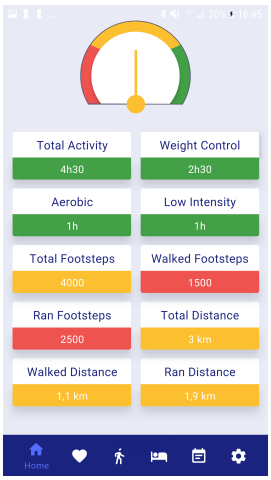

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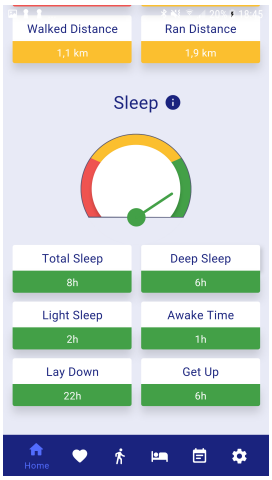

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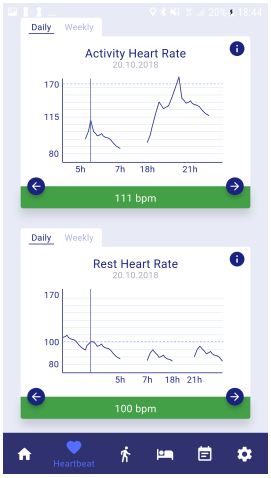

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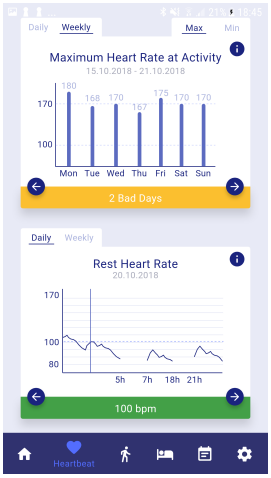

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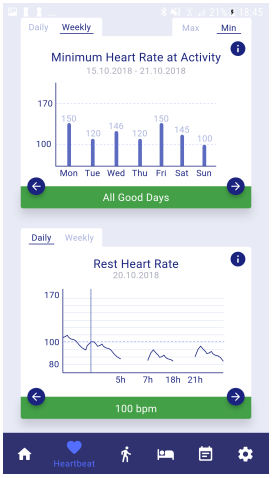
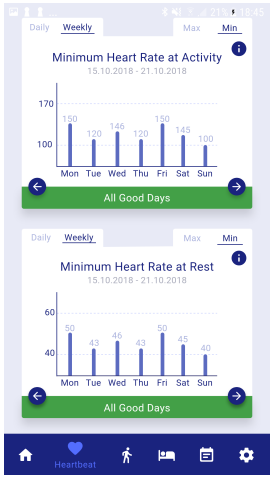


Heart Rate

Heart Rate



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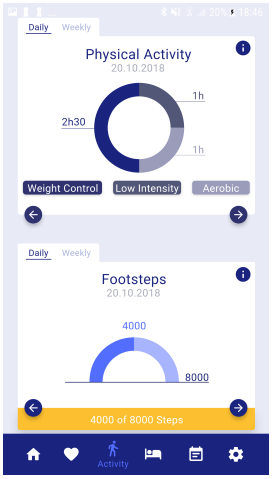
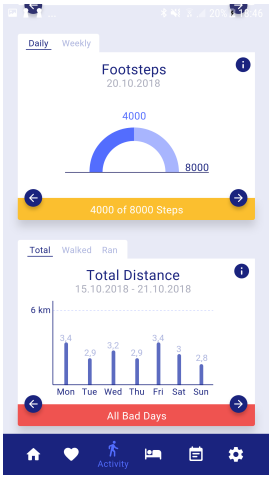


Physical Activity



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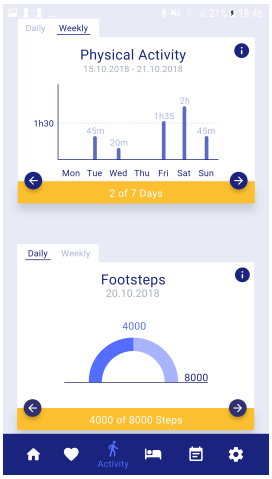

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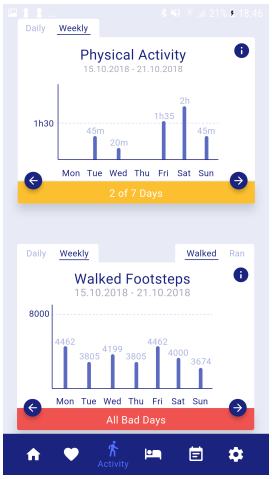

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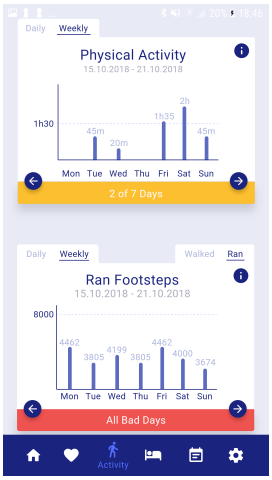
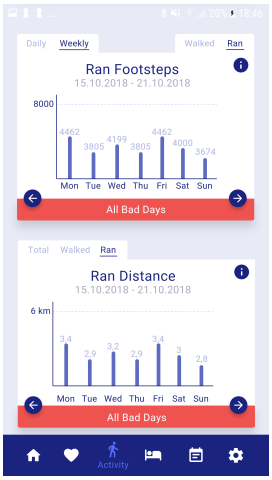


Physical Activity

Physical Activity



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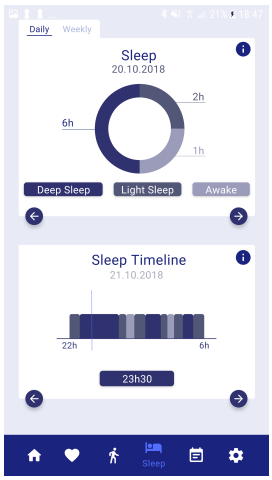
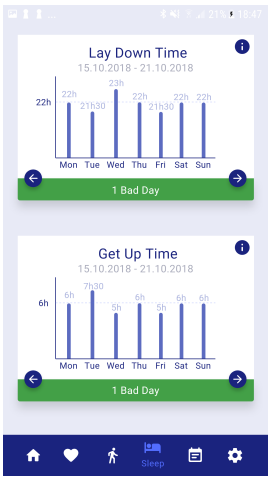
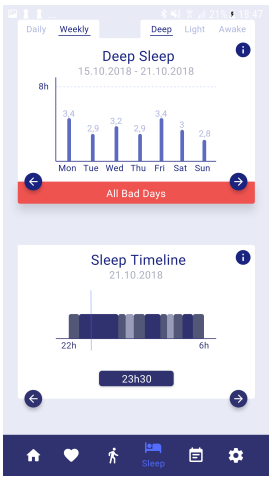


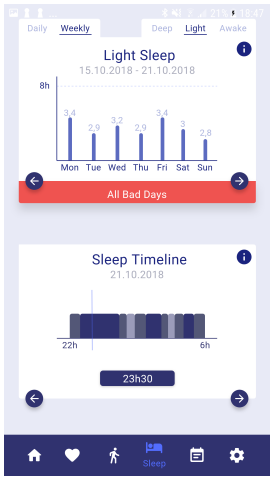
Sleep



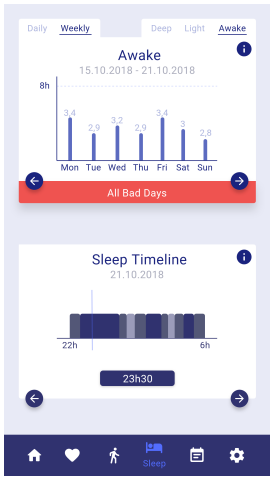
Sleep



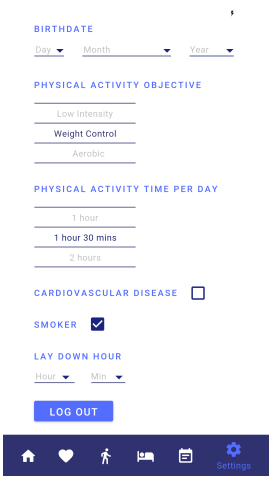
Sleep



Sleep



Sleep



Settings

Appendix C

First prototype tests

C.1 Script

This interview aims to collect information regarding users experience through the use of wearables and about the experience with our non-functional application prototype developed for the Master Thesis “Better Health Tracking Experience”.

Let’s start with some questions about you:

1. What is your name?
2. How old are you?
3. What is your profession?
4. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
5. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?

Now, I would ask you to use the given smart-phone to execute my instructions:

Operation	Success	Failure	Observation
To sign up, it’s needed that you fill the displayed fields.			
Do you have any dough about it?			
Imagine that you have filled all the fields. Please sign up.			
Log out from the application.			
Imagine that you wanted to sign up using a Google account.			
Do the sign up.			

First prototype tests

Operation	Success	Failure	Observation
Log out from the application.			
Imagine that you wanted to sign up using your Facebook account.			
Do the sign up.			
Log out from the application.			
Imagine that you already have an account on our application.			
Sign in with that account.			
Log out from the application.			
Imagine that you don't remember your password.			
Try to recover your password.			
Go back and sing in with one of your accounts Google or Facebook.			
Tell me what your maximum heart rate in activity during this day was.			
Now just look at the information displayed on the home page			
regarding physical activity. What do you think that each of the			
displayed colours mean? (Green, Yellow, Red)			
What do you think the displayed barometer tells?			
To obtain more information about physical activity where would you tap?			
Tell me the hour you lay down last night.			
Navigate to the screen that contains only information about the heart rate.			
Tell me your heart rate around 5 a.m.			
What do you think it's needed for you to know your heart rate in a different			
hour of the day?			
Check your maximum heart rate during physical activity last week.			
Check your minimum heart rate at rest last week.			
Check the quantity of time you have been in aerobic physical activity today.			
Tell me how many kilometres you have done last Monday.			
Check your progress last week regarding the number of			
hours you have been in physical activity.			
Tell me the number of steps you have done today.			
Check your progress last week regarding the number of steps you			
have done walking. Do you think it was good, bad or neither one or the other?			
Check your progress last week regarding the number of kilometres			
you have done walking. Do you think it was good, bad or neither one or the other?			
Check your progress last week regarding the number of steps you			
have done running. Do you think it was good, bad or neither one or the other?			
Check your progress last week regarding the number of kilometres			
you have done running. Do you think it was good, bad or neither one or the other?			
Tell me the number of hours you have been awake last night.			
Through the sleep time line, tell me at 23h30 the type of sleep you were.			
I.e. Light or deep sleep or awake.			
Check your progress last week regarding the number of light sleep hours.			
Do you think it was good, bad or neither one or the other?			

Operation	Success	Failure	Observation
Check your progress last week regarding the number of awaken hours.			
Do you think it was good, bad or neither one or the other?			
Get more information regarding the deep sleep.			
Tell me your lay down hour on the past Wednesday, and what time did you get up.			
Imagine that you want to change the predefined hour regarding			
the lay down time. Where would you do that?			
Tell me your general state regarding the quantity of physical activity you have done today.			
Do you think it is good, bad or neither one or the other?			

C.2 Results of Tester Nr. 1

1. How old are you?
Answer: 25 years

2. What is your profession?
Answer: Writer

3. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

4. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: Yes, I have a Mi Band 2. I usually use Xiaomi app. I like it very much. I wish it could count the number of pools.

Operation	Success	Failure	Observation
To sign up, it's needed that you fill the displayed fields. **Do you have any dough about it?**	✓		
Imagine that you have filled all the fields. Please sign up.	✓		
Log out from the application.	✓		Although it was done successfully, there was a certain difficulty to complete the task
Imagine that you wanted to sign up using a Google account. **Do the sign up.**	✓		
Log out from the application.	✓		
Imagine that you wanted to sign up using your Facebook account. **Do the sign up.**	✓		
Log out from the application.	✓		
Imagine that you already have an account on our application. **Sign in with that account.**	✓		

First prototype tests

Operation	Success	Failure	Observation
Log out from the application.	✓		
Imagine that you don't remember your password. Try to recover your password.	✓		
Go back and sing in with one of your accounts Google or Facebook.	✓		
Tell me what your maximum heart rate in activity during this day was.	✓		
Now just look at the information displayed on the home page regarding physical activity. What do you think that each of the displayed colours mean? (Green, Yellow, Red)	✓		
What do you think the displayed barometer tells?	✓		The user suggests to give less emphasis to barometer. Maybe use it as an icon.
To obtain more information about physical activity where would you tap?	✓		
Tell me the hour you lay down last night.	✓		
Navigate to the screen that contains only information about the heart rate.	✓		
Tell me your heart rate around 5 a.m.	✓		
What do you think it's needed for you to know your heart rate in a different hour of the day?	✓		
Check your maximum heart rate during physical activity last week.	✓		
Check your minimum heart rate at rest last week.	✓		
Check the quantity of time you have been in aerobic physical activity today.	✓		
Tell me how many kilometres you have done last Monday.	✓		
Check your progress last week regarding the number of hours you have been in physical activity.	✓		
Tell me the number of steps you have done today.	✓		
Check your progress last week regarding the number of steps you have done walking. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of kilometres you have done walking. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of steps you have done running. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of kilometres you have done running. Do you think it was good, bad or neither one or the other?	✓		
Tell me the number of hours you have been awake last night.	✓		
Through the sleep time line, tell me at 23h30 the type of sleep you were. I.e. Light or deep sleep or awake.	✓		
Check your progress last week regarding the number of light sleep hours. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of awaken hours. Do you think it was good, bad or neither one or the other?	✓		
Get more information regarding the deep sleep.	✓		
Tell me your lay down hour on the past Wednesday, and what time did you get up.	✓		
Imagine that you want to change the predefined hour regarding the lay down time. Where would you do that?	✓		
Tell me your general state regarding the quantity of physical activity you have done today. Do you think it is good, bad or neither one or the other?	✓		

C.3 Results of Tester Nr. 2

1. How old are you?
Answer: 25 years

2. What is your profession?
Answer: Electrical Engineer

3. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

4. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: At the moment no.

Operation	Success	Failure	Observation
To sign up, it's needed that you fill the displayed fields. Do you have any dough about it?	✓		
Imagine that you have filled all the fields. Please sign up.	✓		
Log out from the application.	✓		
Imagine that you wanted to sign up using a Google account. Do the sign up.	✓		
Log out from the application.	✓		
Imagine that you wanted to sign up using your Facebook account. Do the sign up.	✓		
Log out from the application.	✓		
Imagine that you already have an account on our application. Sign in with that account.	✓		
Log out from the application.	✓		
Imagine that you don't remember your password. Try to recover your password.	✓		
Go back and sing in with one of your accounts Google or Facebook.	✓		
Tell me what your maximum heart rate in activity during this day was.	✓		
Now just look at the information displayed on the home page regarding physical activity. What do you think that each of the displayed colours mean? (Green, Yellow, Red)	✓		
What do you think the displayed barometer tells?	✓		
To obtain more information about physical activity where would you tap?	✓		
Tell me the hour you lay down last night.	✓		The user showed some difficulty to find the corresponding label.
Navigate to the screen that contains only information about the heart rate.		✓	
Tell me your heart rate around 5 a.m.	✓		
What do you think it's needed for you to know your heart rate in a different hour of the day?		✓	
Check your maximum heart rate during physical activity last week.	✓		
Check your minimum heart rate at rest last week.	✓		
Check the quantity of time you have been in aerobic physical activity today.	✓		
Tell me how many kilometres you have done last Monday.	✓		
Check your progress last week regarding the number of hours you have been in physical activity.	✓		

Operation	Success	Failure	Observation
Tell me the number of steps you have done today.	✓		
Check your progress last week regarding the number of steps you have done walking. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of kilometres you have done walking. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of steps you have done running. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of kilometres you have done running. Do you think it was good, bad or neither one or the other?	✓		
Tell me the number of hours you have been awake last night.	✓		
Through the sleep time line, tell me at 23h30 the type of sleep you were. I.e. Light or deep sleep or awake.	✓		
Check your progress last week regarding the number of light sleep hours. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of awaken hours. Do you think it was good, bad or neither one or the other?	✓		
Get more information regarding the deep sleep.		✓	
Tell me your lay down hour on the past Wednesday, and what time did you get up.	✓		
Imagine that you want to change the predefined hour regarding the lay down time. Where would you do that?		✓	The user suggests that it would be easier if there is a pencil icon to edit.
Tell me your general state regarding the quantity of physical activity you have done today. Do you think it is good, bad or neither one or the other?	✓		

C.4 Results of Tester Nr. 3

1. How old are you?
Answer: 24 years

2. What is your profession?
Answer: MIEEC Student at FEUP

3. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

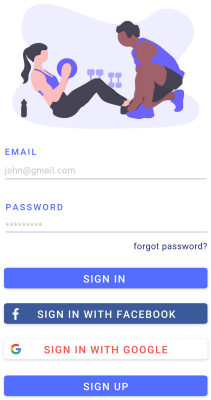
4. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: Yes, daily. I use Mi Fit to check the sleep quality and physical activity.

Operation	Success	Failure	Observation
To sign up, it's needed that you fill the displayed fields. Do you have any dough about it?	✓		
Imagine that you have filled all the fields. Please sign up.	✓		
Log out from the application.	✓		
Imagine that you wanted to sign up using a Google account. Do the sign up.	✓		
Log out from the application.	✓		
Imagine that you wanted to sign up using your Facebook account. Do the sign up.	✓		
Log out from the application.	✓		
Imagine that you already have an account on our application. Sign in with that account.	✓		
Log out from the application.	✓		
Imagine that you don't remember your password. Try to recover your password.	✓		
Go back and sing in with one of your accounts Google or Facebook.	✓		
Tell me what your maximum heart rate in activity during this day was.	✓		
Now just look at the information displayed on the home page regarding physical activity. What do you think that each of the displayed colours mean? (Green, Yellow, Red)	✓		
What do you think the displayed barometer tells?	✓		
To obtain more information about physical activity where would you tap?	✓		
Tell me the hour you lay down last night.	✓		
Navigate to the screen that contains only information about the heart rate.	✓		
Tell me your heart rate around 5 a.m.	✓		
What do you think it's needed for you to know your heart rate in a different hour of the day?	✓		
Check your maximum heart rate during physical activity last week.	✓		
Check your minimum heart rate at rest last week.	✓		
Check the quantity of time you have been in aerobic physical activity today.	✓		
Tell me how many kilometres you have done last Monday.	✓		
Check your progress last week regarding the number of hours you have been in physical activity.	✓		
Tell me the number of steps you have done today.	✓		
Check your progress last week regarding the number of steps you have done walking. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of kilometres you have done walking. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of steps you have done running. Do you think it was good, bad or neither one or the other?	✓		

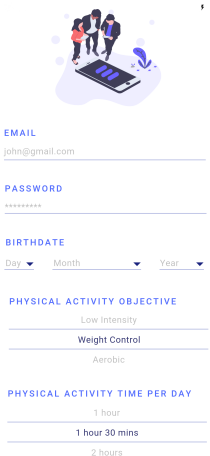
Operation	Success	Failure	Observation
Check your progress last week regarding the number of kilometres you have done running. Do you think it was good, bad or neither one or the other?	✓		
Tell me the number of hours you have been awake last night.	✓		
Through the sleep time line, tell me at 23h30 the type of sleep you were. I.e. Light or deep sleep or awake.	✓		
Check your progress last week regarding the number of light sleep hours. Do you think it was good, bad or neither one or the other?	✓		
Check your progress last week regarding the number of awaken hours. Do you think it was good, bad or neither one or the other?	✓		
Get more information regarding the deep sleep.	✓		
Tell me your lay down hour on the past Wednesday, and what time did you get up.	✓		
Imagine that you want to change the predefined hour regarding the lay down time. Where would you do that?	✓		
Tell me your general state regarding the quantity of physical activity you have done today. Do you think it is good, bad or neither one or the other?	✓		

Appendix D

Final prototype



Sign In



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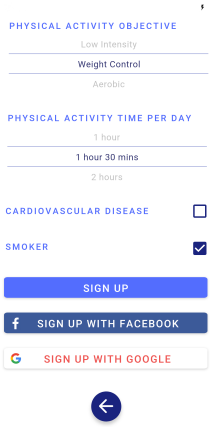
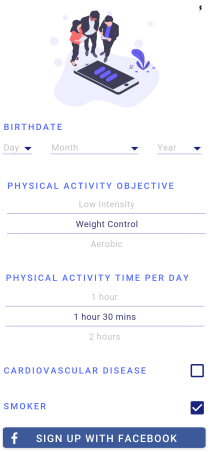
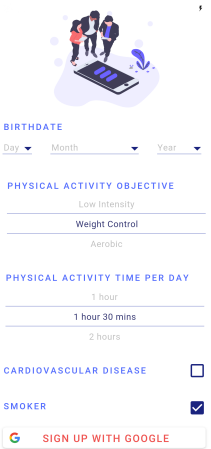


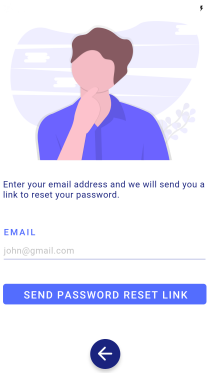
Sign Up



Sign Up Facebook

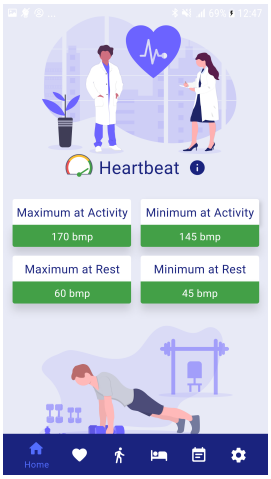


Sign Up Google



Forgot Password

Final prototype



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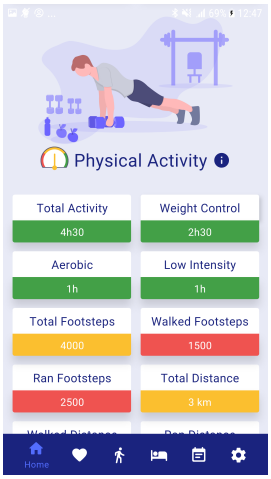
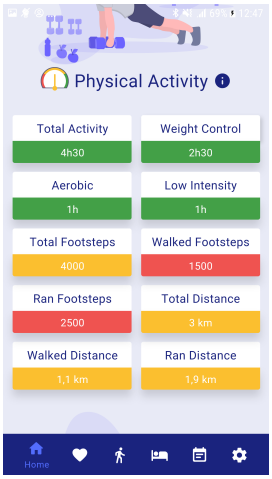
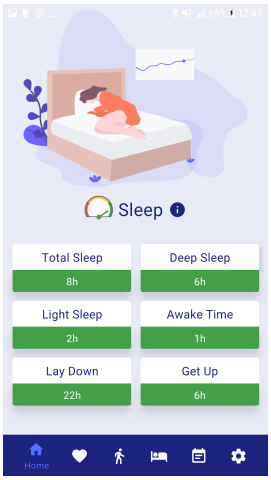


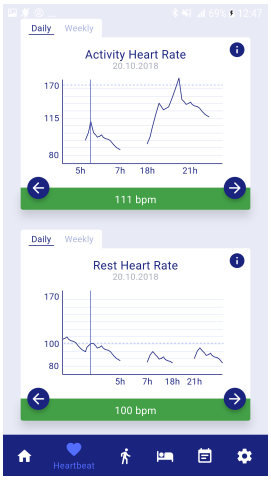
Home



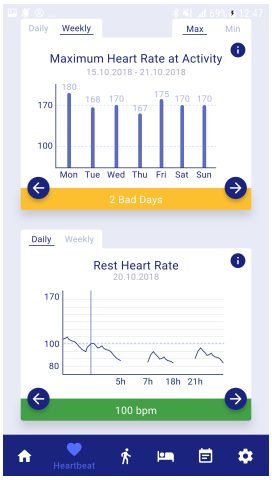
Home



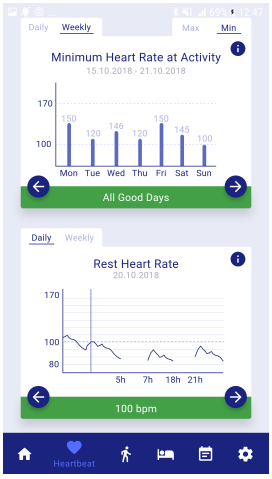
Home



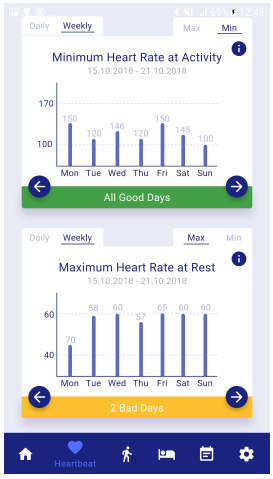
Heart Rate



Heart Rate

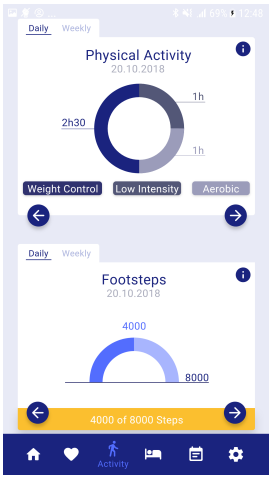


Heart Rate

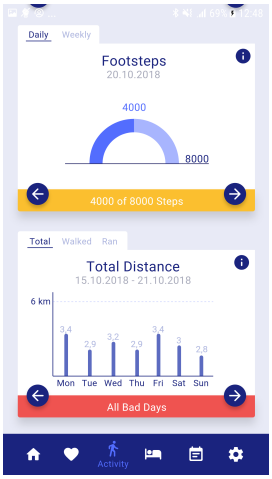


Heart Rate

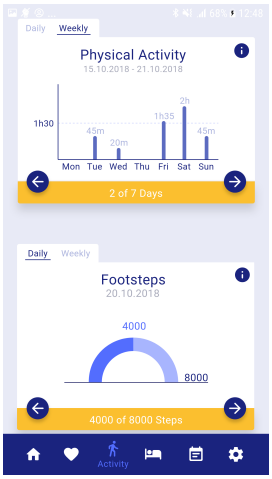
Heart Rate



Physical Activity

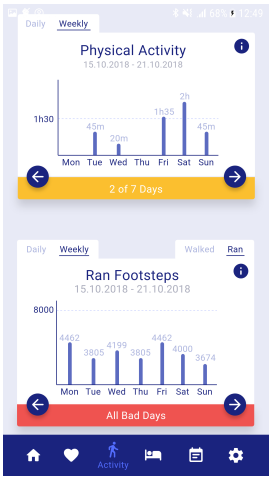


Physical Activity



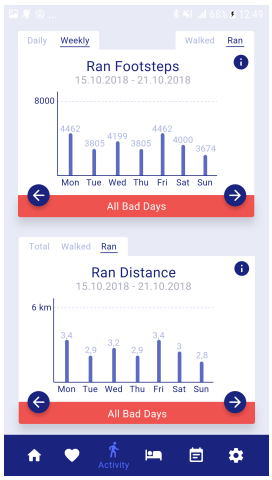
Physical Activity

Physical Activity

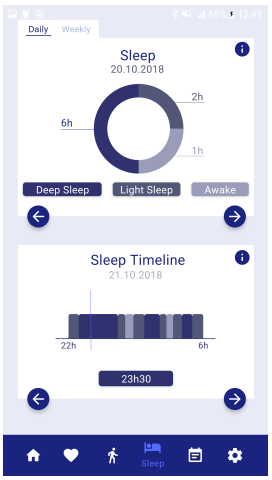


Physical Activity

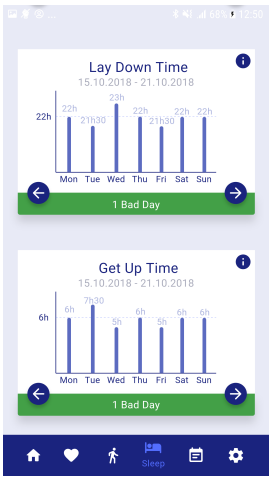
Physical Activity



Physical Activity

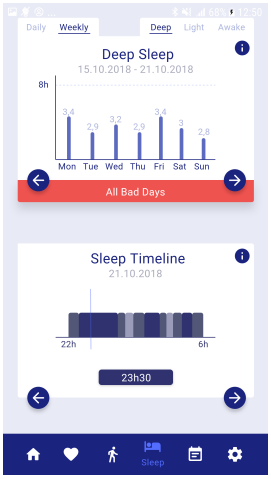


Sleep

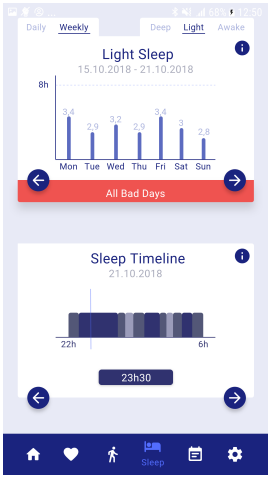


Sleep

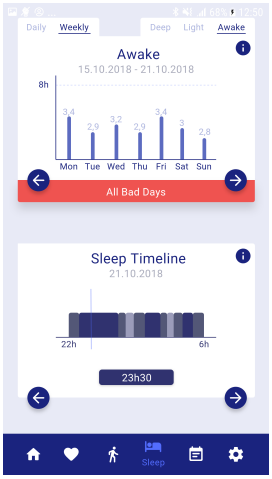
Final prototype



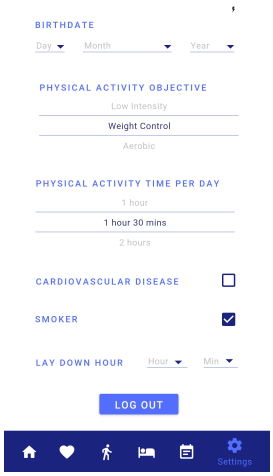
Sleep



Sleep



Sleep



Settings

Appendix E

Solution Requirements

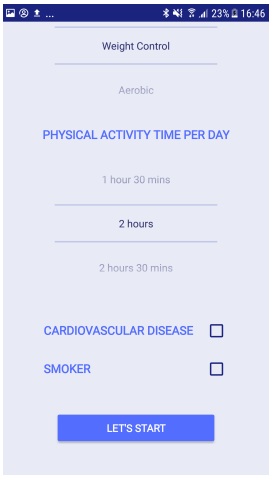
Id	Name	Description	Priority
R1	Form	As a new User I want to set my personal information, so that the values presented could be customised to my age and objectives.	High
R2	Connection	As a registered User I want to pair my Mi Band 2 with the app, so that the values displayed are the collected through my wearable.	High
R3	Home Heartbeat Activity	As a registered User I want to view my maximum and minimum heart rate at activity during the day itself, so that I can understand my actual health state.	High
R4	Home Heartbeat Rest	As a registered User I want to view my maximum and minimum heart rate at rest during the day itself, so that I can understand my actual health state.	High
R5	Home PA	As a registered User I want to view the total physical activity time during the day itself, so that I can understand my actual health state with focus on physical activity.	High
R6	Home PA Types	As a registered User I want to view the time spent on each physical activity type during the day itself, so that I can understand if I reached my goals.	High
R7	Home PA Steps	As a registered User I want to view the number of steps taken during the day itself, so that I can understand if I reached my goal.	High
R8	Home PA Distance	As a registered User I want to view the distance taken during the day itself, so that I can understand if I reached my goal.	High
R9	Heartbeat Activity Daily	As a registered User I want to view a chart with my activity HR on a specific day, so that I can check my progress.	High
R10	Heartbeat Activity Max Weekly	As a registered User I want to view a chart with my maximum activity HR on a specific week, so that I can check my progress.	High
R11	Heartbeat Activity Min Weekly	As a registered User I want to view a chart with my minimum activity HR on a specific week, so that I can check my progress.	High
R12	Heartbeat Rest Daily	As a registered User I want to view a chart with my rest HR on a specific day, so that I can check my progress.	High
R13	Heartbeat Rest Max Weekly	As a registered User I want to view a chart with my maximum rest HR on a specific week, so that I can check my progress.	High
R14	Heartbeat Rest Min Weekly	As a registered User I want to view a chart with my minimum rest HR on a specific week, so that I can check my progress.	High

Id	Name	Description	Priority
R15	PA Types Daily	As a registered User I want to view a chart with the PA on a specific day split through PA types, so that I can check time spent on each one.	High
R16	PA Total Weekly	As a registered User I want to view a chart with the total time spent on PA on each day of a specific week, so that I can check my progress.	High
R17	PA Steps Daily	As a registered User I want to view a chart with the number of steps on a specific day, so that I can check if I reached the recommended by WHO.	High
R18	PA Steps Weekly	As a registered User I want to view a chart with the number of steps on each day of a specific week, so that I can check my progress.	High
R19	PA Distance Daily	As a registered User I want to view a chart with the distance taken on a specific day, so that I can check if I reached the recommended by WHO.	High
R20	PA Steps Weekly	As a registered User I want to view a chart with the distance taken on each day of a specific week, so that I can check my progress.	High
R21	Home Heartbeat Barometer	As a registered User I want to view the heart rate barometer, so that I can understand my general health state regarding heart rate.	Medium
R22	Settings	As a registered User I want to edit my personal information, so that I can change my objectives.	Medium
R23	Home PA Barometer	As a registered User I want to view the physical activity barometer, so that I can understand my general health state regarding PA.	Medium
R24	More Info	As a registered User I want to view more information about a specific theme, so that I can understand the displayed values.	Low

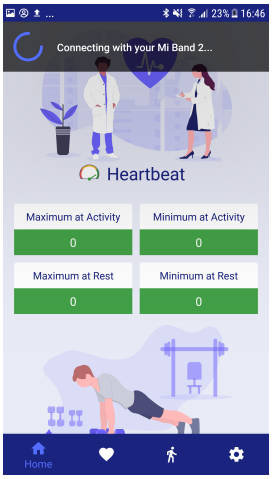
Appendix F

Android solution screens

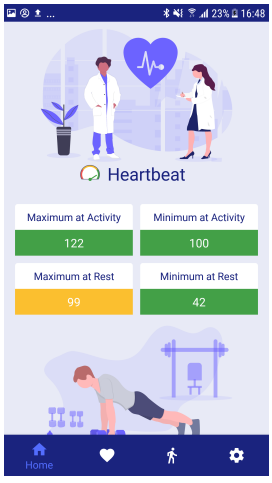
Initial Form



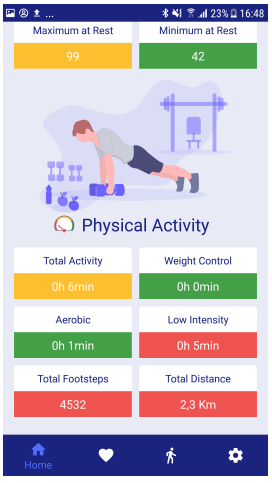
Initial Form



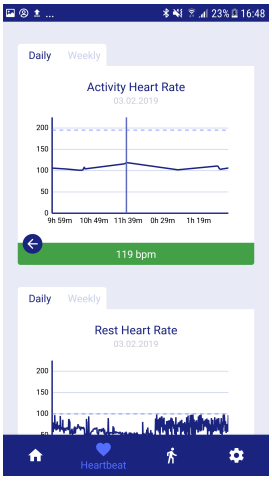
Connection



Home

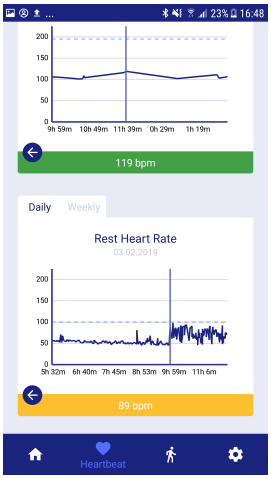


Home

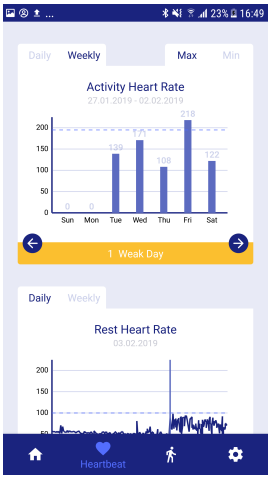


Heartbeat

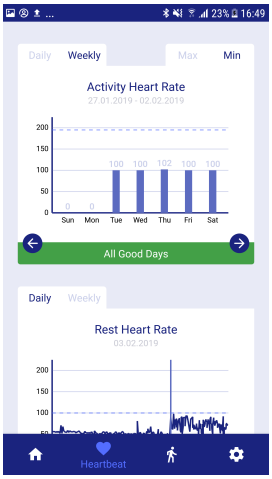
Android solution screens



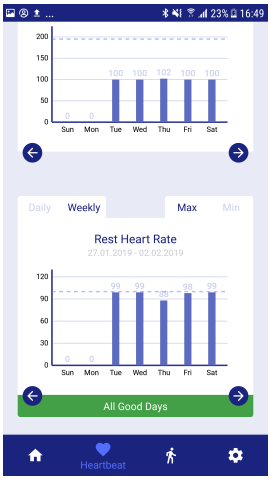
Heartbeat



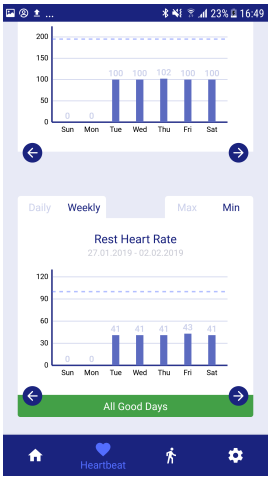
Heartbeat



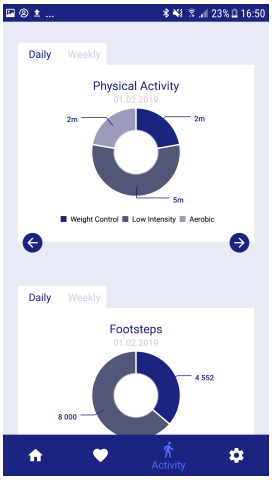
Heartbeat



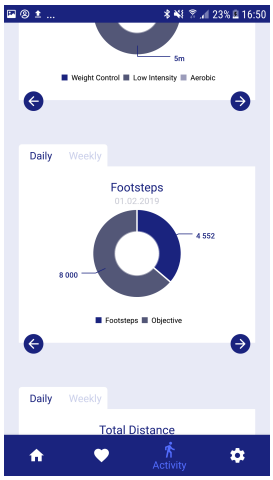
Heartbeat



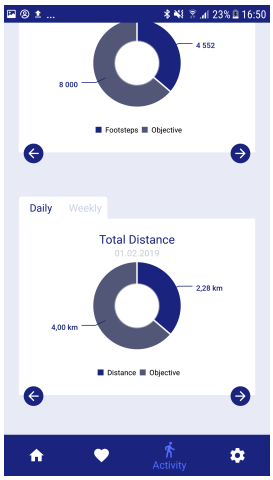
Heartbeat



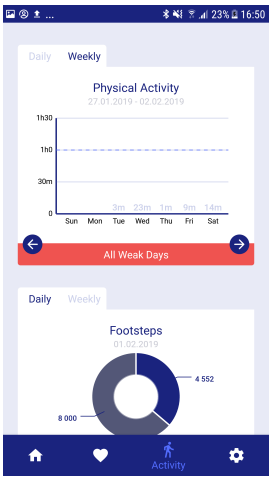
Physical Activity



Physical Activity

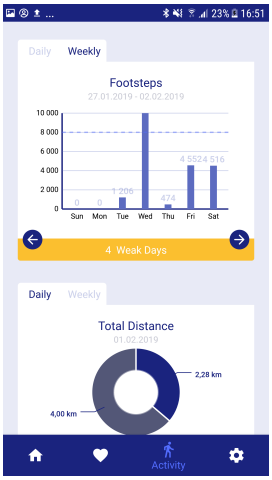


Physical Activity

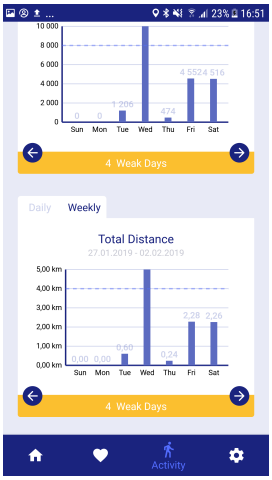


Physical Activity

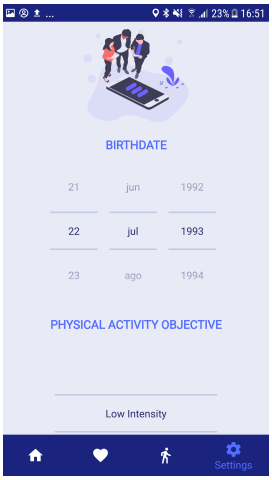
Android solution screens



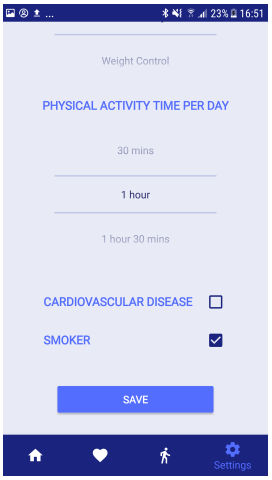
Physical Activity



Physical Activity



Settings



Settings

Android solution screens

Appendix G

Testers initial information

G.1 Initial information of tester nr. 1

1. How old are you?
Answer: 25 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: Yes, I have a Mi Band 2. I usually use Xiaomi app. I like it very much. I wish it could count the number of pools.

4. Do you practice physical activity regularly?
Answer: Yes, I use to swim and to do localised exercises 5 times a week. Normally between 1 and 2 hours.

G.2 Initial information of tester nr. 2

1. How old are you?
Answer: 25 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your

collected data?
Answer: At the moment no.

4. Do you practice physical activity regularly?
Answer: Yes, I use to do jogging and to do localised exercises 3 times a week, more or less between 45 minutes and 1 hour. Usually Mondays, Wednesdays and Fridays.

G.3 Initial information of tester nr. 3

1. How old are you?
Answer: 50 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 2

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: No, I have never used it.

4. Do you practice physical activity regularly?
Answer: Yes, trekking around 45 minutes a day.

G.4 Initial information of tester nr. 4

1. How old are you?
Answer: 26 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: No, I have never used it. However I already used apps on a friend phone and on my phone too. I already used the Huawei app to count the number of steps and also the Samsung Health app to measure the heart rate.

4. Do you practice physical activity regularly?
Answer: No.

G.5 Initial information of tester nr. 5

1. How old are you?
Answer: 27 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: No, I have never used it. However I already used apps like Samsung Health and Google Fit. I used to check every 2 days or 3 days. Usually to measure the stress, heart rate and the number of steps. Those apps are very user friendly but sometimes have a big quantity of information, things that I do not even use.

4. Do you practice physical activity regularly?
Answer: No.

G.6 Initial information of tester nr. 6

1. How old are you?
Answer: 24 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: Yes, daily. I use Mi Fit to check my sleep quality and also to monitor my physical activity.

4. Do you practice physical activity regularly?
Answer: No.

G.7 Initial information of tester nr. 7

1. How old are you?
Answer: 53 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 3

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: No, I have never used it. I already used Samsung Health to count the number of steps.

4. Do you practice physical activity regularly?
Answer: Yes, volleyball 3 times a week, one and a half hours.

G.8 Initial information of tester nr. 8

1. How old are you?
Answer: 54 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 4

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: No, I have never used it. I already used Samsung Health to count the number of steps.

4. Do you practice physical activity regularly?
Answer: Yes, volleyball, football, cycling and swimming. Usually 2 to 3 times a week.

G.9 Initial information of tester nr. 9

1. How old are you?
Answer: 21 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: No, I have never used it. I already counted the number of steps with the app of my

mobile phone.

4. Do you practice physical activity regularly?
Answer: No.

G.10 Initial information of tester nr. 10

1. How old are you?
Answer: 21 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 5

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: No, I have never used it. I already counted the number of steps with the app of my mobile phone.

4. Do you practice physical activity regularly?
Answer: I use to dance during 2 hours one time per week.

G.11 Initial information of tester nr. 11

1. How old are you?
Answer: 51 years

2. How do you classify your experience with technologies from 1 to 5? (where 1 is no experience and 5 is expert)
Answer: 3

3. Are you a frequent user of wearables? If yes, which applications do you use to monitor your collected data?
Answer: No, I have never used wearables or applications.

4. Do you practice physical activity regularly?
Answer: No.

Testers initial information

Appendix H

User Experience Questionnaire template

Please make your evaluation now.

For the assessment of the product, please fill out the following questionnaire. The questionnaire consists of pairs of contrasting attributes that may apply to the product. The circles between the attributes represent gradations between the opposites. You can express your agreement with the attributes by ticking the circle that most closely reflects your impression.

Example:

attractive	○	⊗	○	○	○	○	○	unattractive

This response would mean that you rate the application as more attractive than unattractive.

Please decide spontaneously. Don't think too long about your decision to make sure that you convey your original impression.

Sometimes you may not be completely sure about your agreement with a particular attribute or you may find that the attribute does not apply completely to the particular product. Nevertheless, please tick a circle in every line.

It is your personal opinion that counts. Please remember: there is no wrong or right answer!

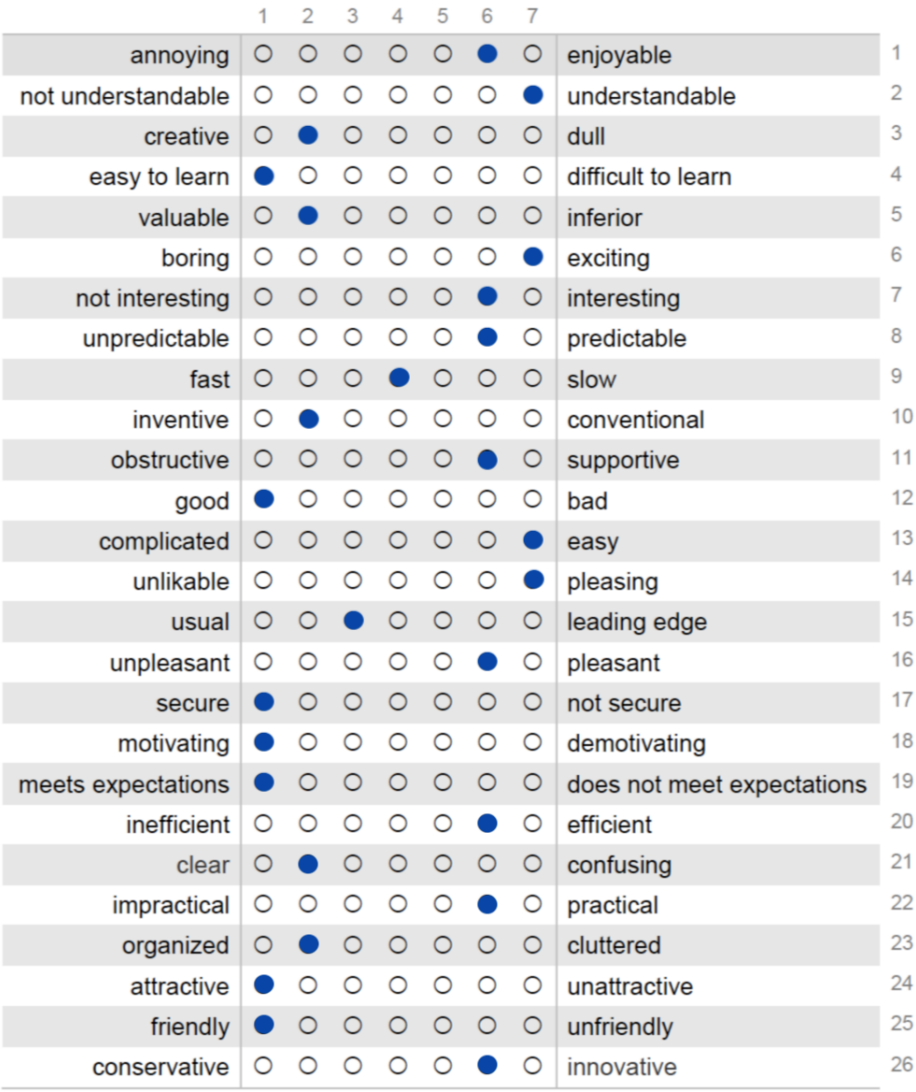
Please assess the product now by ticking one circle per line.

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	○	○	enjoyable	1
not understandable	○	○	○	○	○	○	○	understandable	2
creative	○	○	○	○	○	○	○	dull	3
easy to learn	○	○	○	○	○	○	○	difficult to learn	4
valuable	○	○	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	○	exciting	6
not interesting	○	○	○	○	○	○	○	interesting	7
unpredictable	○	○	○	○	○	○	○	predictable	8
fast	○	○	○	○	○	○	○	slow	9
inventive	○	○	○	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	○	○	supportive	11
good	○	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	○	easy	13
unlikable	○	○	○	○	○	○	○	pleasing	14
usual	○	○	○	○	○	○	○	leading edge	15
unpleasant	○	○	○	○	○	○	○	pleasant	16
secure	○	○	○	○	○	○	○	not secure	17
motivating	○	○	○	○	○	○	○	demotivating	18
meets expectations	○	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	○	efficient	20
clear	○	○	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	○	practical	22
organized	○	○	○	○	○	○	○	cluttered	23
attractive	○	○	○	○	○	○	○	unattractive	24
friendly	○	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	○	○	innovative	26

Appendix I

Testers Answers of UEQ

I.1 Tester Nr. 1



	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	●	○	enjoyable	1
not understandable	○	○	○	○	○	○	●	understandable	2
creative	○	●	○	○	○	○	○	dull	3
easy to learn	●	○	○	○	○	○	○	difficult to learn	4
valuable	○	●	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	●	exciting	6
not interesting	○	○	○	○	○	●	○	interesting	7
unpredictable	○	○	○	○	○	●	○	predictable	8
fast	○	○	○	●	○	○	○	slow	9
inventive	○	●	○	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	●	○	supportive	11
good	●	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	●	easy	13
unlikable	○	○	○	○	○	○	●	pleasing	14
usual	○	○	●	○	○	○	○	leading edge	15
unpleasant	○	○	○	○	○	●	○	pleasant	16
secure	●	○	○	○	○	○	○	not secure	17
motivating	●	○	○	○	○	○	○	demotivating	18
meets expectations	●	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	●	○	efficient	20
clear	○	●	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	●	○	practical	22
organized	○	●	○	○	○	○	○	cluttered	23
attractive	●	○	○	○	○	○	○	unattractive	24
friendly	●	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	●	○	innovative	26

I.2 Tester Nr. 2

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	●	○	enjoyable	1
not understandable	○	○	○	○	○	○	●	understandable	2
creative	○	●	○	○	○	○	○	dull	3
easy to learn	○	●	○	○	○	○	○	difficult to learn	4
valuable	○	●	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	●	exciting	6
not interesting	○	○	○	○	○	○	●	interesting	7
unpredictable	○	○	○	○	○	●	○	predictable	8
fast	○	○	●	○	○	○	○	slow	9
inventive	○	○	●	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	●	○	supportive	11
good	○	●	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	●	○	easy	13
unlikable	○	○	○	○	○	●	○	pleasing	14
usual	○	○	○	○	●	○	○	leading edge	15
unpleasant	○	○	○	○	○	●	○	pleasant	16
secure	○	●	○	○	○	○	○	not secure	17
motivating	○	●	○	○	○	○	○	demotivating	18
meets expectations	○	●	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	●	efficient	20
clear	○	○	●	○	○	○	○	confusing	21
impractical	○	○	○	○	○	●	○	practical	22
organized	●	○	○	○	○	○	○	cluttered	23
attractive	○	●	○	○	○	○	○	unattractive	24
friendly	●	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	●	○	innovative	26

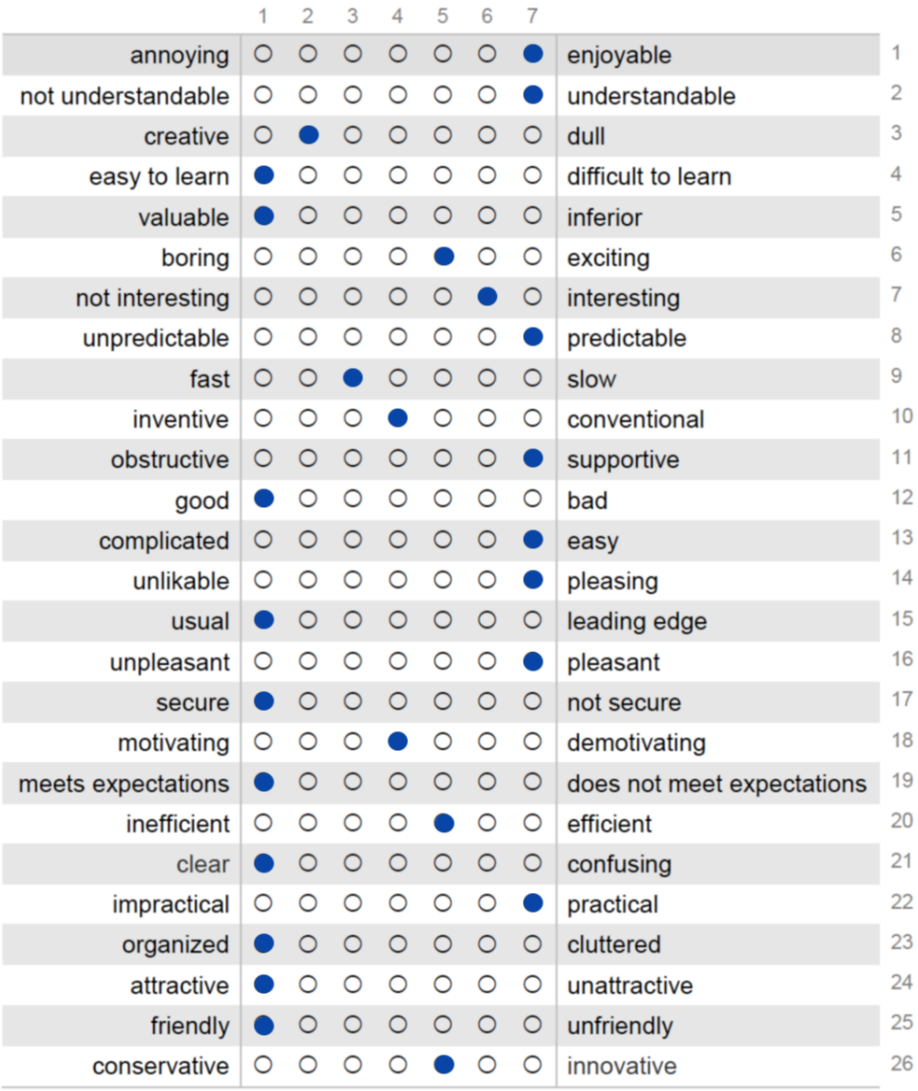
I.3 Tester Nr. 3

	1	2	3	4	5	6	7		
annoying	○	○	○	○	●	○	○	enjoyable	1
not understandable	○	○	○	○	○	●	○	understandable	2
creative	○	○	○	●	○	○	○	dull	3
easy to learn	●	○	○	○	○	○	○	difficult to learn	4
valuable	○	○	○	○	●	○	○	inferior	5
boring	○	○	○	○	○	●	○	exciting	6
not interesting	○	○	○	○	○	●	○	interesting	7
unpredictable	○	○	○	○	○	●	○	predictable	8
fast	●	○	○	○	○	○	○	slow	9
inventive	○	○	●	○	○	○	○	conventional	10
obstructive	○	○	○	○	●	○	○	supportive	11
good	○	●	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	●	easy	13
unlikable	○	○	○	○	○	○	●	pleasing	14
usual	○	○	○	●	○	○	○	leading edge	15
unpleasant	○	○	○	○	○	●	○	pleasant	16
secure	○	○	○	●	○	○	○	not secure	17
motivating	○	●	○	○	○	○	○	demotivating	18
meets expectations	○	●	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	●	efficient	20
clear	○	●	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	●	○	practical	22
organized	●	○	○	○	○	○	○	cluttered	23
attractive	●	○	○	○	○	○	○	unattractive	24
friendly	●	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	●	○	innovative	26

I.4 Tester Nr. 4

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	●	○	enjoyable	1
not understandable	○	○	○	○	○	●	○	understandable	2
creative	○	○	●	○	○	○	○	dull	3
easy to learn	○	●	○	○	○	○	○	difficult to learn	4
valuable	○	○	●	○	○	○	○	inferior	5
boring	○	○	○	●	○	○	○	exciting	6
not interesting	○	○	○	○	○	●	○	interesting	7
unpredictable	○	○	○	○	○	○	●	predictable	8
fast	○	○	○	●	○	○	○	slow	9
inventive	○	○	○	○	●	○	○	conventional	10
obstructive	○	○	○	○	○	●	○	supportive	11
good	○	●	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	●	easy	13
unlikable	○	○	○	○	○	●	○	pleasing	14
usual	○	○	●	○	○	○	○	leading edge	15
unpleasant	○	○	○	○	●	○	○	pleasant	16
secure	○	●	○	○	○	○	○	not secure	17
motivating	○	○	○	●	○	○	○	demotivating	18
meets expectations	○	○	●	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	●	○	efficient	20
clear	○	●	○	○	○	○	○	confusing	21
impractical	○	○	○	○	●	○	○	practical	22
organized	○	●	○	○	○	○	○	cluttered	23
attractive	○	○	●	○	○	○	○	unattractive	24
friendly	○	○	○	●	○	○	○	unfriendly	25
conservative	○	○	○	●	○	○	○	innovative	26

I.5 Tester Nr. 5



	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	○	●	enjoyable	1
not understandable	○	○	○	○	○	○	●	understandable	2
creative	○	●	○	○	○	○	○	dull	3
easy to learn	●	○	○	○	○	○	○	difficult to learn	4
valuable	●	○	○	○	○	○	○	inferior	5
boring	○	○	○	○	●	○	○	exciting	6
not interesting	○	○	○	○	○	●	○	interesting	7
unpredictable	○	○	○	○	○	○	●	predictable	8
fast	○	○	●	○	○	○	○	slow	9
inventive	○	○	○	●	○	○	○	conventional	10
obstructive	○	○	○	○	○	○	●	supportive	11
good	●	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	●	easy	13
unlikable	○	○	○	○	○	○	●	pleasing	14
usual	●	○	○	○	○	○	○	leading edge	15
unpleasant	○	○	○	○	○	○	●	pleasant	16
secure	●	○	○	○	○	○	○	not secure	17
motivating	○	○	○	●	○	○	○	demotivating	18
meets expectations	●	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	●	○	○	efficient	20
clear	●	○	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	●	practical	22
organized	●	○	○	○	○	○	○	cluttered	23
attractive	●	○	○	○	○	○	○	unattractive	24
friendly	●	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	●	○	○	innovative	26

I.6 Tester Nr. 6

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	●	○	enjoyable	1
not understandable	○	○	○	○	○	○	●	understandable	2
creative	○	●	○	○	○	○	○	dull	3
easy to learn	●	○	○	○	○	○	○	difficult to learn	4
valuable	○	●	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	●	exciting	6
not interesting	○	○	○	○	○	○	●	interesting	7
unpredictable	○	○	○	○	○	○	●	predictable	8
fast	○	○	●	○	○	○	○	slow	9
inventive	○	●	○	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	●	○	supportive	11
good	●	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	●	easy	13
unlikable	○	○	○	○	○	○	●	pleasing	14
usual	○	○	○	○	○	●	○	leading edge	15
unpleasant	○	○	○	○	○	○	●	pleasant	16
secure	●	○	○	○	○	○	○	not secure	17
motivating	○	○	●	○	○	○	○	demotivating	18
meets expectations	○	○	●	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	●	efficient	20
clear	○	●	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	●	practical	22
organized	●	○	○	○	○	○	○	cluttered	23
attractive	●	○	○	○	○	○	○	unattractive	24
friendly	●	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	●	○	innovative	26

I.7 Tester Nr. 7

	1	2	3	4	5	6	7		
annoying	○	○	○	○	●	○	○	enjoyable	1
not understandable	○	○	○	○	○	●	○	understandable	2
creative	○	●	○	○	○	○	○	dull	3
easy to learn	●	○	○	○	○	○	○	difficult to learn	4
valuable	○	●	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	●	○	exciting	6
not interesting	○	○	○	○	○	●	○	interesting	7
unpredictable	○	○	○	○	○	●	○	predictable	8
fast	○	○	●	○	○	○	○	slow	9
inventive	○	○	●	○	○	○	○	conventional	10
obstructive	○	○	○	○	●	○	○	supportive	11
good	○	●	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	●	easy	13
unlikable	○	○	○	○	○	●	○	pleasing	14
usual	○	○	○	○	○	●	○	leading edge	15
unpleasant	○	○	○	○	○	●	○	pleasant	16
secure	●	○	○	○	○	○	○	not secure	17
motivating	○	●	○	○	○	○	○	demotivating	18
meets expectations	○	●	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	●	○	○	○	○	efficient	20
clear	○	●	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	●	○	practical	22
organized	○	●	○	○	○	○	○	cluttered	23
attractive	○	●	○	○	○	○	○	unattractive	24
friendly	○	●	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	●	○	innovative	26

I.8 Tester Nr. 8

	1	2	3	4	5	6	7		
annoying	○	○	○	○	●	○	○	enjoyable	1
not understandable	○	○	○	●	○	○	○	understandable	2
creative	○	●	○	○	○	○	○	dull	3
easy to learn	○	●	○	○	○	○	○	difficult to learn	4
valuable	○	●	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	●	○	exciting	6
not interesting	○	○	○	○	○	●	○	interesting	7
unpredictable	○	○	○	○	○	●	○	predictable	8
fast	○	○	●	○	○	○	○	slow	9
inventive	○	○	●	○	○	○	○	conventional	10
obstructive	○	○	○	○	●	○	○	supportive	11
good	○	●	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	●	○	easy	13
unlikable	○	○	○	○	○	●	○	pleasing	14
usual	○	○	○	○	○	●	○	leading edge	15
unpleasant	○	○	○	○	○	●	○	pleasant	16
secure	●	○	○	○	○	○	○	not secure	17
motivating	○	●	○	○	○	○	○	demotivating	18
meets expectations	○	●	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	●	○	○	○	○	efficient	20
clear	○	●	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	●	○	practical	22
organized	○	●	○	○	○	○	○	cluttered	23
attractive	○	●	○	○	○	○	○	unattractive	24
friendly	○	●	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	●	○	○	innovative	26

I.9 Tester Nr. 9

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	○	●	enjoyable	1
not understandable	○	○	○	○	○	●	○	understandable	2
creative	○	●	○	○	○	○	○	dull	3
easy to learn	●	○	○	○	○	○	○	difficult to learn	4
valuable	○	●	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	●	○	exciting	6
not interesting	○	○	○	○	○	●	○	interesting	7
unpredictable	○	○	○	○	○	●	○	predictable	8
fast	●	○	○	○	○	○	○	slow	9
inventive	○	○	●	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	●	○	supportive	11
good	○	●	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	●	○	easy	13
unlikable	○	○	○	○	○	○	●	pleasing	14
usual	○	○	○	○	●	○	○	leading edge	15
unpleasant	○	○	○	○	○	●	○	pleasant	16
secure	●	○	○	○	○	○	○	not secure	17
motivating	●	○	○	○	○	○	○	demotivating	18
meets expectations	●	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	●	○	efficient	20
clear	○	●	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	●	practical	22
organized	●	○	○	○	○	○	○	cluttered	23
attractive	●	○	○	○	○	○	○	unattractive	24
friendly	○	●	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	●	○	innovative	26

I.10 Tester Nr. 10

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	○	●	enjoyable	1
not understandable	○	○	○	○	○	●	○	understandable	2
creative	○	●	○	○	○	○	○	dull	3
easy to learn	○	●	○	○	○	○	○	difficult to learn	4
valuable	○	●	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	●	○	exciting	6
not interesting	○	○	○	○	○	●	○	interesting	7
unpredictable	○	○	○	○	○	●	○	predictable	8
fast	●	○	○	○	○	○	○	slow	9
inventive	○	○	●	○	○	○	○	conventional	10
obstructive	○	○	○	○	●	○	○	supportive	11
good	○	●	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	●	○	easy	13
unlikable	○	○	○	○	○	●	○	pleasing	14
usual	○	○	○	○	●	○	○	leading edge	15
unpleasant	○	○	○	○	○	●	○	pleasant	16
secure	●	○	○	○	○	○	○	not secure	17
motivating	●	○	○	○	○	○	○	demotivating	18
meets expectations	●	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	●	○	efficient	20
clear	●	○	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	●	practical	22
organized	●	○	○	○	○	○	○	cluttered	23
attractive	●	○	○	○	○	○	○	unattractive	24
friendly	○	●	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	●	○	innovative	26

I.11 Tester Nr. 11

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	●	○	enjoyable	1
not understandable	○	○	○	○	○	○	●	understandable	2
creative	●	○	○	○	○	○	○	dull	3
easy to learn	●	○	○	○	○	○	○	difficult to learn	4
valuable	●	○	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	●	exciting	6
not interesting	○	○	○	○	○	○	●	interesting	7
unpredictable	○	○	○	○	○	○	●	predictable	8
fast	●	○	○	○	○	○	○	slow	9
inventive	●	○	○	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	○	●	supportive	11
good	●	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	●	easy	13
unlikable	○	○	○	○	○	○	●	pleasing	14
usual	○	○	○	○	○	●	○	leading edge	15
unpleasant	○	○	○	○	○	○	●	pleasant	16
secure	●	○	○	○	○	○	○	not secure	17
motivating	●	○	○	○	○	○	○	demotivating	18
meets expectations	●	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	●	efficient	20
clear	●	○	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	●	practical	22
organized	●	○	○	○	○	○	○	cluttered	23
attractive	●	○	○	○	○	○	○	unattractive	24
friendly	●	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	○	●	innovative	26