FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

HealthTalks - a mobile app to recognize medical speech

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Abstract

An individual's health condition depends on themselves and their health professional, but both can be unreliable. A person's health literacy, which is their ability to obtain and use health information, has a direct impact on their health; yet half of the Portuguese population has problematic or inadequate levels of health literacy. A patient's ability to seek health information is sometimes flawed, as is their personal health information management proficiency, which may lead them to drop treatments. A patient's relationship with their physician may also be ineffective, either due to the patient second-guessing the latter's recommendations, misinterpreting their assertions, or due to the doctor's limited communication skills. Ultimately, there are several possible hindrances to a good healthcare.

Technology has the potential to change people's lives, and that is what we want to accomplish with HealthTalks by tackling some of the outlined problems. It will be a mobile app that will record a consultation, transcribe it, and allow those files to be easily managed. In the transcriptions, all the medical terms will be highlighted and defined so that the patient may be better informed on their health situation. At the same time, we intend to have a better grasp on the patient's personal health information management methods and their relationship with their physicians through an inquiry at a regional level. The app itself will also be evaluated throughout the development, both in terms of usability and accuracy when transcribing medical speech.

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Abbreviations

API	Application Programming Interface
ASR	Automatic Speech Recognition
CES	Comissão de Ética para a Saúde (Health Ethics Committee)
CHSJ	Centro Hospitalar São João (São João Hospital Center)
CISTI	Conferência Ibérica de Sistemas e Tecnologias de Informação (Iberian Conference on Information Systems and Technologies)
DSIE	Doctoral Symposium on Informatics Engineering
EU	European Union
FEUP	Faculdade de Engenharia da Universidade do Porto (Engineering Faculty of the University of Porto)
HMM	Hidden Markov Model
MIEIC	Mestrado Integrado em Engenharia Informática e Computação (Integrated Masters in Informatics and Computing Engineering)
ODPHP	Office of Disease Prevention and Health Promotion
PDIS	Preparação da Dissertação (Dissertation Planning)
PHIM	Personal Health Information Management
PIM	Personal Information Management
STT	Speech-to-text
UC	Use case
US	User story
USA	United States of America

Chapter 1

Introduction

Every individual has the right to proper healthcare, which is the responsibility not only of the healthcare institutions and professionals, but also of oneself. People are expected to take care of themselves and others, but what can be done when they do not have the appropriate skills to do it? The goal of this thesis is to explain why HealthTalks would be an effective method of helping people in those situations.

1.1 Context

First of all, it is important to understand that an individual's health literacy affects their ability to understand health information and act on it to maintain or improve their quality of life [SVF+12]. This means that, without an appropriate level of health literacy, a person might not be able to efficiently seek health information or manage their personal health information correctly. This, in turn, may result in the individual not taking good care of their own and their family's health.

Alas, health literacy levels are not universally high. In Portugal, for example, only around half of the population had sufficient or excellent general health literacy levels in 2014 [EÁM15]. A logical conclusion would be to turn to physicians in order to surpass that problem, since it is their responsibility to inform and treat their patients. However, the doctor-patient relationship is not always optimal, leading sometimes to miscommunication and lack of trust to confide crucial information [PR00].

Another alternative would be using health technologies to complement the patient's self-care skills. Those can range from health information systems that try to contextualise the patient's health concerns, to personal health information management systems that can be used to better organise and retrieve information concerning someone's health conditions.

Even though the use of technology not always results in better information management, it can do so if kept moderately simple [Jon07]. It is also believed that it can be an informing tool both by exposing data in simple and engaging ways [FF03], as well as by fostering learning through assimilation [LGF+15].

1.2 Motivation and Goals

There are several technologies available to solve the problems outlined in Section 1.1, but they tend to have a narrow focus, specialising in niches or particular health fields. Few are adapted to more realistic and holistic scenarios, such as when a user handles different types of health information, from calories and weight, to blood analysis results and medical treatments. Furthermore, the functionalities are often restrictive, having a lower value for the user due to the lack of customisation and limited potential for innovative uses.

HealthTalks is our solution to tackle those issues, hopefully resulting in a better healthcare for everyone, but especially the individuals with lower health literacy. It is a health information tool that gives contextual definitions of the medical terms most relevant to each user, while also functioning as a personal health information management system by enabling the storage, organization and access to data related to past medical appointments.

HealthTalks' premise relies on the recording of consultations through a mobile app. The resulting audio files will be saved in the app and incorporated in a consultation page. Each page will correspond to one recording and will display that recording's transcription. It will also provide several customisable fields such as its name, the patient involved, the doctor who gave the consultation, their medical speciality, and where it happened. The user can also mark a consultation as a favourite, in case it is important. All those fields, in tandem with the date of the recording, can be used to organise and search for a specific consultation at a later date. All these functionalities will create a robust personal health information system while simultaneously requiring little effort from the user, since the consultation is automatically transcribed and they only have to categorise it.

However, we aim at making a health information app as well, in order to better inform the patient of their conditions. This will be achieved by highlighting the medical terms in each consultation's transcription and providing optional definitions for each, in case the user wants to learn more about them.

By tackling both health information seeking and personal health information management, keeping the app generic so that it can be used in different healthcare fields, supplying optional definitions of medical terms, and providing flexibility to the users through customisability, we hope to contribute to better self-care practices in a way that has not been done before.

1.3 Report Structure

This report is divided in four main chapters. In Chapter 2, we focus on health literacy: what it is, why it matters, what are the levels of health literacy in the population, and what can be done to improve those levels.

Chapter 3 focus on the acquisition and management of health information by the patient. We start by analysing their relationship with the physician, while explaining its relevance and how one could improve it. Then we tackle the health information seeking process, which is about how patients retrieve health information and how efficient they are at doing it. At the end of the chapter we tackle personal information management and, more specifically, personal health information management. We debate on what it entails exactly, while explaining its benefits and shortcomings.

Chapter 4 focuses on technological solutions applied to healthcare. We start by giving an introduction to speech recognition, from its history to the basic workings behind it, and progress to broader mobile applications. In that section, we focus on 5 specific ones that we perceive as having a particular significance due to their uniqueness or functionalities.

In Chapter 5 we introduce HealthTalks: we explain what we plan to develop and how we will manage to do it, while also focusing on the research aspect of this thesis and the ethical and security issues that may arise from this product.

Chapter 6 entails the software requirements for HealthTalks, including requirements, personas and user stories. Those aspects enable us to have a better perspective on the solution, which means we can start working on it more aware of its goals and functions.

Finally, in Chapter 7 we make a brief summary of the work we have done so far and what we plan to do in the next few months.

Chapter 2

Health Literacy

Health literacy is a term introduced in the 1970s that has been increasingly valued by governments and researchers worldwide, as evidenced by the creation of more programs and systems to improve it, as well as more research and studies on its sources and consequences [SVF+12]. In this chapter we explain what it entails and why it matters.

2.1 Definition

Different definitions for health literacy have been proposed over the years. Hur et al. [HLS15] define it as an understanding of basic medical information, but we can go farther and maintain that it also entails the ability to seek, process, and interpret basic medical information in order to get proper treatment [KGJ+06]. Sørensen et al. [SVF+12] corroborate that concept by defending that it empowers an individual to think and act upon their healthcare in order to maintain or improve their quality of life. From that statement one can deduce that it is an important skill regardless of an individual being ill, at risk, or just wanting to stay healthy.

The concept of health literacy has shifted in recent years, with some studies claiming that it is also affected by factors external to the individual. In fact, Heijmans et al. [HUR+15] emphasise that an individual's social support system, such as their family and community, and their context (e.g. the healthcare system in their country), are also important in shaping their health literacy.

Osborne [Osb13] refers yet another component: the ability to convey a health-related message. In her view, the communication skills of a person contribute to their and other's health literacy, which means that one's level of health literacy might affect the message they convey and, hence, the ease of understanding by others. Health knowledge or proficiency is sometimes said to be itself yet another component of health literacy, in addition to the perception of new information already mentioned [Bak06].

It can be therefore inferred that health literacy is not confined to a simple understanding of terms and their meanings, but rather a complex web of interacting components such as knowledge, interpretation, critical thinking, communication, and decision-making, as well as the individual's social network and context. To add to that, other factors such as a person's attitude and willingness to take care of their health may influence their health literacy, even if not inherently part of its definition [HUR+15]. A conceptual model of the different elements often associated with health literacy can be seen in Figure 2.1.

The fact that so many distinct interpretations of the concept exist makes it troublesome to properly evaluate and compare health literacy levels measured in different studies, since they may rely on different definitions. Not only that, but if a definition of health literacy includes the context of the subject, then measuring it becomes a much more demanding task, since it cannot be assessed by looking exclusively at the subject's personal data [Bak06].

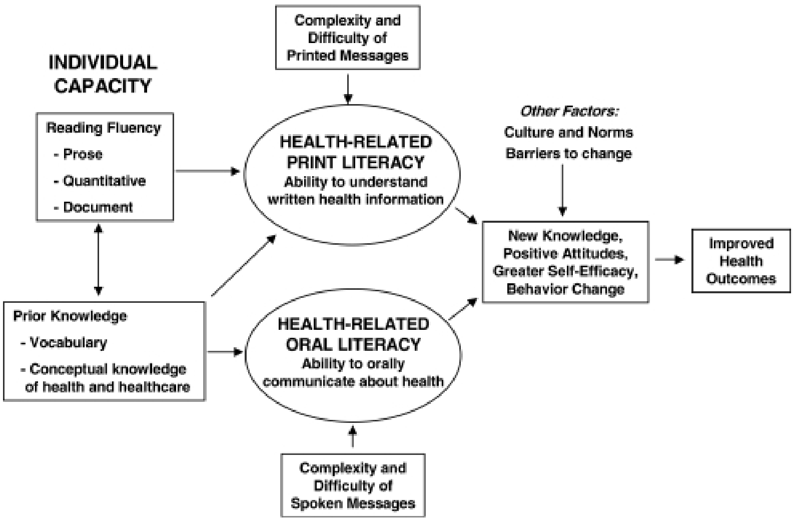

Figure 2.1: "Conceptual model of the relationship between individual capacities, health-related print and oral literacy, and health outcomes." [Bak06]

2.2 Importance

The level of someone's health literacy influences their health behaviours and health conditions [HLS15]. If someone has lower levels of health literacy, they are less likely to understand the importance of preventing illnesses by eating healthily, exercising, and caring for themselves, which may lead to health problems such as obesity, diabetes and heart disease [Car06]. Moreover, they are less likely to get preventive care and more likely to have treatment delays, which results in them going to emergency rooms with more severe symptoms [HLS15]. When getting professional care, individuals with low health literacy are also more vulnerable to misinterpreting their health professional [Car06] and medication instructions [HLS15], which in turn may result in inadequate treatments and self-care.

In summary, higher levels of health literacy have been linked to improved health conditions, reduced costs of healthcare, and reduced use of healthcare services [HUR+15; HLS15; Off16]. By the same token, lower health literacy standings are associated with less knowledge of illnesses and inadequacy in negotiating the healthcare system [JBO10]. In 2006, Carmona [Car06] referred to the unsatisfactory level of health literacy in the United States of America (USA) as a crisis and a national priority due to its impact in every citizen's lives. This has also been referred to as the "health literacy epidemic" by Sørensen et al. [SVF+12].

2.3 Current Situation

Health literacy levels vary according to several demographic variables. Older adults, racial and ethnic minorities, less educated people, poorer people, non-native speakers, and people with weakened health are the most likely to have lower levels of health literacy in the USA [Off16]. But there is evidence of similar statistics in Portugal, being that older people and people with lower levels of education manifest lower levels of health literacy as well [EÁM15].

As can be seen in Figure 2.2, more than a third of Americans had "basic" or "below basic" levels of health literacy in 2003, with the majority of the country having at least an intermediate level. An European Union (EU) study also divides literacy in 4 proficiency groups, from inadequate to excellent. In those statistics, shown in Figure 2.3, Portugal is in 6th place among the 9 countries considered, with almost half of its population presenting "problematic" or "inadequate" levels of health literacy, slightly higher than EU's average of 47,6%. By contrast, the Netherlands has 28,7% of its population with those same levels of health literacy, placing it at the top of the list with the highest levels of health literacy in the considered sampled. However, it is important to note that a direct comparison between the USA and EU studies cannot be made, firstly because their nomenclature for each health literacy level is different, and secondly due to the reasons explained in Section 2.1 related to the absence of a universal definition for the term "health literacy".

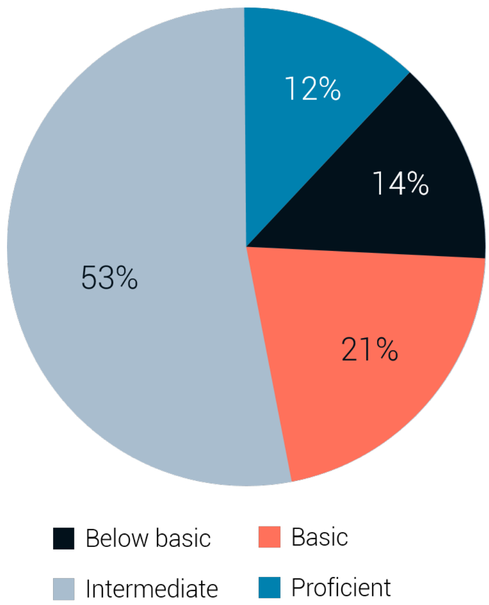

Figure 2.2: Levels of health literacy in the USA in 2003. [Off08]

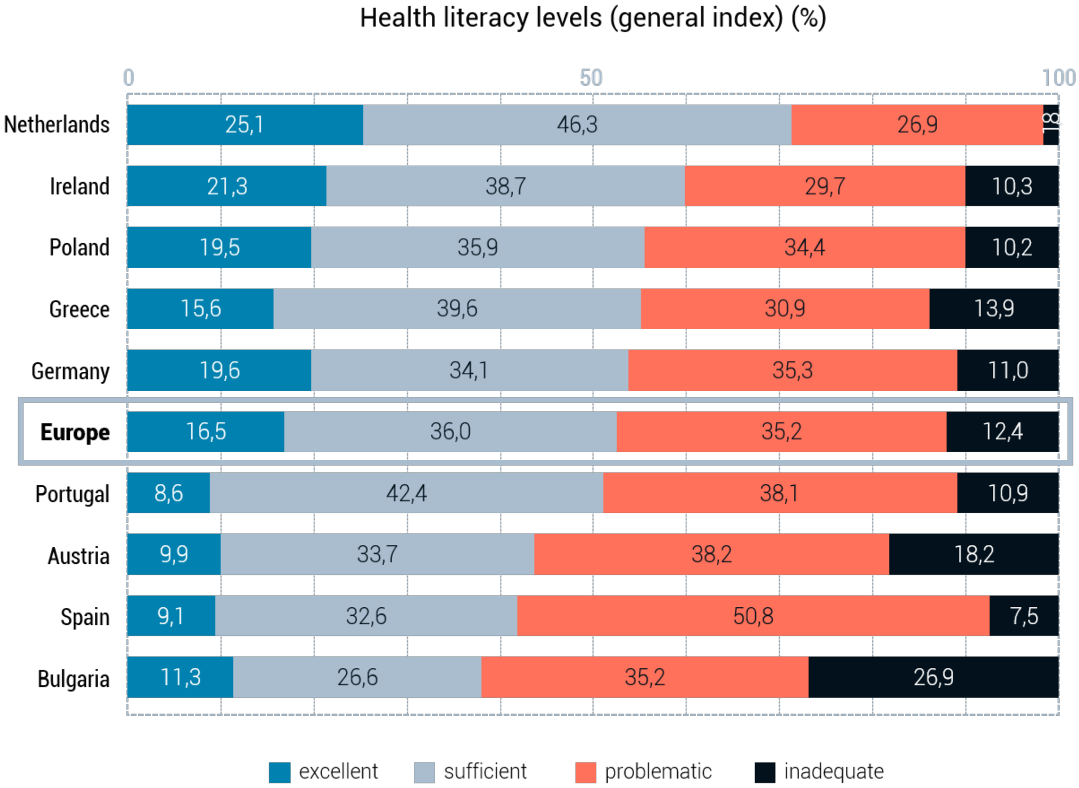

Figure 2.3: Levels of general health literacy in Portugal in 2014, other select EU countries in 2011, and their average. [EÁM15]

2.3.1 Measures to Improve Health Literacy

The American Medical Association established a list of actions that should be taken in order to improve health literacy levels: evaluate current health literacy levels, improve communication with low-literacy patients, study the consequences of a low level of health literacy, and investigate the causality between a person's poor health literacy and their health condition [SVF+12]. These approaches would give a more in-depth knowledge and understanding of health literacy and its ramifications, which in turn might give clues on how to tackle it on a larger scale.

In Portugal, both the 2011-2016 and the 2016-2020 National Health Plans mention health literacy, the latter promoting it at both national and regional levels. The strategies outlined propose getting the citizens engaged in health institutions and systems in order to improve their health literacy. On top of that, the Portuguese Department of Health Promotion and Prevention of Non-transmittable Diseases divulges prevention and control methods for chronic diseases, and cooperates with the Portuguese National Health System in a collaborative research lab that regularly publishes information regarding disease prevention and health promotion. The Calouste Gulbenkian Foundation also tackles these issues by having a fund specifically for researching and promoting health literacy, targeting particular segments of the population (such as low-education, elders, or prisoners) and health conditions (like diabetes type 2 and obesity in adolescence) [HUR+15].

“Literacia para a Saúde” is a platform maintained by the Lusophone Network to Promote Health Literacy, a result of the cooperation between Portugal and Brazil, to gauge the adequacy of existing models of evaluating and promoting health literacy in the context of these two countries [Red17].

2.4 Prospective Developments

Even though it affects mostly the patients, it is the public health professionals who are responsible for promoting health literacy, according to the Office of Disease Prevention and Health Promotion (ODPHP) [Off16]. They also add that educators should reach out to adults with limited literacy skills, while never neglecting accessibility in health information and services.

The ODPHP [Off08] also defends the creation of guidelines for information access and design, so that that the term “accessible health information” can be defined and adhered to, making the information universally available. The health information materials should be regularly tested with consumers and designed in such a way that their health literacy does not substantially affect their understanding of the contents. The ODPHP also highlights the importance of increasing the communication skill requirements both in secondary education and graduate schools in order to improve the communication between health consumers and professionals.

There are several different types of technologies with the purpose of helping users change their behaviour, make decisions or learn. Their accessibility, manifested in ways such as the simplicity of making an appointment or taking the appropriate time to answer e-mails or phone calls, is an important factor for their success [HLS15]. Moreover, Hur et al. [HLS15] also argue that comprehensibility (through the use of low level English, for example) is more important for explicit knowledge learning than specific technical features.

There is a stark difference in the use of health literacy technologies between young and old users. While the former respond best to engaging technologies (such as online gamification experiences, videogames and other multimedia), the latter rely on diverse sources of information and tend to favour smartphones and iPads due to their versatility to do other things (communicate with healthcare providers, discuss issues, being entertained, etc.). One of the most important aspects of health literacy technologies for this age segment is its ease of use. [HLS15].

2.5 Summary

Even though health literacy is not a recent concept, its meaning and nuances have evolved over time. At the moment it is widely believed that it is a skill that involves the ability of an individual to acquire and understand health information, as well as putting it to proper use on themselves and their communities. However, as more attention is directed toward this area, new studies may expand the concept even further.

The reality of health literacy in Portugal may not be very encouraging, since almost half of the population has problematic or inadequate levels of health literacy, but several organisations, both governmental and independent, have proposed measures and are developing studies in order to better understand and improve health literacy. The same is happening in the USA, though their health literacy levels seem to be higher than most EU countries'.

Health literacy technologies should be adapted to their target audience, especially in regards to age groups. While younger users opt for more involving technologies, the elderly give more importance to the versatility and communication capability of mobile devices.

Chapter 3

Patients and Health Information

Health information refers to all the information pertaining to an individual's fitness and well-being that enables them to live a healthy life. It can be acquired in many ways, from a doctor in a consultation, to online search, or specialised media. In this chapter we will analyse the concepts behind health information, its relevance, what may hinder its access, and what means exist to help people finding and keeping it.

3.1 Doctor-Patient Relationship

The doctor-patient relationship has been changing since the second half of the twentieth century from a unilateral exchange in which the physician is the sole contributor, to a more reciprocal, decision-making or relationship-centred exchange [LB14; Aro03]. This emphasis on the health consumer changes the dynamics of the relationship between them and their health professionals. The latter may be unprepared to deal with information found by the health consumers, leading to stressful and frustrating consultations where they have to correct their patients. The second-guessing and questioning of their practitioners may also be seen as a reflection of the patients' diminished trust in them [CH01]. Arora [Aro03], however, advocates that better informed patients will have better health outcomes, use healthcare resources more appropriately, and have better relationships with their health professionals. Fox and Fallows [FF03] endorse both of those theories, asserting that patients who use the Internet to seek information report different — though not always better — relationships with their physicians, depending on the receptivity of the latter to Internet search.

Several studies have shown that a caring, compassionate, respectful, and trusting physician-patient relationship helps cancer patients adjust better to their situation. Its importance may even lead doctors to acquiesce to inappropriate requests from the patients in order not to weaken their bond [Aro03].

3.1.1 Trust

In the realm of physician-patient relationships, trust can have different meanings. Some argue that it refers to the patients' assumptions on how their clinician will behave, whereas others see it as the patient's vote of confidence on the doctor's good intentions. Some people describe their trust as the result of the physician's competence, compassion, privacy, confidentiality, reliability, dependability, honesty, and communication [PR00]. A trusting relationship is beneficial to the patient, since it increases their prospect of treatment compliance [PR00]

With health information so easily available online, double-checking what a doctor says is much more common than before. In fact, 84% of patients verify the veracity of their physician's assertions after an appointment [Lau16]. The information they find may jeopardise their trust in their doctors, which may be misguided since the health information seeking capabilities of the patients are not always accurate (see Section 3.2 for more information on that).

Regardless, any account of a patient's trust on a physician has to take into account not only the interpersonal trust between them, but also the patient's social trust in collective health institutions, which may be influenced by the media and social bias [PR00].

3.1.2 Communication

Regardless of how a physician perceives Internet health information, they should develop their communication skills in order to debate it with the patient [MLP+03]. Moreover, they should listen to the patient's account without interrupting them, so that the patient can establish their identity and develop a stronger relationship with their physician. By not disturbing the narrative, the physician can also understand the patient's experience better, which will lead to a better treatment [Aro03]. But they should not shy away from asking questions either, since the patients will often omit information like their concerns and feelings that, unbeknownst to them, may be important to their healthcare [Aro03].

In a 1993 study involving 97 women with breast cancer, 49.5% of them had difficulty understanding their clinicians [Aro03]. Moreover, health professionals have been shown to underestimate the amount of information wanted by the patients and their understanding of information they receive, while overestimating the amount of information they share with the patients [HL10].

3.1.3 Improving the Relationship

The onus of improving the physician-patient relationship relies on the former. To do it, they have to address the patient's concerns, ensure that they understand the information given, and be affectionate. The shared decision-making process hinges on the health professional showing openness to the patient's contributions and opinions, as well as sharing responsibility and control in the choice of treatments [Aro03].

Personalised social network systems and social dialogue systems have been shown to improve the physician-patient relationship and the latter's health knowledge. Discussion between both through technology is therefore an effective knowledge transfer tool and enables patients to better understand their medical conditions [HLS15].

3.2 Health Information Seeking

Health consumers want access to health information, being particularly fond of visual methods such as health videos with simple language that explain their health conditions [Lau16]. But even though around one in every 20 Google searches are healthcare-related [Lau16], not all consumers can successfully retrieve health information from them [FF03]. The low health literacy of the users and the use of different terminologies between them and their doctors (who may use more medical jargon) results in them not always finding the answers they want [Sou16]. Also, health information on the Internet may be inaccurate, misleading, or misinterpreted, which may result in patients making inappropriate clinical requests to their doctors [MLP+03].

Murray et al. [MLP+03] also point out that health information on the Internet could be a great health equalizer if everyone had the same access to it. However, when the access, processing, and application of information is skewed towards the higher socio-economic groups, then it widens the gap between them and the more vulnerable individuals. The improvement of an individual's health information seeking capabilities is directly linked to their health literacy levels, as explained in Chapter 2. According to Murray et al. [MLP+03], improving the health information retrieving skills of the population should result from a combination of government and private efforts to teach information search and assessment skills. Those are also in line with the measures analysed in the aforementioned chapter.

The Internet seems to be an important factor in improving the health information and services patients receive [FF03]. However, they can also get the information they need from other people. In Section 3.1 we described the interactions between health professionals and patients but, when a health concern involves personal issues related to the endurance of a health problem or fast relief, patients tend to prefer non-professional contacts such as fellow patients, friends and family [Fox11]. This links again to Chapter 2, where the connections between communities, health literacy, and health information acquisition are explained in detail.

3.3 Personal Information Management

In the context of this work, the term "personal information" conveys the type of information an individual keeps for their personal use. According to Jones [Jon07], personal information management (PIM) may be defined by the acquisition, creation, storage, organisation, maintaining, retrieval, use, and distribution of information needed to complete certain tasks. However, he mentions that other definitions may include the person's methods for acquiring, organising, storing, and retrieving information. What all definitions have in common is the focus on how the information is arranged in order to be easier to find.

The main reason for the use of PIM methods is being able to check any information we might need during certain situations that may demand it. By using tools, technologies and techniques to help us spend less time with information management tasks, we gain more time to use that information smartly and innovatively for its intended purpose, as well as more free time for ourselves [Jon07].

The process of finding previously experienced personal information starts by recognising the necessity of looking for the information, followed by recalling details that allow the identification of the intended piece of information, recognising it, and repeating the process until all the necessary data is retrieved [Jon07]. Each of those steps is susceptible to failures, among which are information decentralisation (due to being spread across different locations, devices, forms, and associated institutions); the lack of foresight to know when and where to register information; the forgetfulness of previously stored information; and the bewilderment when confronted with information with an unfamiliar jargon or of extensive volume [PUC+06].

The concept of PIM is used in several fields, including healthcare, since consumers need ways of managing the health information they possess. However, generic PIM tools may not support personal health information management (PHIM) requirements such as grouping information according to the corresponding phase of treatment (e.g. surgery or therapy) [PUC+06].

3.3.1 Applicability in Healthcare

Taking notes on paper is probably one of the oldest forms of managing information, but its flaws have long been recognised. Thankfully, the increasing interest in PIM methods and technologies has been prolific in creating new solutions [TJB06], even though some might increase the overall complexity of PIM by adding extraneous features that may difficult their use, as well as leading to information fragmentation [Jon07]. In healthcare, PHIM methods sometimes fail due to human error such as failing to record information correctly, or making mistakes and omissions when taking notes some time after a consultation [Gur12].

Regardless of where the technologies take us, it is the belief of Robinson et al. [RPE+98] that the health professionals' response to them are crucial to their adoption. They should make an effort to understand new methods, validate them and contribute to their use by the patients. Otherwise, they could suffer without the knowledge and guidance the technologies could bring.

3.4 Summary

A patient can acquire information from different ways: their doctors, their community, and other sources such as the Internet. None of them are flawless: the doctors may not relay all the information they possess nor do it in layman's terms; the community's ability to help is directly linked to their health literacy levels; and the Internet is not always a trustworthy source of information.

Even when the patient successfully gains new health information, they have to manage it correctly in order to enable them to quickly retrieve it at a later date. That system of organisation is called personal health information management, and usually fails due to human errors, but its application in technology has not been perfect either. A crucial point for the technologies to be accepted is the physician's response to them.

Chapter 4

Technology in Healthcare

4.1 Speech Recognition

Automatic speech recognition (ASR), often referred solely as speech recognition, refers to a process in which the voice of a human is heard through a microphone and subsequently examined in order to recognise every spoken word [RM13]. It encapsulates two different fields in itself: the acoustic model, which identifies language units such as phonemes present in the audio input; and the language model, which associates a probability to each word in the dictionary in order to better determine what is being said in each situation. Speech recognition systems have been used for several years and can have different uses, from dictation, to automated translations, or voice interfaces. When a speech recognition program is used to transcribe human speech, it can be called speech-to-text (STT).

There are several aspects that may limit the effectiveness of an ASR system. Gur [Gur12] points out that spoken language is more unintelligible than dictated language due to differences in the proximity to the microphone and succinctness; quieter backgrounds help the the software better understand the speaker; some programs may learn from past experiences and hence be more adapted to specific speaking patterns and accents; and many ASR solutions do not differentiate between speakers, which is not ideal in a conversational scenario.

According to Reddy and Mahender [RM13], the process of recognising human speech is composed of 4 interconnected procedures:

1. Feature extraction, a method of creating evenly distributed discrete vectors of speech characteristics (called observations) from the sample audio;

2. Acoustic models database, a collection of recognisable vectors gathered from the training data which is compared against the extracted vectors in order to identify the sounds being made;

3. Dictionary, which makes the connection between the acoustic models identified in the speech with human vocabulary in the chosen language; and

4. Language model, a component responsible for checking the list of words that may match the speech in order to select the most likely to have been said according to context, grammatical rules, and statistical information.

The most noticeable difference between speech recognition systems lies in the speech recognition algorithm used. Modern ASR solutions use hidden Markov Models (HMM), which Rabiner and Juang [RJ86] define as "a doubly stochastic process with an underlying stochastic process that is *not* observable (it is hidden), but can only be observed through another set of stochastic processes that produce the sequence of observed symbols". They give the example of a hidden coin toss, in which the observer does not know how many coins are being tossed, or any other component of the experiment; they only have access to the result of the total coin tosses (head or tails) and, from that data alone, have to explain how those were obtained. The simplest solution would be a fair coin model, in which the coins used are balanced, there are two possible states for each, and each state correlates to a specific result (head or tails). However, several different models could have been used to obtain the same statistical results, ranging from different coin balances, to a different number of coins, or more complex states. The HMM are labelled as "hidden" exactly because the analysis is made without full knowledge of the data-gathering conditions, and therefore heavily rely on the amount of model training data given.

Hidden Markov Models are widely used in speech recognition because each speech signal can be interpreted as a stochastic process. Each word in the system's dictionary is modelled by a different HMM, and the algorithm can then automatically train with a small data set [RJ93]. However, other techniques have been emerging, such as neural networks and, most recently, end-to-end ASR. Neural networks have been successfully paired with HMM methodologies in the tandem speech recognition system by applying discriminative feature processing before the HMM's Gaussian-mixture distribution modelling [HES00], and also by reducing the dimensions of complex data while preserving its characteristics [HZ10], diminishing the error rates of pure HMM models. End-to-end ASR does not combine neural networks methodologies with existing HMM systems like the previous examples; instead, it uses a recurrent neural network exclusively. Its biggest shortcoming is its reliance on an extra language model to correct the output, since it often presents spelling mistakes [GJ14].

4.1.1 History

Automatic speech recognition has been the culmination of centuries-long conceptualisation and technological advances. It can be argued that it started in the XIX century, when Alexander Graham Bell, Chichester Bell and Charles Summer Tainter created a machine that would record human speech in a wax-covered cylinder with grooves, which would later evolve into the "dictaphone". This product was commercialised as a way of recording dictations from white-collar workers which could later be heard and transcribed by secretaries, reducing the costs of hiring stenographers [JR04]. Even though there was no actual ASR involved, this kind of dictation device illustrates how the automation needs felt more than a hundred years ago led to technological breakthroughs in that field.

The first ASR system was created in 1952 by Davis, Biddulph, and Balashek of Bell Laboratories; their solution recognised isolated digits according to the frequencies of the recorded voice. Other similar solutions such as vowel recognisers emerged in that decade; however, none of them were on-par with current ASR standards since they were all configured to receive only one digit or vowel at a time. The first system that used a speech segmenter to analyse the type of input was developed by Sakai and Doshita in 1962. Just a few years before, in 1959, Fry and Denes created the first system that used statistical data to determine allowable phoneme sequences according to the rules of the English language [JR04]. Both of these studies ended up shaping the design of modern ASR systems.

In the 60's and 70's, influential science fiction films such as "2001: A Space Odyssey" (1968) and the "Star Wars" original trilogy (1977-1983) revitalised the interest in ASR. They both showed automated entities capable of full ASR and speech modulation, highlighting the potential benefits of such systems [JR04].

In the 1980's, the ASR vision changed to a more statistical modelling system instead of a template-based one, and the hidden Markov Model (explained in Section 4.1) gained prominence in the field. Neural networks were also introduced in ASR technologies around the same time [JR04].

More recently, call centres' interest in recognising the department to which a call should be redirected led them to create an ASR solution that would do just that. AT&T's Voice Recognition Call Processing, for example, was introduced in 1992 and currently handles around 1.2 billion calls per year. This and other similar solutions were only possible because great progress in ASR technologies was made during that decade, as systems became more sophisticated and able to handle more processing power and data [JR04].

Nowadays, speech recognition exists in several different ways around us, from simple transcription and translating applications, to intelligent home assistants such as Amazon Echo or Google Assistant.

4.1.2 Applicability in Healthcare

The use of a speech interface in healthcare may help eliminate spelling mistakes, alternative spellings, and abbreviations that could cause confusion due to the specificity and complexity of medical jargon [LTH+11]. It also helps people who type slower by automating that job and increasing their efficiency [JLL+14].

Several studies have been made in regards to the applicability of speech recognition technology in healthcare [Gur12; LTH+11; Rod13; FAR+13; Lob13; PKS04; SZH+15]. Their scopes are extremely varied, from apps that support the elderly, to real-time translations during medical interviews, clinical handover aids, or health advisors. Despite the diverse scopes, some conclusions can be drawn from those projects.

First of all, ASR makes less grammatical errors than humans when writing transcriptions, even though it is not as accurate overall; it is cost effective and significantly improves patient outcomes such as turnaround times [JLL+14].

Devine et al. [DGC00] compared, in 2000, three different products: IMB ViaVoice 98 (discontinued since then), Dragon Systems NaturallySpeaking, and L&H Voice Xpress. Their results show the IBM solution had the lowest mean error rate for vocabulary recognition, at 7 to 9.1%, for general English vocabulary, medical abbreviations, and numbers. However, those trials were made by reading a script, so naturally occurring speech characteristics (such as hesitations, filler sounds, etc.) were not taken into account.

On the other hand, Liu et al. [LTH+11] did a similar study in 2011, focused on spoken clinical questions. To that effect, they used Nuance Dragon Gen and SRI Gen, both generic versions of ASR solutions; as well as Nuance Med, a medical version of the first solution. They also modified the SRI solution through a language model approach, calling the result SRI Adapted, which was developed specifically to better recognise medical speech. Their conclusions were that none of the original systems performed well with the clinical questions they were given. The best was SRI, with a 41.5% error rate. However, SRI adapted had an error rate of 26.7%, significantly better than its unmodified version. A good example on how the two differed is the term "Paget's disease". While the second word is present in all dictionaries, the first one is usually misinterpreted due to its specificity to the medical field. Since SRI Adapted was given a domain-specific adaptation, it was configured to recognise the first word based on the successful interpretation of the second word.

It is important to notice that the considerable discrepancies between the results of both those studies can be attributed to different definitions of error rates. For Liu et al. [LTH+11], the error rate is the "report [of] the sum of substitution, insertion, and deletion errors (referred to collectively as word error rates (WER), an established metric for evaluating speech-recognition systems)". On the other hand, Devine et al. [DGC00] only considered substitution and deletion when considering their error rates. That may help understand the significant disparities between the results achieved in both studies.

4.2 Mobile Applications

Nowadays there are several technologies that try to negate the adverse effects of a low health literacy, bad physician-patient relationships, and inadequate PHIM. Not all at-risk groups are equally represented in the app market though, as can be seen in Figure 4.1.

Even though healthcare apps tend to be well received by physicians and patients alike, methods to evaluate them are lacking. Often doctors are hesitant to recommend a specific app and health consumers have to rely on the app's rating, which may not be representative of the app's quality but rather of other users' experiences with it, which is a subjective metric [SDN+16]. Singh et al. [SDN+16] also noticed other problems with most apps: most are not secure, one third don't inform their users on privacy issues, and many are often conceived as a paper alternative, which means that they don't react to irregular input such as levels of blood sugar above the recommended amount, for example, nor do they encourage the user to engage in healthy behaviours [Bro16].

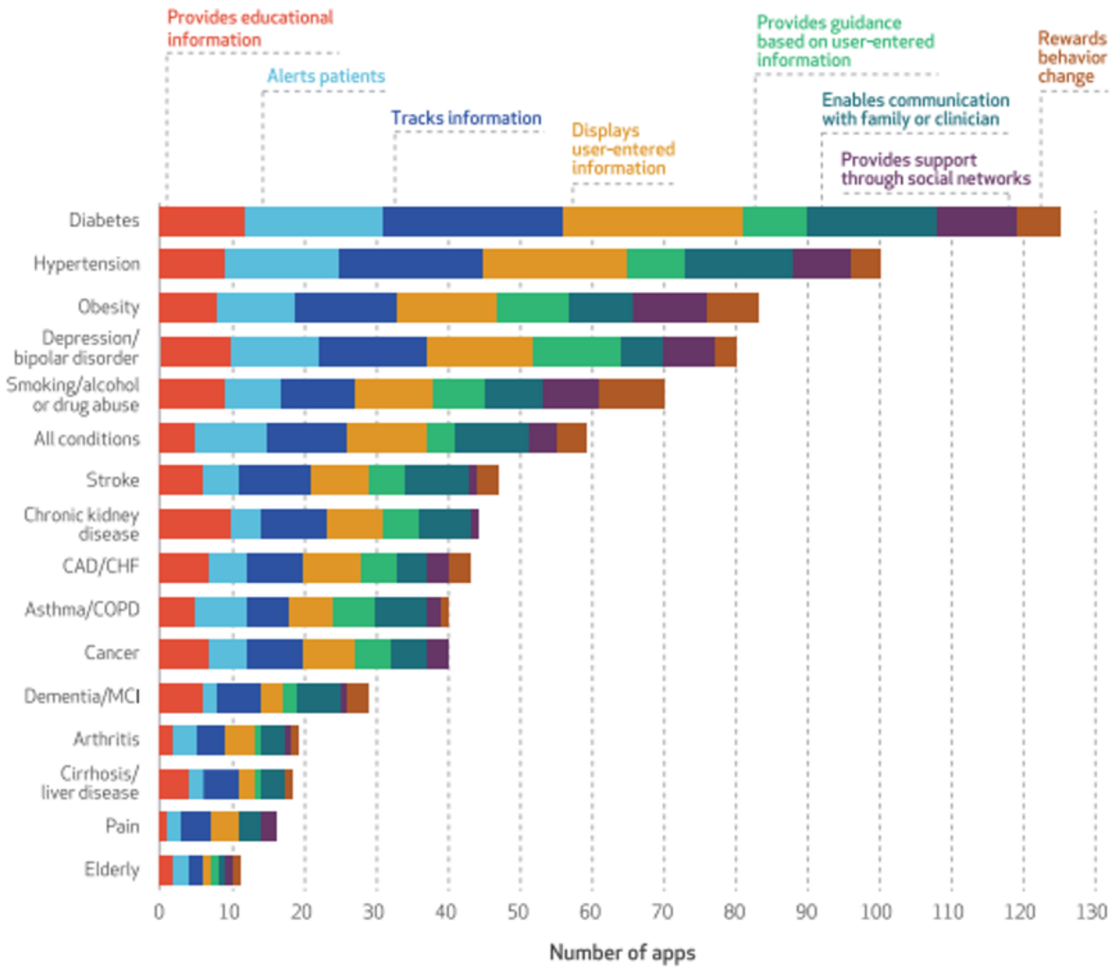

Figure 4.1: "Patient engagement–related functionalities of selected [mobile health-related] apps, by high-need, high-cost population, 2014–15." [SDN+16]

4.2.1 MyFitnessPal

MyFitnessPal [MyF17] is both a Web and mobile app for iOS and Android. It is free to use, but includes in-app purchases of 0,79 Euro up to 56,20 Euro. It is very widespread, with more than 50 million downloads. Its popularity might have to do with its compatibility with external devices such as smartbands and complementary apps, which make this app a more versatile choice and more inclusive of different user groups.

Its functionalities are mostly based on calorie counting, both the ingested calories through detailed logs of food consumption, and the spent calories by means of an exercise calculator and instigator. A study by Luna et al. [LGF+15] discovered that a group of people questioned before and after using this app for 15 days actually learned information that is shown passively in the menus. The subjects recognised with much more ease the families to which certain food products belonged to after using the app, and that information is shown in the screen associated with each food product when the user is listing their calorie consumption habits. Therefore, it was information that was not actively looked for by the participants, but ended up being learnt by them.

On top of its aforementioned functionalities, it also works as a PHIM system by saving calories and weight over large periods of time and showing that information back to the user whenever it is requested. This app is available in 21 different languages, including English and Brazilian Portuguese.

4.2.2 Patient Journey App

Patient Journey App [Hea17] is an Android and iOS mobile app developed by Health Care Labs B.V. that works both as a communication tool between physicians and patients and as an educational information source.

It gives health professionals the tools to curate what information to show each patient and when to do it. That information is meant to be both instructional and educational, guiding the patient in their current step of treatment. The physician can also set reminders in the form of push notifications for specific issues like taking a certain medication or carrying out certain actions (such as fasting before a surgery).

The app also supports direct communication between both parties, encouraging the patient to ask questions when having doubts and the physician to check-up regularly on them. The patient's family and friends can also be granted permission to access the patient's information timeline.

Throughout the whole process, the physician has access to a dashboard that shows statistics on how engaged the patients are, so that the physician can adjust the flow of information accordingly.

The app is free of charge for patients, but has to be first acquired by the health institutions in order to personalise it and grant them access to the back-office functionalities. The price they have to pay is unknown. The app is available in Dutch, English, French, Italian, Japanese, German, and Spanish.

4.2.3 Patient.info

Patient.info, or Patient.co.uk [PE16], is both a Web and mobile app (supported in Android and iOS devices) with an extensive database of medical conditions, medical services (from general practitioners to dentists, pharmacies, hospitals, and opticians), drug information, medical calculators, decision aids, clinical guidelines, health checks, and, contingent upon the purchase of an upgrade, clinical articles and medicine leaflets. It was first launched in 1997 by Patient information Publications (PIP), but since 2002 it has also been supported by Egton Medical Information Systems Ltd (EMIS).

Its main goal is, just like their slogan advertises, to give "trusted medical information and support", aiming at giving patients more access to free and complete health information. The users can check their conditions by searching for any term or by grouping the results by symptoms, alphabetical order, or category. It is therefore focused on people with health conditions who want to better understand what illness afflicts them and the closest places they can go for help. However, the medical calculators and online checks can also instil and promote healthy behaviours in the users.

As mentioned before, the access to the available information is mostly free, with the aforementioned extras costing around 12 Euro each. The location services work exclusively in England, and the information can only be displayed in English.

4.2.4 Patient Access

Also developed by PIP and EMIS, Patient Access [PE15], formerly known as EMIS Access, is a Web platform and mobile app for Android and iOS devices that supports the scheduling of general practitioner consultations, the consultation of one's medical record, and the ordering of repeat prescriptions for patients from the United Kingdom. The patients find in the app an easier and faster method to do those tasks while keeping a personal health record that gathers data measured from Apple Health and can be shared with the patient's physician. This app is also available exclusively in English.

4.2.5 Other Apps

There are several more apps available that prompt users to lead better and healthier lifestyles by exercising, eating adequately, sleeping better and being generally more self-caring. Among those we can highlight MySNS[1], Apple Health[2], S Health[3], C25K[4], Daily Yoga[5], ShopWell[6], Meditation Studio[7], HealthTap[8], and several others. They vary wildly in terms of information available and functionalities, being that many of them are not only health information apps, but also personal health information management systems and are sometimes associated with health assessment hardware such as smartwatches.

Those apps were not described in greater detail either because their scope falls outside the intended breadth of this dissertation or because they are alternatives to the apps already detailed in subsections 4.2.1 through 4.2.4. However, there is another type of apps that, even though not meant to be used exclusively for healthcare, is worth mentioning: note-taking apps. From those, we would like to highlight Evernote due to its pervasiveness in that market, as well as its use of STT technology.

[1] https://www.sns.gov.pt/apps/mysns/
[2] http://www.apple.com/ios/health/
[3] http://shealth.samsung.com/
[4] https://play.google.com/store/apps/details?id=com.c25k
[5] http://www.dailyyoga.com/
[6] http://www.shopwell.com/
[7] http://www.meditationstudioapp.com/
[8] https://www.healthtap.com/

4.2.5.1 Evernote

Evernote [Cor17] is a note-taking app with several added functionalities. It is supported online through Web, desktop, iOS, and Android apps. Its most fundamental functionality is taking written notes on a subject by specifying the post's title, contents, and tags, and by enabling simple formatting of the text and organisation through a folder system.

However, the app is also capable of saving web pages, storing pictures, parsing hand-written text, taking speech notes, and scanning documents. It is hence a multi-purpose tool that works as a PIM system and can be used in the healthcare area. However, its lack of focus on any specific field makes it more generic and less able to cope with specific information problems that may be prevalent in a particular area. Instead of expanding its services horizontally it chose to grow vertically, increasing its utilities across a plethora of related and useful extra functionalities.

Evernote's usage was tested in a scientific context by Walsh and Cho in 2013 [WC13] and was shown to be more efficient than traditional paper-based PIM methods. The biggest advantage of paper was the ability to freehand directly into a notebook, but in the experiment Evernote overcame that inadequacy with its multiple extra functionalities that are simply not achievable without a digital medium.

It is free to use, but has an associated premium service which goes from a 29,99 Euro to a 59,99 Euro one-year subscription and adds some of the mentioned extra functionalities, customer support, extra storage, and more sharing options. It is available in 24 different languages, including English from the USA and Portuguese from both Portugal and Brazil.

4.3 Summary

Automatic speech recognition has improved significantly over the last few decades, to the point where it is now commercially available to the public in several different solutions ranging a lot of functionalities. However, its efficiency at recognising human speech does not always apply to the medical field due to the specificity of the vocabulary used in that area. In this field, tests suggest that the inclusion of a dictionary of specific terms heavily influences their perception.

Several healthcare-related apps already exist. Even though some are more popular and used than others, they all have benefits and drawbacks that should be taken into consideration when creating a potential competitor.

Chapter 5

Problem and Solution Proposal

After contextualising HealthTalks in the previous chapters, what follows is the highlighting of the main problems with today's solutions and how HealthTalks could help solve them.

5.1 Problem

As discussed in Chapters 2, 3 and 4, there are several problems with the current level of healthcare, partly due to the patient's level of health literacy and their relationship with their doctor. Even though governments and independent organisations are trying to study the links between those areas in order to improve the healthcare of the populations, their work may not be enough to completely revert the health illiteracy problems seen in Portugal and other countries in a timely manner.

Therefore, developers and specialists have some space in which they can act in order to elicit change in behaviours and attitudes and, hopefully, bring a quicker end to those problems.

5.2 Solution Proposal

HealthTalks wants to tackle all the problems outlined in Section 5.1 by empowering the patients with tools that may ease their day-to-day health tasks and self-care ability. It is an Android app[1] with 4 major functionalities:

1. It can record the doctor's speech. From the landing page (see Figure 5.1), the user has quick access to the recording page (see Figure 5.2), in which they can record the audio of the consultation.

[1]The selection of this specific operating system was based on a) its ubiquity nowadays; b) the familiarity of the authors with its development tools; and c) the easier access by the authors to Android smartphones for testing.

2. It associates each recording with a customisable consultation page, which can then be sorted and organised with the other existing ones. Figure 5.6 shows the layout for a consultation, which are ordered in folders such as the ones in Figure 5.3. The contents of those folders can be reorganised by different parameters (see Figure 5.4), and when opened show the list of consultations with that common characteristic (as shown in Figure 5.5).

3. For each consultation, it transcribes the recording (see Figure 5.6).

4. For each transcription, the app highlights the medical terms used and gives small definitions for each (as can be seen in Figure 5.6, with the term's definition appearing in Figure 5.7).

Figure 5.1: Mockup of HealthTalk's landing page.

Figure 5.2: Mockup of HealthTalk's recording page.

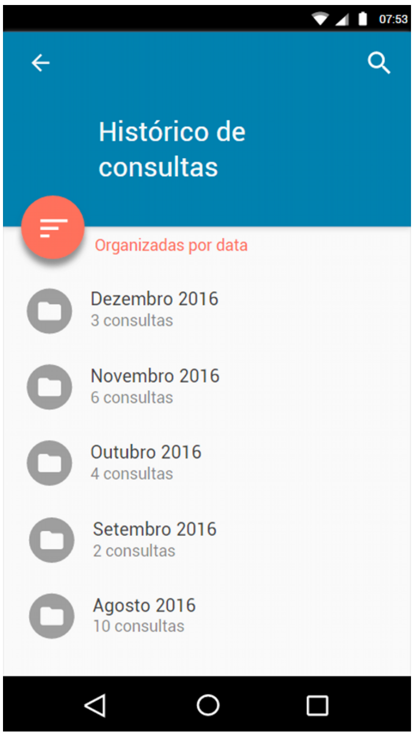

Figure 5.3: Mockup of HealthTalk's consultation groupings.

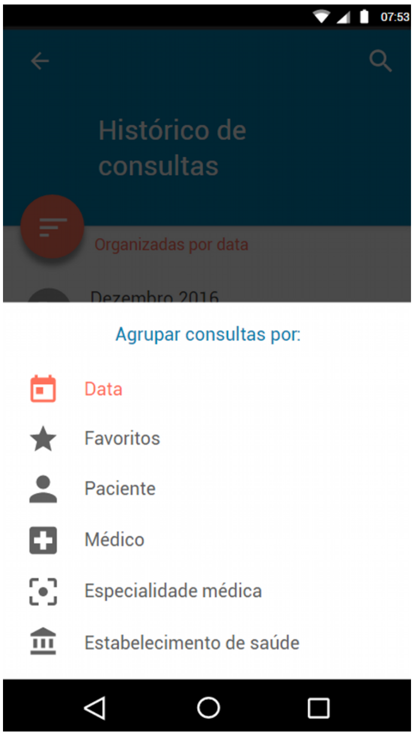

Figure 5.4: Mockup of HealthTalk's option to change grouping variable.

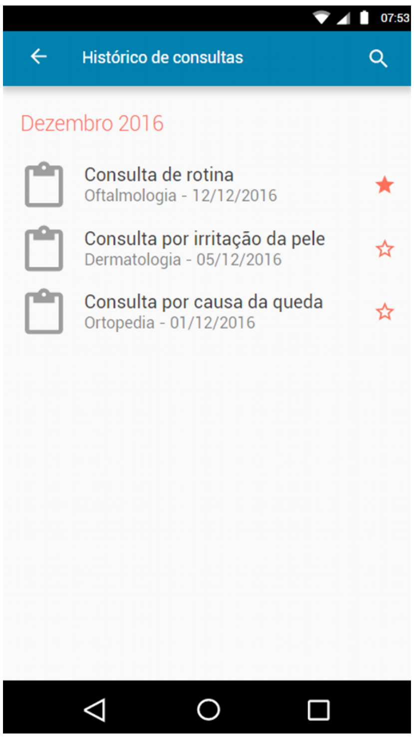

Figure 5.5: Mockup of HealthTalk's consultation listing.

Figure 5.6: Mockup of HealthTalk's consultation page.

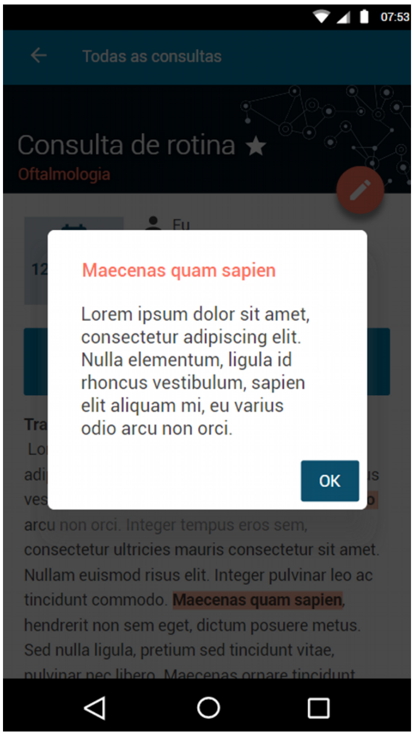

Figure 5.7: Mockup of HealthTalk's consultation page with the definition of a medical term.

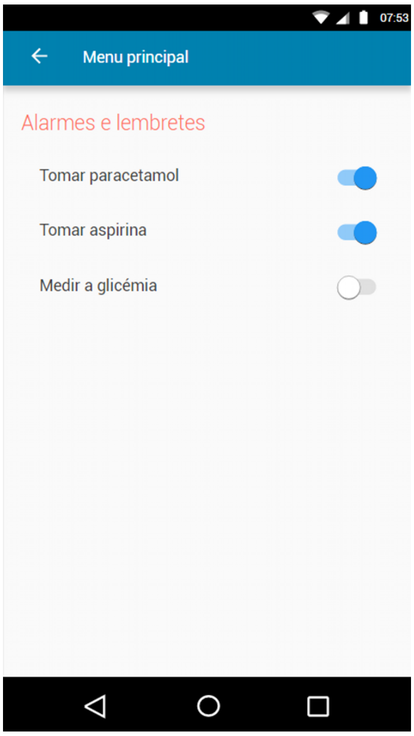

Figure 5.8: Mockup of HealthTalk's alert options.

This solution will hence be a health information provider as well as a personal health information management system. The transcriptions will be obtained via an external Application Programming Interface (API) through the Internet.

More functionalities may be included over time, such as alerts (as seen in Figure 5.8), which themselves can evolve from simple alarms to more complex timers that are automatically created according to instructions found in the transcriptions (such as analysing a sentence similar to "take this medication every 8 hours" and triggering an alarm every 8 hours).

5.3 Research

Even though the app is the main objective of this thesis, it is certainly not the only one. We intend to do thorough research in several areas related to this topic, and have already started two of them.

5.3.1 Questionnaire

During the conceptualisation of the app, we thought that surveying real patients in our region would give us a better perspective on their reality, so we decided to distribute a questionnaire. We planned the questions in order to focus three major areas: 1) the kind of note-taking behaviours they presented when it came to personal health information; 2) the relationship and behaviours they presented in front of their doctors during an appointment; and 3) their interest in the functionalities planned for HealthTalks.

The questionnaires went through various iterations over a few weeks. We were especially concerned with the language we were using, since we wanted everyone who could read to be able to answer it, even if they had no formal education. During that process we were helped by Dr. Dagmara Paiva, a physician in São João Hospital Center (CHSJ), who helped us in order to get a better understanding of the kind of language we should use.

After the first prototype was developed, we decided to test it with friends and family in order to get a better perception on its clarity and simplicity. We ended up testing it with 8 different adults, with ages ranging from 29 to 92 and all education levels. On top of that, we also presented the questionnaire to two children aged 8 and 11, since their feedback was relevant when it came to their education level, even if they did not grasp some of the ideas presented.

Our conclusions with that test were very enlightening and led us to iterate on the prototype once more. We had used arrows to indicate dependencies between questions and jumps that the readers had to make, but after those tests we understood that they were not very clear at all for most people, so we chose to replace them with text that indicated the question the respondent should answer next. Even though that was the most significant change, several other details were polished, from vocabulary, to the survey's structure, and further clarifications.

The final version was ready after those tests, and we chose to submit a request to the Health Ethics Committee (CES) of the CHSJ in order to get permission to hand the questionnaires to patients inside that health establishment. However, to this date we still have not received an answer.

To complement the answers we would get from the CHSJ, we decided to also make it available online[2] and divulge it among our networks of friends and colleagues. We have gotten over 1000 responses, but have not had the opportunity to analyse the results yet.

The questionnaire can be seen in Appendix A.

5.3.2 Speech-to-Text Software

Even though it was always a certainty that the speech-to-text solution used in HealthTalks would be one already developed by a third-party, no specific software was specified. Therefore, we developed a process to chose the best option.

The first step was to look for the most used STT solutions in the market and compare them. A summary table can be seen in Table 5.1. We focused on objective variables such as price, language options, and personalised dictionaries, as well as more subjective characteristics among which were the amount of documentation available, reviews from other users, and ease of integration with Android. Another option to think about in the future would be offline use of the STT system, which some solutions provide.

[2]It can be accessed at https://goo.gl/forms/MCX6nyCZrxRAOway2 (Portuguese only).

Table 5.1: Comparison between different STT options

Name	Languages	Price	Customisable
Android Speech-to-Text[3]	EN, PT	Free	Yes
Bing Speech API[4]	EN, PT	4$ for 1000 calls	–
DynaSpeak[5]	EN	1000 mins	–
Dragon NaturallySpeaking 13[6]	EN	169 Euro	–
Google Cloud Speech API[7]	EN, PT	Free 1000 mins/month	Yes
HTML5 Web Speech API[8]	EN, PT	Free	Yes
IBM Watson Speech to Text[9]	EN	Free 100 mins/month	Yes
iSpeech[10]	EN	Free	Yes
Microsoft Speech Platform[11]	EN, PT	Free	Yes

We immediately disregarded any options that could not be used for free, as well as all those that did not have the option of transcribing Portuguese recordings. Since the remainder of the options were relatively similar in terms of their characteristics, we chose to rely on our impression on the amount of support and examples each provided and so, from those options, we decided we would focus on Google Cloud Speech API and Microsoft Speech Platform, since they looked the best candidates. However, we wanted to pick just one of them to use in the final version, so we decided to test them and compare the results.

Even though we have not had the opportunity to test them yet, each option will be evaluated in the following circumstances:

- Transcription of a small text with generic vocabulary;
- Transcription of a small text with medical vocabulary;
- For each text, transcribe English and Portuguese versions;
- For each text in each language, attempt reading them in two different conditions (varying distance between the speaker and the microphone, amount of background noise, etc.).

Hence, 8 tests will take place in total, since each will only be done once barring any hurdles. The metric we wish to use is the one specified by Fiscus et al. [FAG08], which accounts for word replacements, removals and insertions and divides that total by the amount of words in the text.

5.3.3 Usability Tests

During its development, HealthTalks will be presented to several different people in order to gauge their understanding of its interface and functionalities. These tests have not been fully formalised yet, but will occur after the first minimum viable product is completed and until the end of the development phase. The goal is to go back and forth between the design board, programming, and the users, in order to iteratively create better experiences according to their difficulties and suggestions.

5.3.4 App Evaluation

HealthTalks will be evaluated at the end of its development in order to measure the quality of the transcriptions it will make. No specific tests have been planned yet, but there is interest in exploring specific aspects:

- Try it with different people, focusing especially on different pronunciations and accents;
- Test with different phones, particularly ones with different microphones;
- Compare the results from tests where the subject reads a text with tests where they improvise (and are hence more prone to using filler words, speaking at an irregular rhythm, pausing more often and longer, etc.);
- See how transcriptions with a lot of medical jargon compare to more generic ones;
- Check the differences between using or not a dictionary of medical terms;
- Try to test the app in real-world scenarios (with noises, the patient's and doctor's voices sometimes overlapping each other when speaking, etc.);
- Check how it handles different people talking without any overlaps, as well as long silences and other possible use cases.

5.4 Solution Innovation

The main novelty in HealthTalks is holding the patient accountable for their own health condition while supporting their methods of doing so. It looks at their biggest weaknesses, such as low health literacy levels and bad personal health information management practices, and gives patients a tool to overcome them specifically in the context of physician consultations. Even though it will be a sporadically used tool, it is expected that its learnings may have lasting effects on the users.

The fact that real users are giving their input through the questionnaires is also extremely positive, since their ideas, motivations, and feedback can help shape a solution truly adapted to their needs. However, in the scope of this work there will not be enough time to create a truly comprehensive and functionality-heavy app, nor should it be too complex as to not push away possible users of low technology proficiency; instead, we will focus on its main functionalities outlined in Section 5.2 in order to get a minimum viable product.

5.5 Ethics

There are several different ethical dilemmas to consider in a healthcare context, including clinical care, health services and systems, public health, epidemiology, bio-technology and the use of animals in research [Glo15]. However, the only one relevant for this project lies with the physician-patient confidentiality, which may be broken with HealthTalks due to the recording of consultations.

Confidentiality is the basis on which medical practice is built, since health professionals have access to an individual's personal health information and have the obligation of keeping it private unless consent to release the information is explicitly given by the patient or the law enforces it [BBD13].

Since this project aims at putting the information in the hands of the patient, the physician's Hippocratic Oath [Eva14] does not interfere in any way with what we are trying to accomplish. However, the collected information can still be used against the patient's will (for more on that, please see Section 5.6), or against the physician's privacy.

In the USA, health professionals are often the target of prosecution and there is a very noticeable position from government officials against any possible errors from their part, being that health fraud was the highest priority "white-collar" crime, above even violent street crime, after the September 11th 2001 terrorist attack [Lib08]. Therefore, many physicians may feel reticent towards an app that records their every word during a consultation due to fear of backlash from the patients.

However, two aspects should be acknowledged before proceeding: firstly, there are several different audio recording options available to everyone at the moment, all subject to the same privacy concerns as HealthTalks in regards to recording the physician's dialogue. Nonetheless, HealthTalks clearly encapsulates that functionality in a healthcare-oriented solution, which may be misinterpreted as a reassurance of the right of covertly record a consultation. But secondly: measures can be taken to decrease the possibilities of patients recording their physicians against the latter's will. Such measures may include a loud signal when starting the recording; the constraint of being forced to have the device's screen turned on with a microphone or similar icon displayed for the duration of the whole recording process; or not allowing recordings longer than a predetermined amount of time. This last point may even be turned into the main functionality of the app: instead of recording the entire consultation, we might advocate for recording only a few minutes at the end of the consultation, during which the patient asks the physician to repeat the most critical information they shared (e.g. diagnosis, medication, dosage, treatment, etc.).

A new questionnaire is intended to be shared among health professionals after the end of this dissertation with the goal of inquiring them on their views on this subject and plan further measures to implement in the app according to the responses.

5.6 Privacy

The parts of HealthTalks to be developed during this dissertation will not require Internet access nor any other potentially vulnerable external communication system. All the data (the recordings, transcribed text, and custom fields) will be saved locally in the device used. No login system will be implemented either, so the safety of the data will be assured only on the assumption that the device itself is safe. However, if the device is breached, all that data will become vulnerable since it is in no way protected from someone with access to the device. Moreover, there will be a third party API used remotely to transcribe the recordings, which means that those files (both the audio files and the text transcriptions) will be even more vulnerable to attacks when sent and received from the API[12]. Even though they are being sent to a third party, the responsibility of protecting the user's privacy lies within the main application [Com17]; in this case, HealthTalks. On top of that, the user has to be informed that their data will be shared with a third party in order to develop the transcription.

According to the new European Data Protection Regulation to be implemented after May 25th 2018 [Com17], the users have the right to erase their data at any time. Moreover, the data in HealthTalks is deemed personal data since it pertains to an individual's health and biometric information [Eur16], so further security measures have to be ensured, including the manifested will of the user to share that information. Finally, a system of notification of the Portuguese Data Protection National Centre in case of safety violations by a third party has to be developed. The full extent of the knowledge that has to be given to the user is as follows (reproduced *ipsis verbis* from the 2016/680 European Directive [Eur16]):

- the identity and the contact details of the controller;
- the contact details of the data protection officer, where applicable;
- the purposes of the processing for which the personal data are intended;
- the right to lodge a complaint with a supervisory authority and the contact details of the supervisory authority;
- the existence of the right to request from the controller access to and rectification or erasure of personal data and restriction of processing of the personal data concerning the data subject.

The main feature that has to be added is a privacy declaration agreement where the user is informed, in layman's terms, of every aforementioned item. Besides that, an option should be added either in the landing page or one of the menus to 1) review the privacy statement at any time, and 2) report any privacy concern to the applicable protection officer (in this case, the Portuguese Data Protection National Centre).

Either Google's or Microsoft's privacy statements will have to be thoroughly analysed, according to which solution is chosen for the final product. Even though both are multinational

[12] The possibility of cyphering the messages will be studied before implementing the solution, in order to reduce potential risks.

companies that abide by European laws, HealthTalks retains the culpability of any wrongdoing done by the chosen API's company.

All these privacy measures have to be taken into account when developing the app. Even though it will not be freely available before the end of the dissertation, it is important to have all those requirements in mind since some will affect how the app is built.

5.7 Summary

HealthTalks will be a unique app, since its functionalities have not been incorporated in a single solution before. It has the potentially to make a difference in the patients' everyday life, since it tackles the issues they have more problems with (health information seeking and management) while demanding very little effort from them (all they have to do is record a consultation).

Even though ethics and privacy issues may be regarded as possible impediments, we are convinced that, as long as we develop it with those concerns in mind, it will be up to the patients' standards. As mentioned, we also plan to involve doctors in the development after the end of the thesis.

Chapter 6

Software Requirements

This chapter expands on the functionalities of the app HealthTalks. To this effect, requirements, personas, and user stories are outlined in the following sections.

6.1 Requirements

Table 6.1: Stakeholder requirements

ID	Description
SR01	The recording act has to be clear and unambiguous so that both parties are aware that they are being recorded.
SR02	The privacy of the user's data must be assured.
SR03	The user must know their responsibilities when using the app.

Table 6.2: Offering requirements

ID	Description
OR01	The information given to the patient has to be truthful and up-to-date.
OR02	The error margin for the transcriptions has to be 5% or lower.
OR03	The app has to work both online and offline.
OR04	The app should be free to use.

Table 6.3: Functional requirements

ID	Description
FR01	The app must be able to record the audio of a conversation.
FR02	There has to be a transcription option included.
FR03	The meanings of medical terms found in the transcriptions have to be given.
FR04	The user has to be given a way to organise and search their consultation records.
FR05	A user should be able to take notes in the app.
FR06	There must be an option to set reminders.

Table 6.4: Non-functional requirements

ID	Description
NR01	The app has to be simple and intuitive to use.
NR02	A user should not have to click more than twice to start a recording.
NR03	A user should not have to click more than once to stop an on-going recording.
NR04	No more than 5 clicks should be required to access any basic functionality.
NR05	The array of functionalities available should be explained to the user.
NR06	The app has to be compatible with a large amount of devices.
NR07	The interaction with the chosen speech-to-text software happens through its API.

6.2 Personas

According to Cooper et al. [CRC07], a persona is a design tool that represents a user archetype in order to convey how real users behave, what are their goals, and their motivations. They claim that personas are the strongest models for interaction design and allow developers to focus on specific functionalities in order to please a certain user base.

They argue that there are six different kinds of personas: primary, secondary, supplemental, customer, served, and negative. Primary personas reflect the product's main functionalities and are the ones on which the development team should be most focused. Secondary personas use extra functionalities that, while useful, do not significantly alter the final solution. Supplemental personas refer only to functionalities mentioned in both previous types; their presence originates from a need to differentiate different types of users that may use the same functionalities. Customer personas only exist for products for which the person who acquires it is not the same person that uses it (children toys are a good example). Served personas represent people that, even though they do not use or interact with the product's interface, are affected by its use (e.g. a patient doing an x-ray). Lastly, negative personas are the ones specifically not targeted by the product, but that could be mistakenly assumed as such (like early adopters of consumer products).

Five personas were developed in order to portray the archetypes of users intended to use HealthTalks. Their descriptions can be found in Subsections 6.2.1 to 6.2.5.

6.2.1 Primary Persona: Margarida Fonseca

Figure 6.1: Photo chosen to represent Margarida Fonseca.

Age: 74
Technological proficiency: Low
Quote: "The older we get the more we need our memory not to fail us because of all the health issues we have to keep track of, and yet that's when it fails us the most."
Description: Margarida lives at home with her husband. They both have a few age-related health problems like poor sight, memory issues and frail bones, but nothing too serious or life-threatening. Those issues do require her to go to her general practitioner regularly though, and he usually redirects her to specialists according to the illness. Margarida feels blessed for having such good health for her age, but finds the amount of medical information she has to handle in her daily life very daunting and she's struggling to cope with it. She and her husband can't rely too much on one another either since taking care of their own health is already difficult as it is.
Goals, motivations and context scenarios: See Table 6.5.

Table 6.5: Goals, motivations and context scenarios of persona Margarida Fonseca.

Goals	Motivations	Context Scenarios
Remembering all her medication and treatments	Remaining independent	She creates reminders for her medications and future consultations
Keeping track of her health situation	Maintaining a good quality of life	She checks the list of consultations she had for each specialty and their transcripts, as well as her personal notes for each of them

6.2.2 Primary Persona: Gustavo Brandão

Figure 6.2: Photo chosen to represent Gustavo Brandão and his daughter Ana.

Age: 29
Technological proficiency: High
Quote: "I want to give my children the best life I possibly can, but sometimes it's hard to manage everything all by myself."
Description: Gustavo is the proud father of two small children. He does mostly odd jobs, which means he has more time for taking care of them than his girlfriend does, since she has a full-time job. Their eldest child, Ana, has Crohn's disease, which requires special attention from them. Gustavo has to manage her doctor appointments, as well as her medication and treatments, not to mention their son Hugo's healthcare and his own. He gets by thanks to a small journal he carries everywhere and where he writes down the doctors' orders and any other relevant information. The problem is that he sometimes doesn't fully understand what he's told and is too intimidated to ask. When that happens he writes what he hears and when he gets home he tries to search for those terms online to learn more about what they mean.
Goals, motivations and context scenarios: See Table 6.6.

Table 6.6: Goals, motivations and context scenarios of persona Gustavo Brandão.

Goals	Motivations	Context Scenarios
Organise each person's health information	Get better and faster access to the details of each family member's healthcare situation	He associates each consultation with the family member in question to be easier to find
Understand the medical terms	Get a better grasp of his children's health status and how to improve it	He transcribes the consultations and checks the transcriptions for definitions of the terms he doesn't know

6.2.3 Supplemental Persona: Diana Magalhães

Figure 6.3: Photo chosen to represent Diana Magalhães.

Age: 18
Technological proficiency: Very high
Quote: "Even though my condition does not define me, it never really leaves me. So I just have to work around it in order to be as efficient as anyone else."
Description: Diana has a hearing impairment, but you would not notice if you did not know. She is young, but since she has never been able to hear, she developed her own means of get around that, mostly based on lip-reading and contextual clues. However, now that she is starting to be her own carer after reaching adulthood, she is noticing a stark difference between everyday language and medical speech. The latter is much more difficult for her to understand, since it contains a lot of words that are mostly unknown to her. She often asks her physicians to communicate with her by writing, but that can quickly become cumbersome to both.
Goals, motivations and context scenarios: See Table 6.7.

Table 6.7: Goals, motivations and context scenarios of persona Diana Magalhães.

Goals	Motivations	Context Scenarios
Understand the physician's speech	Be more independent and less inconvenient	She records her physician and transcribes their speech so she can read what they said
Understand the medical terms	Learn new words and their enunciation	She checks the transcription for medical terms and clicks on them to see their definitions

6.2.4 Supplemental Persona: Luís Correia

Figure 6.4: Photo chosen to represent Luís Correia.

Age: 46
Technological proficiency: Medium
Quote: "I am used to taking notes on paper, but I don't like to manually look for each patient's notes on all my notebooks each time I want to check something."
Description: Luís is a psychologist. His profession demands that he always remember the details pertaining to each patient's life every time they visit him, so that they feel heard and the talk can flow easily every time. In order to brush up on each individual's life and behaviours, he reviews their processes the day before the consultation. However, since he takes notes on that on paper, he finds himself often piecing together information from different notebooks or separate papers.
Goals, motivations and context scenarios: See Table 6.8.

Table 6.8: Goals, motivations and context scenarios of persona Luís Correia.

Goals	Motivations	Context Scenarios
Record the main points of each patient's accounts	Remember them in later consultations	He records himself recapping the session he had with a patient and associates that consultation with that patient
Get faster access to each patient's history	Be more efficient	He searches for all the consultations associated with a specific patient

6.2.5 Served Persona: Rute Tavares

Figure 6.5: Photo chosen to represent Rute Tavares.

Age: 32
Technological proficiency: Medium
Quote: "Even though I try to treat each patient as a unique individual, it's difficult to do so after long work hours and strict schedules."
Description: Rute is a general practitioner at a hospital and loves what she does. However, it can get quite tiresome, since the hospital is lacking doctors and so she often has to work overtime in order to make up for that. She notices that at the end of the day her concentration decreases noticeable and her actions become more automatic. That leads her to treating patients in a more detached way, not being as attentive to the degree to which they understand what she tells them, and trying to quickly wrap up consultations. She is aware of those flaws and tries to correct them every chance she gets, but sometimes it is very hard to perceive those faults in real time.
Goals, motivations and context scenarios: See Table 6.9.

Table 6.9: Goals, motivations and context scenarios of persona Rute Tavares.

Goals	Motivations	Context Scenarios
Ensure that patients understand her	Empower them with important information	She incentivises her patients to use HealthTalks and resort to it when in doubt of a term's meaning
Guarantee that her patients do not forget what she says	Avoid that they mishandle their own self-care	She impels her patients to use HealthTalks to manage past consultations and set reminders

6.3 User stories

HealthTalks will only have one type of user, referred to simply as "user". In Table 6.10 all of HealthTalks' functionalities are listed from the viewpoint of the user.

Table 6.10: User stories

ID	Description
US01	As a user, I want to record the audio of a consultation in order to listen to it later.
US02	As a user, I want to read the transcribed text of the audio of a consultation in order to skim through it quicker.
US03	As a user, I want to see the definitions for the terms that I don't know in the transcription in order to gain more knowledge from that content.
US04	As a user, I want to set reminders for the medication my physician prescribed me in order not to forget to take them.
US05	As a user, I want to be able to edit all the details pertaining to a consultation in order to make it as comprehensive as possible.
US06	As a user, I want to be able to search for consultations by their different fields in order to find the one I'm looking for faster.

Chapter 7

Conclusion and Future Work

The project has been successful so far, but this is not the end. Although until know there has been a strong emphasis in literature review and problem specifications, the next step will consist in the development of the HealthTalks app and all the research associated with it.

7.1 Objective fulfilment

Even though the planning for the activities changed a few times during the course of the semester, in the end the major activities planned were successfully accomplished, and some extra were added as well. The main differences between what was done compared to the initial proposal were 1) the extra participation in DSIE in January, and 2) the postponement of the speech-to-text testing activities for the second phase of the project.

In retrospect, time predictions for many tasks were not very accurate; while some tasks such as creating the mockups and planning the STT software tests were given several weeks to be done and were finished in a few hours, others such as writing the final report took significantly longer than expected. However, such discrepancies can be at least partially attributed to the need of completing other courses simultaneously, which will not be an issue in the next phase of the project. Also, the time allocated for each task was often not directly correlated with the time the task took to be completed, but rather about when the deadline was and from which point onwards could it be realistically started.

Besides the work related to the Dissertation Planning course (PDIS) and the thesis itself, HealthTalks was also presented in the 12th Edition of the Doctoral Symposium in Informatics Engineering (DSIE), a seminar organised by informatics doctorate students from the Engineering Faculty of the University of Porto (FEUP). To that effect, an extended abstract was submitted and later reviewed taking into account the panel's feedback. There was also a presentation of a scientific poster during the conference.

7.2 Future work

Stricter time management tools such as a day-to-day schedule and more flexibility in terms of tasks will be applied going forward. Furthermore, the lessons taken from lack of time for writing the report will be applied to the writing of the thesis, in order to ensure it is written well in advance of its delivery. It is hoped that those practices will streamline the development process and make room for unexpected situations.

In terms of specific tasks, they can be seen in Figure 7.1. In broad terms, we can divide the project in two big phases: pre-development and development. The pre-development phase has just ended, and was mostly characterised by the review of the state of the art. However, it also entailed the creation of mockups for the final app, the listing of requirements, research on different STT solutions, and the creation and distribution of the questionnaires. On top of that, as mentioned in Section 7.1, an extended abstract and a poster were also created for DSIE.

The first tasks to complete in the second phase of the project will be the choosing of an STT technology to use in the final product, the analysis of the questionnaire's answers, the writing of an article on that for the Iberian Conference on Information Systems and Technologies (CISTI), and the creation of a website to publicise the thesis.

The main product of this thesis will be the app described in Section 5.2. Its development will be completed in three different stages, and from each of them will result a functioning prototype. The first stage will involve the implementation of the recording functionality, as well as the incorporation of those recordings in the consultation pages, with all the associated search and organising options included. The second stage will focus on the creation of the transcriptions from the recordings and the highlighting of medical terms in them. The third and final stage will be spent trying to fix possible errors, polishing existing functionalities and adding extra ones. Each of those stages should last approximately one month.

The research around the app will also be a focal point during development. We already started it with the questionnaires, and will expand that research if we get permission to spread them in CHSJ. On top of that, we will do usability tests during the development of the second and third app prototypes, in order to iteratively review design choices. At the end of the project, we will also review the app by testing it under different conditions and scenarios. Our goal is to study its efficiency and its reception by the general population.

The process of writing the thesis will span around one month at the end of the project, but some work such as review of this report might be done throughout the semester. At around the same time, our goal is to use the data obtained during the research to publish a scientific article in a scientific journal yet to determine. After that, the thesis will have to be defended and later reviewed.

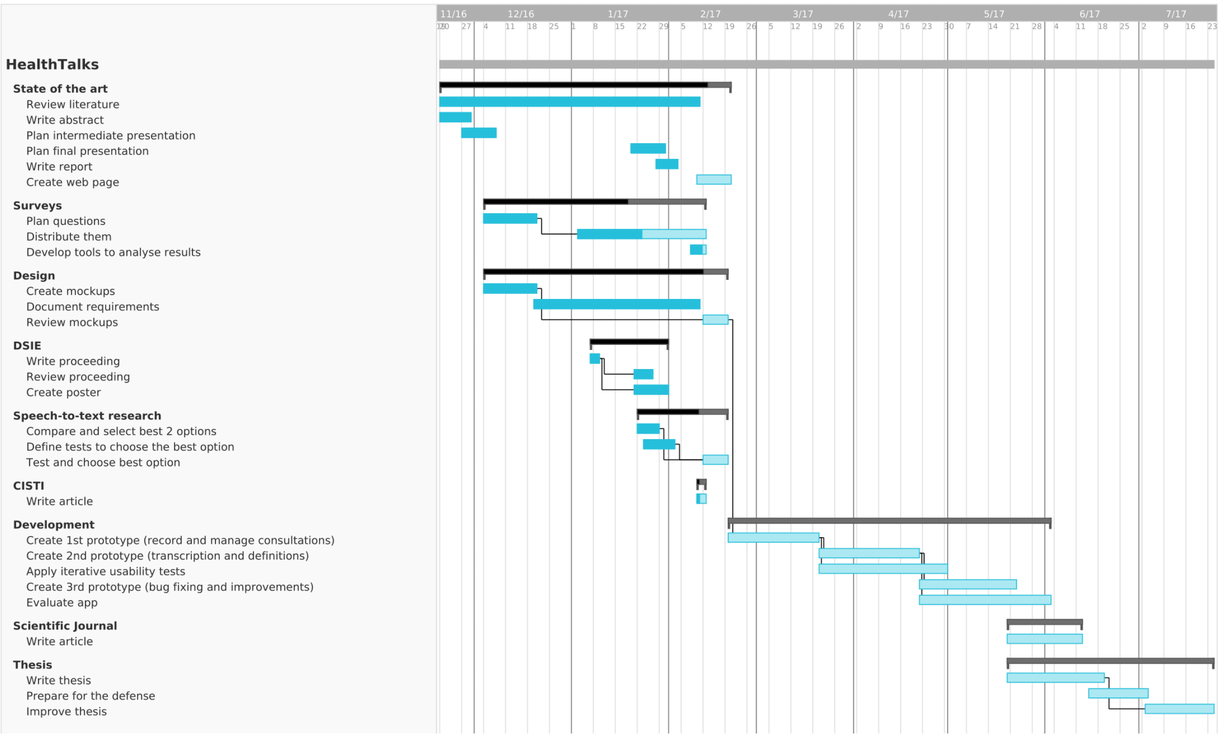

Figure 7.1: Gantt chart of past and future tasks related to HealthTalks.

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Appendix A

Questionnaire

During the development of this report, a questionnaire was distributed in order to get a better characterisation of the physician-patient relationship, the degree to which individuals manage their health information, and how receptive they would be to a platform such as HealthTalks. On January 3rd 2017 a request was made with the CES of the CHSJ in order to get permission to distribute copies throughout CHSJ, but as of the date of this report no answer has been given yet. Despite that, an online copy was published online and advertised in social media, by mass e-mails aimed at students and staff of the University of Porto, and during a poster session in DSIE. More than 1060 answers have been registered so far. All of the questions included in the questionnaire and the answer options are listed in Figures A.1 to A.4 in their original Portuguese version.

HEALTH
TALKS

Este questionário foi desenvolvido no âmbito de uma dissertação de mestrado na Faculdade de Engenharia da Universidade do Porto e pretende aferir a eficácia da comunicação médico-paciente e dos métodos de gestão pessoal de informação de saúde. O inquérito demora aproximadamente 5 minutos a responder.

Por favor, assinale as suas respostas marcando com um 'X' os círculos ou quadrados que as antecedem; em algumas questões poder-lhe-á ser permitido dar mais do que uma resposta. Por vezes ser-lhe-á pedido no final de uma pergunta para saltar para outra pergunta especificada dependendo da resposta que tiver dado. Se nada for dito, prossiga para a questão seguinte.

A sua identidade permanecerá anónima.

Se quiser esclarecer alguma dúvida pode contactar o mestrando João Monteiro através do seguinte endereço de correio eletrónico: ei11055@fe.up.pt

Quando terminar, por favor coloque o questionário na caixa para o efeito que se encontra na receção.

Obrigado pela sua colaboração!

1. Dados demográficos

1.1. Género

- ○ Masculino
- ○ Feminino
- ○ Outro: __________

1.2. Idade

- ○ 18-25 anos
- ○ 26-35 anos
- ○ 36-49 anos
- ○ 50-64 anos
- ○ 65+ anos

1.3. Habilitações (Selecione o grau de ensino mais elevado que tenha completado)

- ○ Não completei a 4.ª classe
- ○ 4.ª classe
- ○ 9.º ano
- ○ 12.º ano
- ○ Licenciatura ou bacharelato
- ○ Mestrado
- ○ Doutoramento

2. Apontamentos

2.1. Costuma tomar nota de informações de saúde?

- ○ Sim *(se esta for a sua resposta, continue para a pergunta **2.2.**)*
- ○ Não *(se esta for a sua resposta, salte para a pergunta **2.5.**)*

2.2. Tira notas de saúde sobre quem?

(Escolha todas as opções que se aplicam)

- ☐ Sobre si próprio(a)
- ☐ Sobre um familiar
- ☐ Sobre um(a) amigo(a)
- ☐ Outro: __________

2.3. Que informações costuma apontar? (Escolha todas as opções que se aplicam)

- ☐ Peso
- ☐ Calorias ingeridas e/ou despendidas
- ☐ Batimentos cardíacos ou pulso
- ☐ Tensão arterial
- ☐ Sintomas ou sinais clínicos
- ☐ Nome da(s) doença(s) que tem
- ☐ Pontos a discutir numa consulta futura
- ☐ Informações encontradas na Web
- ☐ Resultados de exames ou análises (exemplo: picar o dedo para saber o açúcar no sangue)
- ☐ Outro: __________

1

Figure A.1: First page of the written version of the questionnaires.

2.4. Onde costuma tirar notas de informações de saúde? (Escolha todas as opções que se aplicam)

- ☐ Em papel (exemplo: bloco de notas)
- ☐ Num livro de registo fornecido na instituição de saúde (exemplos: livro de grávida, boletim de saúde infantil e juvenil, livro para registo de tensões)
- ☐ Numa aplicação para tomar notas (exemplos: Evernote, OneNote, Dropbox Paper, Box Notes)
- ☐ Numa aplicação especializada (exemplos: Fitbit, MyFitnessPal, MyChart, BG Monitor Diabetes)

2.5. Com que frequência se esquece de algo que um médico disse numa consulta?

○ Sempre ○ Muitas vezes ○ Poucas vezes ○ Nunca

2.6. Para não se esquecer, aponta o que foi dito na consulta?

- ○ Sempre *(se esta for a sua resposta, continue para a pergunta **2.7.**)*
- ○ Muitas vezes *(se esta for a sua resposta, continue para a pergunta **2.7.**)*
- ○ Poucas vezes *(se esta for a sua resposta, continue para a pergunta **2.7.**)*
- ○ Nunca *(se esta for a sua resposta, salte para a pergunta **2.9.**)*

2.7. Normalmente, quando tira apontamentos sobre o que foi dito na consulta?

- ○ Durante a consulta
- ○ Imediatamente após a consulta
- ○ Algum tempo depois da consulta

2.8. Quando tira apontamentos sobre uma consulta, que informações regista? (Escolha todas as opções que se aplicam)

- ☐ Nomes das doenças
- ☐ Opiniões médicas
- ☐ Medicamento(s) receitado(s)
- ☐ Tratamento prescrito
- ☐ Posologia (dose do medicamento, quando o tomar, etc.)
- ☐ Outra: ___________

2.9. Durante uma consulta, o médico entrega-lhe informação em papel (exemplos: folhetos, resumos, notas)?

○ Sempre ○ Muitas vezes ○ Poucas vezes ○ Nunca

3. Comunicação

3.1. Entende tudo o que os médicos lhe dizem?

- ○ Sempre *(se esta for a sua resposta, salte para a pergunta **4.1.**)*
- ○ Muitas vezes *(se esta for a sua resposta, continue para a pergunta **3.2.**)*
- ○ Poucas vezes *(se esta for a sua resposta, continue para a pergunta **3.2.**)*
- ○ Nunca *(se esta for a sua resposta, continue para a pergunta **3.2.**)*

2

Figure A.2: Second page of the written version of the questionnaires.

3.2. Por que é que é difícil entender o que o médico diz? (Escolha todas as opções que se aplicam)

☐ Pronúncia ou sotaque

☐ Volume de voz

☐ Atitude

☐ Uso de termos médicos ou técnicos

☐ Uso de palavras "caras"

☐ Sequência de ideias

☐ Falta de tempo do médico

☐ Outra: __________

3.3. Quando não percebe algo, pede ao médico para repetir ou reformular o que disse?

○ Sempre *(se esta for a sua resposta, salte para a pergunta **4.1.**)*

○ Muitas vezes *(se esta for a sua resposta, continue para a pergunta **3.4.**)*

○ Poucas vezes *(se esta for a sua resposta, continue para a pergunta **3.4.**)*

○ Nunca *(se esta for a sua resposta, continue para a pergunta **3.4.**)*

3.4. Quando não pede ao médico para repetir ou reformular o que disse, porque não o faz? (Escolha todas as opções que se aplicam)

☐ Falta de confiança

☐ Receio de parecer ignorante

☐ Não querer incomodar

☐ Alguém lhe explicará mais tarde

☐ Confia no médico e não precisa de saber mais

☐ Falta de tempo ou oportunidade

☐ Desinteresse

☐ Outra: __________

4. Aplicação

4.1. Possui um smartphone ou tablet?

○ Sim *(se esta for a sua resposta, continue para a pergunta **4.2.**)*

○ Não *(se esta for a sua resposta, o seu questionário termina aqui. Obrigado pela sua colaboração!)*

○ Não sei *(se esta for a sua resposta, o seu questionário termina aqui. Obrigado pela sua colaboração!)*

4.2. O que usa no seu smartphone ou tablet? (Escolha todas as opções que se aplicam)

☐ Chamadas e SMS

☐ Acesso à Internet

☐ Aplicações originais do dispositivo (exemplos: bloco de notas, calculadora)

☐ Aplicações que instalou (exemplos: jogos, redes sociais)

☐ Outra: __________

3

Figure A.3: Third page of the written version of the questionnaires.

4.3. Qual é o sistema operativo do seu dispositivo?

- O Android
- O iOS
- O Windows
- O Blackberry
- O Não sei
- O Outro: __________

4.4. Numa aplicação para smartphones/tablets seria importante permitir...

	Não concordo	Indiferente	Concordo
Gravar a voz do seu médico, com a autorização deste, durante a consulta e permitir-lhe ouvir essas gravações mais tarde.	O	O	O
Gravar a voz do seu médico, com a autorização deste, durante a consulta e permitir-lhe consultar o texto do que foi dito nessas gravações mais tarde.	O	O	O
Fornecer definições dos termos médicos nos textos do que foi dito numa consulta.	O	O	O
Associar anotações às consultas e gerir outra informação de saúde.	O	O	O

4.5. Usaria uma aplicação que permitisse fazer o que foi indicado na pergunta anterior?

O Sim O Talvez O Não

4.6. Se pudesse criar uma aplicação para resolver os problemas descritos neste questionário, que outras utilidades gostaria que se acrescentassem? Como é que a aplicação funcionaria?

4

Obrigado!

Figure A.4: Fourth page of the written version of the questionnaires.