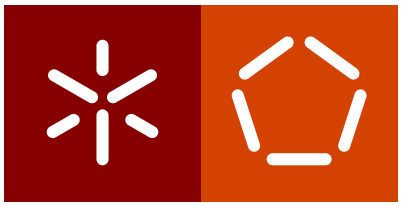

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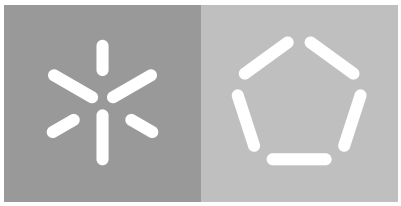

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E-anamnesis: A clinical observation electronic platform for emergency departments

Master dissertation
Master Degree in Biomedical Engineering

Dissertation supervised by
José Manuel Ferreira Machado
Nuno Feixa Rodrigues

January 2021

STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

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ABSTRACT

One of the reasons for the increased number of visits to emergency departments is the primary health care inability to handle urgent needs and provide all the health services needed to assess complex conditions. A significant amount of these visits are due to the abnormal flow of patients whose clinical condition is of low severity and could ideally be resolved with self-care and primary health care.

The crowding in emergency departments causes operational and logistical problems and has undesirable consequences for patients, health professionals and hospitals. Delays in treatment interventions and increased mortality, medical errors and waiting times are just a phew examples of critical consequences that can occur, resulting in a significant barrier to the quality of health care delivery.

With the advances in technology, several institutions have found in self-service an alternative for the patient's collection of health information autonomously. These devices can be used by low clinical severity patients (with the blue, green or yellow bracelets from Manchester triage) to reduce waiting time in the emergency departments.

This dissertation proposes a technological solution to improve both the time and quality of the anamnesis procedure performed by medical staff in the emergency department. The introduction of a self-service kiosk in the emergency department waiting room will make it possible to quickly and intuitively collect the patient's past medical history, usual medication, main complaint symptoms and vital signs. Subsequently, this data will be made available to the physician before each clinical observation. The hypothesis considered is that by providing a selective, structured and uniform anamnesis information's presentation of each patient, medical staff observation can proceed much faster and accurately, focusing on the confirmation of the most relevant aspects. The primary purpose of this solution is to reduce the period of clinical observation and thus improve the response capacity of the emergency department with the same resources.

Keywords: Primary Health Care, Emergency Department, Crowding, Health Kiosk, Self-Service Kiosk

RESUMO

Uma das razões para o aumento do número de visitas ao serviço de urgência é a incapacidade dos cuidados de saúde primários de lidar com necessidades urgentes e de fornecer todos os serviços de saúde necessários para avaliar condições complexas. A maioria destas visitas deve-se ao fluxo anormal de doentes cuja condição clínica é de baixa gravidade que poderiam, idealmente, ser resolvidos com recurso ao auto-cuidado e aos cuidados de saúde primários.

A lotação nos serviços de urgência provoca problemas operacionais e logísticos, apresentando consequências indesejáveis para os doentes, profissionais de saúde e hospitais. Atrasos nas intervenções de tratamento e o aumento da mortalidade, dos erros médicos e dos tempos de espera são apenas alguns exemplos de consequências críticas que podem ocorrer, resultando numa barreira significativa à qualidade da prestação de cuidados de saúde.

Com os avanços da tecnologia, diversas instituições, encontraram nos serviços de auto-atendimento uma alternativa para a recolha autónoma de informações de saúde do doente. Estes dispositivos, poderão ser usados por doentes de baixa gravidade clínica (com pulseira azul, verde ou amarela da triagem de Manchester) nos serviços de urgência com vista à redução do tempo de espera.

Esta dissertação propõe uma solução tecnológica para melhorar tanto o tempo como a qualidade do procedimento de anamnese realizado pelos médicos no serviço de urgência. A introdução de um quiosque de auto-atendimento na sala de espera do serviço de urgência permitirá recolher de forma rápida e intuitiva a história clínica, medicação habitual, sintomas da queixa principal e sinais vitais do doente. Posteriormente estes dados serão colocados à disposição do médico antes de cada observação clínica. A hipótese considerada é que ao fornecer uma apresentação seletiva, estruturada e uniforme da informação de anamnese de cada doente, a observação dos médicos possa proceder de forma muito mais rápida e precisa, concentrando-se na confirmação dos aspectos mais relevantes. O principal objectivo desta solução é reduzir o período de observação clínica e assim melhorar a capacidade de resposta do serviço de urgência com os mesmos recursos.

Palavras-Reservadas: Cuidados de Saúde Primários, Serviço de Urgências, Lotação Hospitalar, Quiosque de Saúde, Quiosque de Auto-Atendimento

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ACRONYMS

A

AIDS Acquired Immune Deficiency Syndrome.

B

BP Blood Pressure.

C

CC Citizen Card.

CHUSJ Centro Hospitalar Universitário de São João.

CRISP-DM Cross-Industry Standard Process for Data Mining.

E

E-ANAMNESIS Electronic Anamnesis.

E-MAIL Electronic Mail.

ED Emergency Department.

EEA European Economic Area.

EMA European Medicines Agency.

EU European Union.

H

HIV Human Immunodeficiency Virus.

HR Heart Rate.

L

LE Low Energy.

M

MAHS Holders of Marketing Authorizations.

P

PHC Primary Health Care.

PSSUQ Post-Study System Usability Questionnaire.

S

SMS Short Message Service.

SPO2 Saturation of Peripheral Oxygen.

U

UI User Interface.

UX User Experience.

1

INTRODUCTION

1.1 CONTEXTUALIZATION

Healthcare is provided through various settings, including small or medium-sized practices, hospital outpatient departments, community health centres, and integrated care systems. The fundamental premise of *Primary Health Care (PHC)* is that all people, everywhere, deserve the right care, right in their community.

PHC addresses the majority of a person's health needs throughout his lifetime, providing physical, mental and social well-being through a people-centred rather than disease-centred approach. However, 50% of people in the world still lack some or all essential health services and a shortfall of 18 million health care workers is forecasted by 2030 1.

Nevertheless, even in countries with good primary care coverage and health insurance, patients do not seek PHC, going instead directly to the *Emergency Departments (EDs)*. Reasons for this behaviour may well reside in PHC not being able to handle urgent needs that require same-day care or to provide all health services necessary to evaluate complex conditions Pines et al. (2011).

The model most referred to when describing the ED crowding problem distinguishes three interdependent components: input, throughput, and output. Input factors include not only the volume but also the acuity and patients' type. Throughput factors refer to the activities within the ED that may interfere with patient flow. Output factors refer to obstacles preventing patients from leaving the ED Bergs et al. (2016).

The leading cause of ED crowding is the low clinical severity emergency visits (with the blue, green or yellow bracelets from Manchester triage), which usually result from patients inability to obtain rapid "reassurance" or counselling in PHC Bergs et al. (2016); Blackburn et al. (2013). However, other factors also influence this condition, such as the increasing use of technical investigations, through laboratory tests or imaging, which contribute to

the patient staying longer in the ED, as well as difficult access to hospital beds for patients requiring hospitalization Bergs et al. (2016).

In a study conducted in fifteen countries in Europe, Asia, North America and Africa, ED crowding is still a relevant phenomenon in countries with allegedly strong primary care networks, as seen in Italy, France, and Saudi Arabia. One of the main factors for ED crowding is "inappropriate use", often attributed to the use of the ED for problems that could potentially be cared for in a physicians office Pines et al. (2011). In Portugal, ranked number 12 in overall performance by the World Health Organization in 2000, 30% of visits to the ED in 2001 could be inadequate Tandon et al. (2000); Pereira et al. (2001). In 2015, a report published by the National Health Service identified a 7% increase in this percentage de Almeida et al. (2017). These patients of low clinical severity, represent internationally 24% - 40% McHale et al. (2013).

ED crowding remains an important topic that has received special attention from health professionals, and decision-makers Tabriz et al. (2019). Medical errors, such as administering medicines at incorrect doses, frequencies and duration, and increasing mortality rates, have become a constant of extreme consequences in the ED George and Evridiki (2015). Timeliness of care is considered one of the core aspects of quality health care. Patient wait times that exceed 20 minutes may decrease the quality of care by reducing patient satisfaction Gatto (2018). Currently, the patients' waiting time in the ED has reached high proportions, reducing the likelihood of patients being examined by a physician within the recommended time George and Evridiki (2015).

Technology improvements allow new alternatives to provide health information and advise patients over the Internet, television, and telephone. Besides, it offers the ability to obtain and use health data parameters without needing to go to a hospital or other form of a medical facility Silva et al. (2017).

Emerging medical devices create integrated systems that can help in the collection of vital signs from patients. Along with an interface, usually a computer or tablet, these devices allow the conception of a system that can collect and evaluate these parameters and provide users with useful feedback by analyzing the data Silva et al. (2017).

Self-service kiosks are independent units that contain computer programs that provide the user with information services. They are widely portable so they can be moved and adapted for new service needs. Kiosks-based programs are primarily interactive and generally have a simplified *User Interface (UI)*, such as a touch screen or keyboard Joshi and Trout (2014).

To these self-service kiosks are applied different health's areas, such as management, information, prevention, telemedicine, triage, diagnosis and substitution of face-to-face consultation. Generally, self-service kiosks have been successful in reducing patient wait times, and increasing patient's satisfaction Gatto (2018).

This work proposes a technological solution to improve both the time and quality of the anamnesis procedure performed by ED medical staff, by introducing a self-service kiosk placed in the waiting room of the ED. Anamnesis information, such as past medical history, usual medication, main complaint symptoms and vital signs, collected through the kiosk by patients with the blue, green or yellow bracelets from Manchester triage, will be made available to the physician before each clinical observation. The hypothesis considered is that by providing a selective, structured and uniform anamnesis information presentation of each patient, medical staff observation can proceed much faster and accurately, focusing on confirming the most relevant aspects. The primary purpose of this solution is to reduce the clinical observation time and thus improve the response capacity of the ED with the same resources.

1.2 MOTIVATION

There is a growing interest in self-service healthcare kiosks for a wide range of solutions, from helping to simplifying administrative tasks to reducing medical errors and patients' waiting time.

An opportunity arises to develop a self-service kiosk, which allows patients in the EDs to take advantage of their waiting time before the medical consultation in a productive way. The patient's anamnesis information collected through a self-service kiosk will be provided to the physician before the medical consultation. This information will help physicians to concentrate on verifying the most relevant aspects of each patient's anamnesis information, giving a much faster and accurate clinical observation.

The medical consultations duration will decrease through the use of the kiosk, reducing physicians workload. Furthermore, it may result in the reduction of the EDs' waiting time. Both healthcare professionals and patients will benefit from this platform.

The different age ranges and digital competence of patients are a significant challenge in the platform design. It is necessary to focus on the kiosk usage experience to make it as simple as possible for the patient. This experience will allow the patient to make use of this

solution independently and without prior training.

Supplying the system with large amounts of data will allow the data mining processes execution. The patients' clinical registers and biometric data exploration will help determine diagnoses before medical consultations. Determining this diagnoses may become a decision support system for various healthcare professionals, reducing possible medical errors.

1.3 OBJECTIVES

The work presented in this dissertation aims to build a care platform for EDs so that patients can register their clinical condition information quickly and intuitively without prior training. Afterwards, the system provides the patient's data to the physician before the medical consultation. It will be necessary to develop a mobile application which interacts with biometric sensors. Besides, a web application is useful for physicians to access the patients' clinical condition information. The mobile application should implement the following functional requirements:

- Identification of the patient, collection of past medical history and usual medication;
- Collection of biometric data (*Blood Pressure (BP)*, *Heart Rate (HR)*, *Saturation of Peripheral Oxygen (SPO2)* and body temperature);
- Brief exploration of the main complaint;
- Registration of several indicators, for further analysis of performance and research.

For the system's development, according to the functional requirements mentioned, the solution was divided into the following sub-objectives:

- Planning a solution that ensures the security and confidentiality of all data involved;
- Development of a prototype of the solution, highlighting the following elements:
  - A system that allows the patient's identification, collection of the past medical history, usual medication and main complaint symptoms;
  - A module to collect and store biometric data acquired through the sensors;
  - A UI that highlights the action the users should perform next;
  - A system to store the patients' anamnesis information and solution performance indicators;
  - A back-end system to respond to the requests performed by the mobile kiosk application and web application.

- Implementation of the prototype solution, for testing and evaluation of the developed system.

1.4 Document Structure

The dissertation is divided into six chapters.

The second chapter, the **"Literature Review"**, introduces health self-service kiosks through the literature review carried out. This chapter describes the search strategy as well as the analysis and summary of the most relevant studies. In the end, the results of each study are discussed.

The third chapter, the **"E-Anamnesis Platform"**, consists of planning the entire solution and its architecture, presenting the system specification through several models and diagrams. Simultaneously, theoretical and technical concepts are also addressed for a better understanding.

The fourth chapter, the **"E-Anamnesis Platform Implementation"**, presents the self-service kiosk components and explains the most relevant decisions taken to implement UI elements and functionalities in the developed platform. Moreover, this chapter also defines the indicators for clinical business intelligence.

The fifth chapter, the **"E-Anamnesis Platform Test and Evaluation"**, explains the assessment performed on the developed platform and presents a critical analysis of the tests' results, which is used to identify the main required improvements on the platform. At the end of this chapter, there is a brief explanation of an intelligent UI/*User Experience (UX)* system that adapts to the type of user.

The final chapter presents the entire work conclusions and topics for future work. The contributions provided to the scientific community are also presented.

2

LITERATURE REVIEW

This chapter presents a literature review concerning health kiosks. The literature review analyses the effectiveness of the self-service kiosk usage compared with standard procedures for each kiosk application. Besides, this review identifies the main effectiveness features of self-service kiosks, also assessing the acceptability of this approach for the elderly or the less educated community.

2.1 SEARCH STRATEGY

The bibliographic research was carried out in PubMed, IEEE Xplore, Web of Science, Cochrane Library, ScienceDirect and Scopus, considering only articles published from January 2009 to October 2019. Search terms included 'hospital kiosks', 'public health kiosk', 'health kiosk', 'healthcare kiosk', 'systematic review kiosk', 'hospital kiosk and medication' and 'urgency kiosk'. The use of Boolean operators among the terms, in addition to the keywords, was a strategy used to obtain more accurate searches (queries are exposed in electronic supplementary materials). Regarding the choice of the mentioned terms, the keywords considered related to kiosks in health area. Publications in newspapers and books were also considered for analysis.

2.2 DATA ITEMS

The extraction variables taken from each study were: (1) Domain (the process that the kiosk will perform), (2) Area (location of the kiosk), (3) Country (the country where the kiosk was tested), (4) Study period (length of the kiosk test period), (5) System Objective (purpose of the kiosk), (6) Architecture (characteristics of the system architecture), (7) Population (characteristics of the population that intervened in the kiosk usage), (8) Study parameters (metrics used to evaluate the kiosk) and (9) Results (effects of the application of the kiosk). System architecture refers to the type of system implemented, description of the biosensors and their connectivity, use and presence of touchscreen. The population variable contains

the number of participants who used the kiosk and their average age or range of ages. It also includes the presence of support in the use of the kiosk or patient referral.

2.3 SEARCH RESULTS

Self-service kiosks are an alternative that allows assistance in the triage process, clinical diagnosis and replacement of face-to-face consultations. The kiosks in the triage domain work as a pre-consultation tool to give healthcare professionals more time to assess a larger number of patients Silva et al. (2017). One study demonstrated that placing kiosks in the waiting room allowed patients to use their waiting time more productively by providing important information to be used later on in the health delivery process Ng et al. (2018). Concerning diagnostic systems, they are designed to facilitate the diagnosis of common diseases by performing a set of pre-established physiologic and mental tests. Data obtained is then compared with the information available in the kiosk workstation Sun et al. (2011); Maunder and Hunter (2018). Public places have been used for health kiosks, especially for population screening or control, as a form of health surveillance of elderly communities Silva et al. (2017). This approach has been increasingly sought after in places with poor access to electricity, transportation and communication replacing face-to-face consultation. A study in India indicates that the physician-patient ratio for primary care in rural areas is only 39.8 physicians per 100,000 people, compared to 53.3 physicians per 100,000 in urban areas Mukhopadhyay et al. (2019). After analysis and selection of articles, eight studies were obtained. Tables 1 and 2 contain a summary of these studies for later discussion.

2.3.1 *Study Characteristics*

In all eight studies, four were considered from the triage domain and four from face-to-face consultation replacement. Of all the associated countries, four belong to America, two to Asia, two to Europe and one to Oceania. Regarding the area, five studies were conducted in health areas (Hospital, Polyclinic, Clinic), and the remaining outside this context (Community room, Rest Homes, Private Apartments, University, Villages). The studies period varies between eight weeks and twelve months. The total number of participants was 2298 and the mean age of these ranged from twelve to ninety-four years. Most kiosks provided assistance. The main objective of the system in the various studies is to measure vital signs and extract health information from patients according to the domain applied. The type of architecture of the system varies between Web App and Software. Most studies mentioned the usage of biosensors (height, weight, BP, pulse oximeter, glucometer and HR) and their type of connectivity at kiosks. The use of touchscreen was predominant in most studies. The study parameters identified in the studies meet the evaluation of the effectiveness of the

kiosks.

Authors of the studies were contacted to obtain missing information or confirmation of data extracted. In Soares et al. (2016), the age range was clarified by contact with the author, since it was not mentioned in the article.

2.3.2 *Risk of Bias within Studies*

To analyse the risk of bias, the limitations of each study were extracted. The use of assistance is a common limitation in most studies, except for studies Silva et al. (2017); Bahadin et al. (2017). The assistance is considered a limitation and may generate results at the level of usability unreliable, because, as the patient is given help in the use of the kiosk, he will be influenced for the ease of use of it. In study Coyle et al. (2019), the kiosk was tested only at peak hours, which according to the authors, ED stressors would be felt most during these times, and the kiosk's success or failure would be highlighted. The single centre design and modest sample size were the main factors contributing to the increase in the risk of bias in study Ng et al. (2018). In the study Silva et al. (2017), the usability tests were made at a Sciences Faculty, where a great number of participants had some technical background, and it was not the first time they interacted with medical devices or a touchscreen interface, thus presenting increased usability rates. Most relevant limitations in Bahadin et al. (2017) are the modest sample size and the accessibility of the kiosks only at certain times. The study period in Soares et al. (2016), is only 21 days of testing, which may cause unfeasible results due to the short test period. The absence of information on illiteracy and educational level of the population in most studies account for other limitations.

2.3.3 *Study Results*

This literature review systematizes and clarifies the results of the various studies related to healthcare kiosks. The various outcomes will enable the creation of relationships between studies, offering a more concrete interpretation of the effectiveness of kiosks in health services. Studies Silva et al. (2017); Soares et al. (2016); Ahn et al. (2014); Demiris et al. (2013) did not take place only in hospital settings, but also in community rooms, villages, universities, rest homes and private apartments. The biosensors that use batteries as an energy source were employed in studies Silva et al. (2017); Soares et al. (2016); Ahn et al. (2014). Bluetooth was used to transmit data in Silva et al. (2017); Soares et al. (2016); Demiris et al. (2013). Studies Ng et al. (2018); Silva et al. (2017); Soares et al. (2016); Bahadin et al. (2017); Chung et al. (2016); Ahn et al. (2014); Demiris et al. (2013) used kiosk with BP sensors and some providers and clinic staff were concerned about the accuracy of measurements. Some

patients were concerned to hygiene and about measuring their BP in public, others reported that are worried about abnormal values, particularly those with BPs in the prehypertension Chung et al. (2016). Touchscreen interfaces were used in Ng et al. (2018); Silva et al. (2017); Soares et al. (2016); Ahn et al. (2014). Elderly patients showed capacity and willingness to participate in technological interventions Bahadin et al. (2017); Chung et al. (2016); Ahn et al. (2014); Demiris et al. (2013). Older adults with specific health issues (e.g., tremor, or use of hearing aids) require customized training and assistance Demiris et al. (2013). Poor and less educated patients were able to use the kiosks Soares et al. (2016).

Table 1 *Summary of the included studies and the intervention detail*

Authors	Domain	Area	Country	Study period	System objective	Architecture				Population			Study parameters	Results
						Type	Biosensors	Sensors Connectivity	Touchscreen	Sample size	Age (SD)	Assistant presence		
Coyle, N., et al (2019) Coyle et al. (2019)	Triage	Hospital	Canada	10 weeks	Self-identify and capture the arrival times of patients. Alert triage nurses arrival patients and primary complaint before triage	—	—	NA[6]	—	898	53 (21.0) avg.age	Yes	Prove that ED[4]patients can use a self-check-in kiosk upon arrival and to compare time-to-first-identification with current triage system	Time-to-first-identification was 13.6 minutes (time-to-first-identification was 4 for intervention patients and 9 for control patients) faster for patients who used the kiosk. Kiosk usability was 97%
Ng, G., et al (2018) Ng et al. (2018)	FCR[1]	Polyclinic	Malaysia	12 months	Measure patients physiological parameters and combines of this and their recent laboratory results to classify patients. Furthermore, also produces a result slip for the patient	Web App	BP[2] Height, Scale	—	Yes	120	21-75 y	Yes	Evaluate visit duration, patient satisfaction with the management process, health-related quality of life and the occurrence of any adverse	Patients and physicians expressed high levels of acceptance and satisfaction. Kiosk allowed more physician time to be allocated to the management of patients
Silva, J., et al (2017) Silva et al. (2017)	Triage	University	Portugal	—	Measure vital signs for screening or continued monitoring	Web App	Scale, BP[2] PO[3]	Bluetooth	Yes	74	—	No	Assess kiosk usability, the tools developed, the results of the evaluation, the identified problems, and how to solve those problems	The oximeter is portable. The scale needs calibration. The BP[2] monitor generates difficulties and is the device that takes longer to collect. An average of 26.1 seconds to the process of identification and average of 31.3 seconds for manually entered the data. The average time for a complete kiosk session is 283 seconds. Global acceptance was very positive
Soares, E., et al (2016) Soares et al. (2016)	Triage	University and Villages	Portugal and Brazil	21 days	Measure vital data prior to a consultation, in the scope of a population screening, or for routinely monitoring	Web App	Scale, BP[2] PO[3]	Bluetooth	Yes	833	12-89 y	Yes	Analyse the difficulties of building a simplified health kiosk capable of measuring BP[2] weight and PO[3]using PHDs[5]	Incorrect or difficult placement of the BP[2] cuff. Patients the poor and less educated completed the session without help. The kiosk free up human resources. A full session took around 5 min

Information not provided by the study is represented by a dash;
[1] FCR = Face-to-face consultation replacement;
[2] BP = Blood Pressure;
[3] PO = Pulse Oximeter;
[4] ED = Emergency Department;
[5] PHDs = Personal Health Devices;
[6] NA = Not applicable;

Table 2 *Summary of the included studies and the intervention detail (continuation)*

Authors	Domain	Area	Country	Study period	System objective	Architecture				Population			Study parameters	Results
						Type	Biosensors	Sensors Connectivity	Touchscreen	Sample size	Age (SD)	Assistant presence		
Bahadin, J., et al (2016) Bahadin et al. (2017)	FCR[1]	Clinic	Malaysia	2 months	Automates the management of stable patients with chronic conditions to complement face-to-face PCP[2]visits	—	BP[3]	—	—	95	61.4 (6.7) avg.age	—	Show that the kiosk could be a feasible means of delivering care for stable patients with chronic conditions and could generate cost savings for the management of patients with stable chronic disease	Kiosk was easy to use, and 96% agreed that they could use the kiosk instead of a physician. BP[3]reading was higher than that of the nurse. Reduction of 128 physician visits, saved of $5335. Patients need to spend only about 7 min at the kiosk
Chung, C. F., et al (2016) Chung et al. (2016)	FCR[1]	Clinic	USA[7]	9 months	Used to measure BP[3]	Web App	BP[3]	—	—	152	—	Yes	Evaluate BP[3] kiosk acceptability and usability, as well as its effects on the workflow of patient BP[3]self-measurement	Some older patients seemed to take longer to use the new technology, whereas others felt the self-service technologies were impersonal. 80% of patient thought kiosk blood pressures were as accurate, than those taken by clinic staff. MA[6]reported that the time saved (1.5 minutes) allowed them to spend more time in clinical stuff.
Ahn, H. S., et al (2014) Ahn et al. (2014)	FCR[1]	Hospital Rest Homes Private Apartments	New Zealand	12 weeks	Gives helpful information to older people. Stores health information of older people for managing their health conditions	Software	BP[3]	Cable	Yes	99	—	Yes	Assess feasibility and acceptability in robot system for older people in private and public places	Kiosk can help older people. The participants in the private apartments were satisfied with the BP[3]measurements service. A kiosk may be more acceptable in rest-homes and hospital lounges than in private homes
Demiris, G., et al (2013) Demiris et al. (2013)	Triage	Community room	USA[7]	8 weeks	This provides users secure access to their patient profile with the ability to capture relevant vital sign data into their personal health record, and to view pertinent nutritional or educational content	Software	BP[3], HR[5] Glucometer, PO[4] Scale	Bluetooth	—	27	78-94 y	Yes	Demonstrate how informatics applications can support the assessment and visualization of older adult's wellness. Assess the acceptability and feasibility of the kiosk	Older adults are willing to participate in technology-enhanced interventions. Kiosk is "convenient", "easy and fast", and participants can "repeat the test" and "do it myself". The duration of each session corresponds to 20 minutes (more 5 min, once a week) and is held 3 times a week. The model of a community is cost-effective

Information not provided by the study is represented by a dash;
[1] FCR = Face-to-face consultation replacement;
[2] PCP = Primary Care Physician;
[3] BP = Blood Pressure;
[4] PO = Pulse Oximeter;
[5] HR = Heart Rate;
[6] MA = Medical Assistant;
[7] USA = United States of America;

2.4 DISCUSSION

Studies Silva et al. (2017); Ahn et al. (2014); Bahadin et al. (2017); Ng et al. (2018) expressed very positive kiosk acceptability and satisfaction, revealing that people are willing to use this kind of technological interventions to replace standard procedures. In Demiris et al. (2013); Soares et al. (2016), the autonomy of participants during the use of these systems showed that the kiosks can be used practically without assistance. Studies Silva et al. (2017); Soares et al. (2016) present kiosks for screening or continued monitoring, that allow streamlining procedures in healthcare facilities, for expanding healthcare access to populations that otherwise might not have it, and for performing large scale population screenings at very low marginal cost. This evidence shows that kiosks could help more isolated populations with lacking some essential health services.

Almost all studies use biosensors, but only in some of these the data was transmitted via Bluetooth Silva et al. (2017); Soares et al. (2016); Demiris et al. (2013). This type of communication brings benefits in terms of interoperability and accessibility. However, they can cause some problems hard to solve and the only option is to skip the exam and move forward, as mentioned in Soares et al. (2016). Studies Silva et al. (2017); Soares et al. (2016); Ahn et al. (2014) present biosensors that use batteries as an energy source, and Silva et al. (2017); Soares et al. (2016) reported that the use of batteries could create the need for their replacement, which may indirectly interfere with the usability of the system. Biosensors with Bluetooth *Low Energy (LE)* technology are a possible alternative for battery replacement reduction, since it provides considerably reduced power consumption.

The quality of the measurements performed by the sensors compared to those performed by health professionals was another evaluation performed in Sun et al. (2011); Bahadin et al. (2017); Chung et al. (2016). Most patient respondents in Chung et al. (2016) thought kiosk BPs were accurate, even though some reported higher values of BP. The physicians explained that this happened because patients did not have the chance to sit and wait in the reception area before measuring their BP. These instructions regarding the BP sensor should be considered at any kiosk or may be provided by clinical staff in an initial process to reduce unrealistic measurements. In Bahadin et al. (2017), a discrepancy between the values of measurements made by the kiosk and by clinical professionals was described, affecting the confidence in the system. This difference in BP readings may be caused by BP measurements changing from minute to minute and can be affected by various factors. Single measurements are taken by the BP of the kiosk as opposed to repeated measurements by a nurse clinician are another possible factor. The patient's level of anxiety about new measurement protocol in contrast to the familiar face of the nurse clinician which may also account for the observed differences.

The BP monitor is the device whose result takes longer to collect, due to the cuff not being

rigid. In the choice of this device, one must take into account the type of cuff, to avoid that users have to manually adapt it to their arm Silva et al. (2017). The incorrect or difficult placement of the BP cuff, hint that a cuff-less BP device would be preferable Soares et al. (2016). The users with several layers of clothing have more difficulty in taking the BP exam, since it involves clearing the left arm of anything that might block the circulation. The choice of a BP wrist monitor may be the solution to this problem since the measurement will be taken at the wrist and there is no need to collect clothing. BP measurement is a procedure that requires a set of several instructions, making it difficult for the user. Instructions with more compact information to be presented simultaneously with the measurement will make the procedure more supportive and avoid forgetting instructions Silva et al. (2017). George Miller found that people are only able to keep five to nine items in the short-term memory before they forgot or had errors 24 (2014 (accessed December 3, 2020). The concern of the providers, patients and clinic staff and the need to obtain accurate measurements, require that in the choice of BP or another type of sensor, the accuracy of the same must be taken into account. A good accuracy or certification of the sensors provides confidence to the healthcare professionals and patients in the results obtained from the measurements Chung et al. (2016).

In Chung et al. (2016), patients expressed hygiene concerns, which led them not to use the kiosk. Hospital institutions must provide solutions to ensure the kiosk's hygiene. The kiosk use by different patients requires constant hygienic cleaning of the sensors, which is not always possible, and the choice of sensors that are easy to clean or without body contact with the patient should be taken into account.

The oximeter is a small and extremely portable device, but at the same time, some restrictions have to be made in order to make it safe to be used in a public location Silva et al. (2017).

The need for the scale calibration step in the study Silva et al. (2017), lead to users spending an excessive amount of time on the weighing, due to not being familiar with scales that have to perform this calibration. The choice of sensors that need calibration should be avoided, so that patients do not suffer this type of problem.

Some patients were confused and concerned by the prehypertension notations on the kiosk paper printout Chung et al. (2016). Results classification can make patients more anxious and worried, affecting their state of health, and should be avoided after each measurement.

Some patients had concerns about measuring their BP in public, in part because of the need to remove an arm from clothing or because of concerns about others seeing their BP readings Chung et al. (2016). The location of the kiosks in a private area, outside the field of view of other patients, makes the user more comfortable to interact with the system. The kiosks should also be placed in places that do not affect the workflow of hospital institutions.

The use of touchscreen offers direct and easy to use interfaces Ng et al. (2018); Silva et al. (2017); Soares et al. (2016); Ahn et al. (2014). This feature allows saving space as it eliminates

keyboards and mice. Touch-based kiosks are very easy to operate, even for the elderly, as their intuitive use does not require any technical knowledge about using accessories such as the mouse and keyboard, improving human-computer interaction.
Studies Bahadin et al. (2017); Chung et al. (2016); Ahn et al. (2014); Demiris et al. (2013) were successfully applied to participants with a more advanced age group, showing that elderly patients demonstrate the capacity and are willing to participate in technological interventions. Still with an initial need for care, the elderly show good learning capacity in the use of kiosks, showing that independent use of kiosks to routinely and unobtrusively assess and identify patterns of elder wellness is possible, without the need to go to hospital environments. The measurement of vital signs in private homes is more satisfying than in hospitals, public spaces or rest homes. This may be due to older adults living independently are not in an environment that monitors their BP every day, so they wanted to check their BP in their homes. For the development of these types of kiosks, it is necessary to take into account their size, because probably smaller kiosks will be more acceptable in terms of portability and comfort in private homes, which essentially contain small partitions Ahn et al. (2014).
Older adults with specific health issues (e.g., tremor, or use of hearing aids) may experience considerable difficulties in using this equipment, which may be overcome by customized training and assistance for this type of users. The kiosk tools should be adapted to the user's preferences in order to allow a comfortable and familiarised use Demiris et al. (2013).
Although the elderly population begins to participate in technological interventions Bahadin et al. (2017), some still prefer face-to-face visits rather than the use of kiosks Chung et al. (2016). These self-service technologies can be impersonal, causing lack of confidence with the equipment and can be solved by providing assistance or even recommending the use of this type of kiosks by health professionals.
Study Soares et al. (2016) provides evidence that even poor and less educated patients were able to use the kiosk. The use of instructions containing text (which is also spoken), images, audio and video and the use of images for iteration with the kiosk can help patients with reading difficulties to understand how to perform each of the measurements on the kiosk. Results showed that the use of colour to discriminate between good and bad results will also help patients to know their state of health without the need for knowledge about standard normal values. A smart-card for authentication also facilitates patient identification process by reducing patient interaction with the system Soares et al. (2016).
The implementation of the kiosk resulted in a saving of $5335 concerning to face-to-face consultations, offering a better cost-benefit option to patients Bahadin et al. (2017). Modularity which allows for the health kiosk to be easily adapted for different use cases Silva et al. (2017), the automation of hospital procedures Soares et al. (2016), and the application of kiosks in community environments (eliminating the need for monitoring equipment to

be installed in every residence) Demiris et al. (2013) has advantages of being cost-effective, allowing cost reduction in terms of human resources and operating costs, which can be invested in other hospital resources. The cost-effectiveness of a healthcare kiosk in clinical care is a parameter to evaluate in the development of a kiosk since this analysis can also bring cost benefits to patients derived from reduced physician visits and the flexibility of alternative health service options Ng et al. (2018); Ahn et al. (2014).

The kiosk may be a feasible care option; however, the studies Ng et al. (2018); Bahadin et al. (2017) presents a low sample size, which contributes to limit the generalization of the results. In the test phase of a kiosk, one should have a heterogeneous and high sample size to obtain a study that provides well-founded evidence. In the study Soares et al. (2016), the Brazilian patients do not need assistance makes the results of the usability of the kiosk more reliable. The identification time at the self-control kiosk was 13.6 minutes faster, half the time that the standard procedure performed by health professionals would take, possibly avoiding high waiting times caused by ED crowding. Collecting the main complaint in this identification process allows nurses to prioritize triage, being able to select the patients for triage faster and more accurately Coyle et al. (2019). The use of kiosks allowed more time for physicians to be allocated to the treatment of other patients since the system allowed performing the procedures, which would normally be performed by health professionals Ng et al. (2018); Chung et al. (2016). By utilizing a kiosk for taking BP and performing other activities means the physician can spend more time talking with the patient Gladia and Kavya (2017), and the nurses get another 1.5 minutes per patient to spend preparing documents and educational materials as well as handling telephone encounters and voicemails Chung et al. (2016). The participants that used *Citizen Card (CC)* took less 5.2 seconds to go through the process of identification, than while those who manually entered the data, avoiding minutes-long form-filling Silva et al. (2017).

Kiosk usage time was not highly time-consuming, which is beneficial considering the possible use cases Silva et al. (2017). The time of use in Silva et al. (2017) was slightly shorter than study Soares et al. (2016) since users had a technological background. In relation to study Demiris et al. (2013), the time of use was the longest, due to the collection of cognitive evaluation data performed at the kiosk. In addition, the study required patients to be enrolled for a period of two months, which made it more conducive to withdrawals.

3

E-ANAMNESIS PLATFORM

The system's specification allows the solution planning and the best architecture's choice. First, the system's functionalities are presented to define all the system's functional and non-functional requirements. Next, is projected the system architecture, the first phases of the UI/UX design process and the *Electronic Anamnesis (E-anamnesis)* design.

3.1 SELF-SERVICE KIOSK REQUIREMENTS

The self-service kiosk's actor and its functionalities are shown in figure 1, through a use case diagram. This diagram shows the possible interactions between the user and the system.

Use Cases

- **Register digital competence** - A patient should manually register his digital competence.
- **Register identification data** - A patient must register his identification data. This registration is done through a webcam that allows the scan of information from the patient's CC.
- **Register past medical history** - A patient must manually register his past medical history.
- **Register usual medication** - A patient must manually register his usual medication.
- **Register main complaint** - A patient must manually register his main complaint. This complaint will be explored slightly by the system.
- **Collect biometric data** - A patient should collect his biometric data using the sensors.
- **End session** - A patient may end the kiosk session at any time.

Based on these use cases, the several functional and non-functional requirements of the self-service kiosk were identied. These are presented in the Appendix section A.

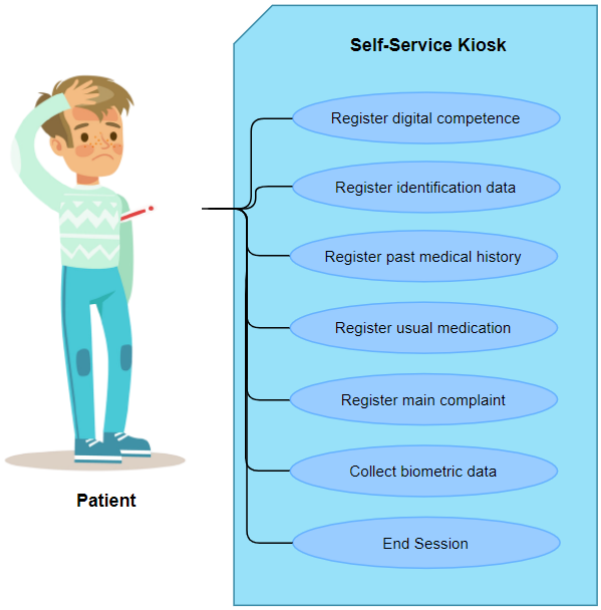


Figure 1: *Diagram of use cases of the self-service kiosk*

The self-service kiosk workflow is presented in figure 2 through an activity diagram. The sequence's order was defined so that the patients were first presented with simple tasks. Throughout the kiosk's usage, the patients learn how to handle it. With that, they can complete the final steps, which are associated with complex tasks.

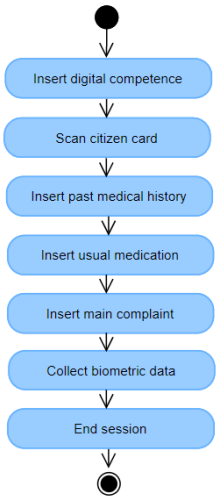


Figure 2: *Self-Service kiosk workflow*

3.2 WEB PLATFORM REQUIREMENTS

The web platform's actor and its functionalities are shown in figure 3, through a use case diagram.

Use Cases

- **Login** - The system should check whether the credentials entered by the user are valid or not.
- **Patient search** - A physician should search the patient.
- **Consult the patient's clinical data** - A physician may consult the patient's clinical data collected at the kiosk.
- **Copy the patient's clinical data** - A physician may copy the patient's clinical data.
- **Register diagnosis** - A physician should register the diagnosis of patients.
- **Logout**- A physician may log out of the system.

Based on these use cases, the several functional and non-functional requirements of the web platform were identied. These are presented in the Appendix section B.

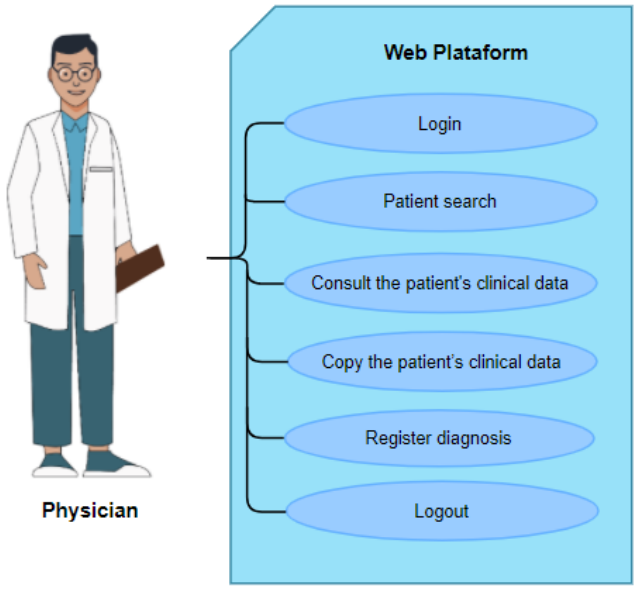


Figure 3: *Diagram of use cases of the web platform*

The workflow of the web platform is presented in figure 4 through an activity diagram. It is noteworthy to mention that the copy the patient's clinical data and diagnosis register are not mandatory steps.

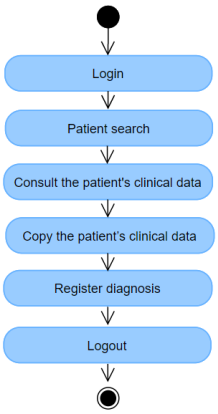


Figure 4: *Web platform workflow*

3.3 SYSTEM ARCHITECTURE

The system's architecture components are shown in figure 5, whereas their implementation can be found in Pacheco (2021).

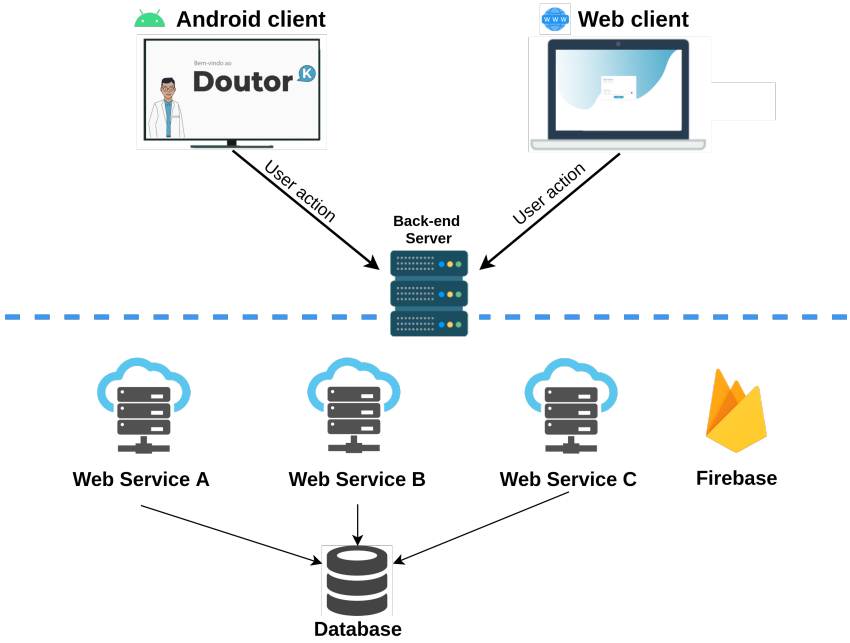


Figure 5: *System architecture*

The system architecture follows the client-server communication model, in which an Android client and a Web client will communicate with the same back-end system.

3.3.1 *Clients*

There are two types of clients embedded in this architecture, the Android client and the Web client. The Android client will provide past medical history, usual medication, and main complaint symptoms registers, while the Web client will perform data query operations. All the requests made by the clients will be received and answered by the web services.

As there is a heterogeneity of age ranges and digital competence in patients, the Android client will contain a key component, the UI. The purpose of this component is to facilitate patient iteration with the Android application, making it intuitive.

3.3.2 *Web Services*

The back-end system integrates three Web services that will perform operations in the same database and two Firebase services. A web service is described as a method for exchanging/communicating information between devices over a network Halili and Ramadani (2018). Web services offer a common platform in which many heterogeneous applications can communicate with each other due to their interoperability nature. The web services can be used alone or with other web services to carry out a complex aggregation, as used in this architecture Chawla et al. (2018).

The correct performance of both clients requires web services to be connected to the internet to receive requests from them. This dependency on connectivity may compromise the availability of web services, making web and Android applications inoperable. Thus, client programming logic will be performed to decrease web service dependency. When an initial upload is made to the application's local database, the only requests made to the web services are at the beginning and end of the kiosk session, to store the registers in the back-end database, reducing the dependency of the Internet connection. The biometric data collected will be received and processed by the application and sent to the server, without the need for web services to be processed or validated.

Although a single web service can respond to multiple client requests, it may overload, causing an increase in waiting time. To avoid this problem, three Web services were created. Web Services A and C receive requests from the Android client and Web Service B receives requests from the Web client. Web Service A takes requests for usual medication and past

medical history, Web Service C takes requests for main complaints symptoms, and Web Service B takes all requests from the Web client.

The number of users' system, which may initially be reduced, may increase in the future, causing an overload. With three web services, the system becomes easy to scale, allowing only overloaded web services to be replicated.

The Firebase services used in this system will store the images of the patient's CCs and the user's click coordinates.

3.3.3 *Database*

The database is a relational database. It receives Web Service A, B, and C requests and stores the patient clinical data and some solution performance indicators.

3.4 UI/UX DESIGN

UI focuses on anticipating what users might need to do and ensuring that the interface has elements that are easy to access, understand, and use to facilitate those actions. UI brings together concepts from interaction design, visual design, and information architecture 29 (2014 (accessed November 11, 2020).

UX focuses on having a deep understanding of users, what they need, what they value, their abilities, and also their limitations. It also takes into account the business goals and objectives of the group managing the project. UX practices promote improve the quality of the user's interaction and perceptions with the product and any related services 30 (2014 (accessed November 11, 2020).

When designing the interface, one should be consistent and predictable in the choice of its elements. Users become familiar with elements acting in a certain way, so choosing to adopt those elements when appropriate will help them in the tasks' completion, efficiency, and satisfaction.

Interface elements include but are not limited to:

Input Controls

- **Checkboxes:** Checkboxes allow to select one or more options from a set.

- **Radio buttons:** Radio buttons are used to select one item at a time;
- **Dropdown lists:** Dropdown lists enable the selection of one item at a time, similarly to radio buttons, but are more compact allowing to save space;
- **List boxes:** List boxes, like checkboxes, allow users to select multiple items at a time. Notwithstanding, the list boxes are more compact and can support a long list of options when needed.
- **Buttons:** A button indicates an action upon touch and is typically labelled using text, an icon, or both;
- **Dropdown Button:** The dropdown button, when clicked, displays a drop-down list of mutually exclusive items;
- **Toggles:** A toggle button allows to change a setting between two states;
- **Text fields:** Text fields permit to enter text. It can allow either a single line or multiple lines of text;
- **Date and time pickers:** A date picker allows users to select a date and/or time.

Navigational Components

- **Search Field:** A search box allows to enter a keyword or phrase (query) and submit it to search the index so that the most relevant results are returned. Typically search fields are single-line text boxes which are often accompanied by a search button;
- **Breadcrumb:** Breadcrumbs allow users to identify their current location within the system by providing a clickable trail of proceeding pages to navigate by;
- **Pagination:** Pagination divides content up between pages, and allows users to skip between pages or go in order through the content;
- **Tags:** Tags allow users to find content in the same category;
- **Sliders:** A slider, also known as a track bar, allows users to set or adjust a value;
- **Icons:** An icon is a simplified image serving as an intuitive symbol that is used to help users to navigate the system;
- **Image Carousel:** Image carousels allow users to browse through a set of items and make a selection of one if they so choose.

Informational Components

- **Notifications:** A notification is an update message that announces something new for the user to see;
- **Progress bar:** A progress bar indicates where a user is as he advances through a series of steps in a process. Typically, progress bars are not clickable;
- **Tool Tips:** A tooltip allows a user to see hints when he hovers over an item indicating the name or purpose of the item;
- **Message Boxes:** A message box is a small window that provides information to users and requires them to take an action before they can move forward;
- **Modal Window (pop-up):** A modal window requires users to interact with it in some way before they can return to the system.

Containers

- **Accordion:** An accordion is a vertically stacked list of items that utilizes show/hide functionality Affairs (2013 (accessed November 11, 2020).

3.4.1 *UI/UX Design Process*

The UI/UX design process can be divided into four key phases: user research, design, testing, and implementation, as represented in figure 6.

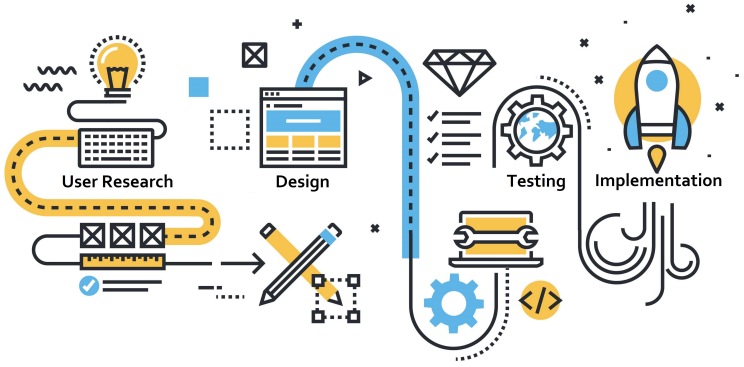


Figure 6: *UI/UX design process*

User research is the starting point for a UX design project. This research teaches about the users, their behaviour, goals, motivations, and needs. The empathy maps and personas are fundamental tools to use at this phase.

The empathy map is a technique that assists in designing business models according to customers' perspectives. It goes beyond demographic characteristics and develops a

better understanding of a customer's environment, behaviour, aspirations and concerns. The empathy map's goal is to create a degree of empathy for a specific person (or group of people). Additionally, it reveals the rationale underlying users' actions, decisions and choices. Therefore it helps in designing for users' real needs Ferreira et al. (2016). Traditional Empathy Maps are split into four quadrants. The four quadrants reflect four crucial traits concerning what the user: Says, Does, Thinks and Feels Plattner (2010 (accessed November 11, 2020).

Says Quadrant - The Says quadrant contains what the user says throughout the experience;
Does Quadrant - The Does quadrant encloses the actions the user takes;
Thinks Quadrant - The Thinks quadrant captures what the user is thinking throughout the experience;
Feels Quadrant - The Feels quadrant reflects the user's emotional state, often represented as an adjective plus a short sentence for context.

Empathy maps for the patient and the physician were performed based on the literature review of self-service kiosks. These empathy maps allow understanding the patient and physician needs and behaviours during the self-service kiosk usage and web platform, as can be seen in the figures 7 and 8, respectively.

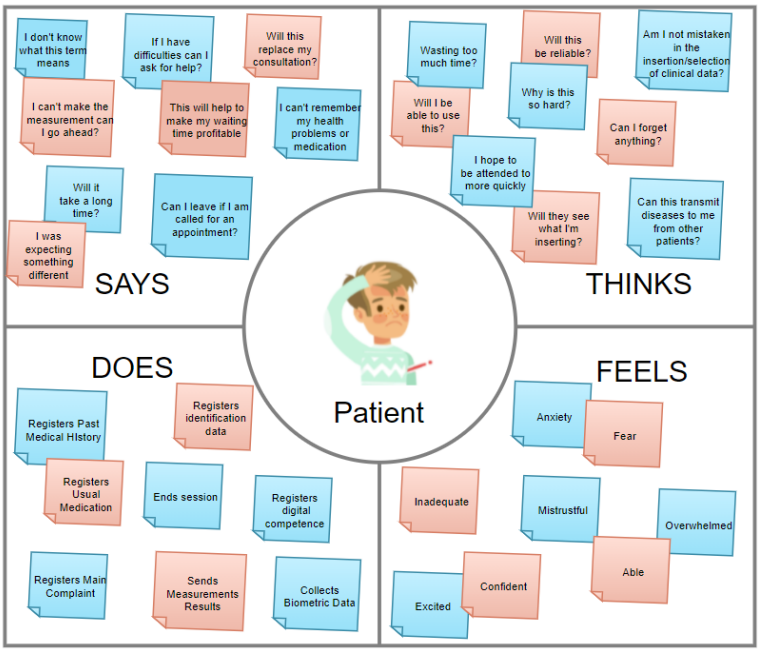


Figure 7: *Patient's empathy map*

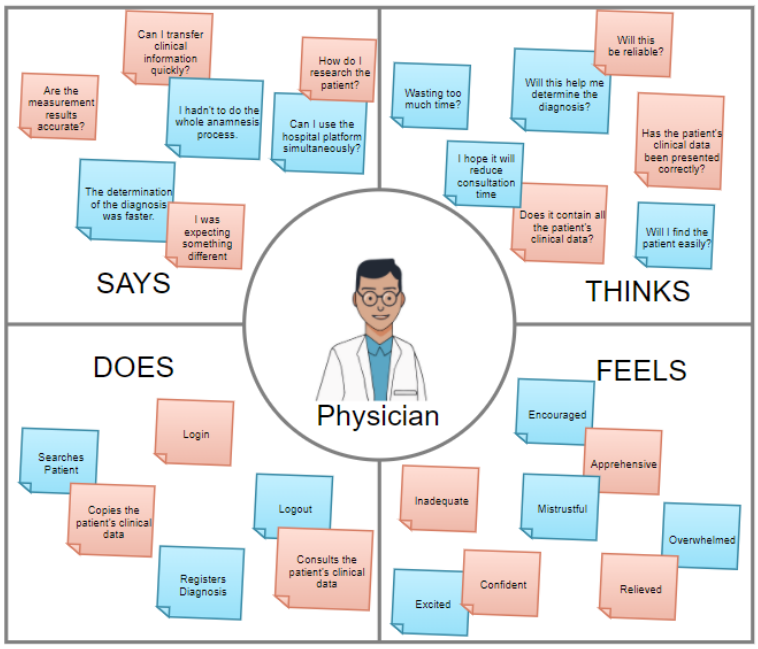


Figure 8: *Physician's empathy map*

A persona is a fictional character that represents a type of important user of the product under development. The purpose of personas is to create reliable and realistic representations of key audience segments for reference. Personas help to focus decisions surrounding product components by adding a layer of real-world consideration Affairs (2013 (accessed November 10, 2020). Below are defined the three personas who will use the self-service kiosk, as can see in figures 9, 10 and 11.

Persona I

Young student of the Universidade do Minho

Mariana Araújo

Age	23
Education	Graduate in Biomedical Engineering
Location	Barcelos, Braga
Job title	Biomechanics Master's Student
Status	Single
Salary	Unpaid
Residence	Lives in a T3 with parents and sister

Lifestyle

Mariana is an extremely curious person since she was a child she loves to research and read science books and articles, having participated in several living science fairs and lectures dedicated to studies in the areas of science and technology. Occasionally, Mariana uses her social networks, although she is an apologist that this activity takes a lot of time away from her. At the end of the day, Mariana practices figure skating in a skating club in Barcelos, to relax a little and keep in shape.

Context of use of the product

Mariana sometimes suffers injuries during her figure skating training which can only be treated by the emergency department. As Mariana doesn't like to waste time, she wants to leave ED as soon as possible. Mariana would like the ED to make her waiting time profitable through a kiosk, where she could record all her clinical data before the appointment, avoiding wasting time during the consultation and informing the physician about her clinical condition.

"Every second is time, we have to make it profitable"

Figure 9: *Persona I*

Persona II

Middle-age farmer in Agricultura É Fácil, Lda

Domingos Santos

Age	50
Education	9th year of schooling
Location	Mirandela, Bragança
Job title	Farmer
Status	Married
Salary	EUR 700 monthly
Residence	Lives in a T4 with wife and two children

Lifestyle

Domingos loves to cultivate the land, either with rural methods or mechanized. Since he was a boy, he loved to plant potatoes and other vegetables on his grandparents' farm. This passion has remained to his adult life, exercising in Agriculture É Fácil, Lda, activities of services related to agriculture. Domingos likes to research new tools that will allow him to have more productive agriculture. He uses the internet from his mobile phone or the company computer to read content about new tools. Besides doing some searches on the internet, Domingos sometimes uses the weather application to see the weather for the next few days.

Context of use of the product

Domingos wears out your body a lot in agriculture and sometimes you feel a lot of back pain. Only when the pain is agonizing does Domingos turn to ED because he does not want to receive a lower salary at the end of the month. Domingos would like the ED's waiting time to be shorter so as not to lose many hours of work and suggests that the ED should provide some technology to advance the consultation process.

"Time is money"

Figure 10: *Persona II*

Persona III

Elderly woman retiree

Rosa Pereira

Age	78
Education	4th year of schooling
Location	Vizela, Braga
Job title	Retired
Status	Widow
Salary	EUR 300 monthly
Residence	Rest Home

Lifestyle

During the day, Rosa likes to do crossword puzzles and watch television. She has trouble walking, so she spends all her time sitting on the sofa or lying on the bed. Rosa calls her children through her phone with keys, which is the only functionality that Rosa knows how to do on this device. The grandchildren when they visit Rosa at the rest home invite her to play games on their tablets. The rose is receptive to play but only if her grandchildren play with her.

Context of use of the product

Rosa falls many times due to her difficulties in walking, being transferred to ED after the falls. She hates hospitals and is immensely afraid of catching other patients' diseases while staying there. She wants the waiting time to be quick and she is willing to use any kind of technology to reduce her stay in the ED. However, Rosa says that assistance is essential to learn how to use this technology.

"Less time in the ED, my health is grateful"

Figure 11: *Persona III*

Having established during user research what users expect from the product, what their goals are and how they like to operate a system, the process moves on to the product design. The product's design revolves around functionality and usability, and at this phase, the UIs of the system are planned, and the flowchart of states and mockups are developed.

Since patients' personal information and clinical data will be collected, a privacy policy should be set up and accepted so that patients can access the kiosk's functionalities. Afterwards, they register their digital competence and personal information. The digital competence register is only performed in the second version of the kiosk application. The system's main functionalities are to register the patient's past medical history, the usual medication and main complaint symptoms. Biometric data collection and sending are also functionalities of the system, the latter being optional and only performed in the first version of the kiosk application. The patient should also be able to finish the kiosk session at any time. Given these system particularities, the kiosk's UI was planned and presented in table 3.

The components of the UI depend on the state the application is in since the flow of the application's interfaces is the response given to the different states. These states, in turn, depend on the user's actions in the application itself. Therefore, it was developed a flow between the application's states of the self-service kiosk.

Initially, the patient will have to accept the privacy policy to be able to continue the session. Once the terms are accepted, the patient can proceed to the digital competence interface and then to the personal information interface. In the past medical history interface, the patient registers the health problems and moves on to the usual medication interface. Here, is questioned whether the patient takes any usual medication or not. If so, the patient will register it, and if not, the system launches the main complaint interface. In this interface, the patient specifies the main complaint by selecting one of the main complaints provided or inserting a new one. Afterwards, the main complaint registered by the patient will be explored. If the patient inserts a new main complaint, the main complaint exploration is not performed, and the patient proceeds to the biometric data measurements. After the measurements were collected, the patient can *Electronic Mail (E-mail)* the results by entering the address. If the patient does not want to receive the results, the system launches the final interface. The flow between states is translated into the flowchart in figure 12. The registration of digital competence and the send of the results are in dashed form since these functionalities are only performed in the second and first version of the kiosk application, respectively.

Table 3: *Kiosk's UI*

Interface	Description
Welcome	First application interface, from which patient can start the kiosk session.
Privacy Policy	If the patient accepts the privacy policy terms, the patient may be admitted to the system.
Digital Competence	This interface allows the patient to answer some questions regarding the digital competence.
Personal Information	In this interface, the patient will register the personal information.
Past Medical History	The patient will be able to register the health problems through this interface.
Usual Medication	If the patient presents a usual medication, the patient can describe it in the interfaces associated with this functionality.
Main Complaint	The patient can choose the main complaint according to those provided by the interface, or insert a new main complaint. After the choice of the main complaint is made, it will be explored.
Biometric Data	This interface will provide the patient with instructions for correctly measuring the SPO2, HR, body temperature, and BP.
Send Results	After the measurements were collected, the patient can send the results by E-mail through this interface.
Final	This interface invites the patient to go to the waiting room after the session has ended.

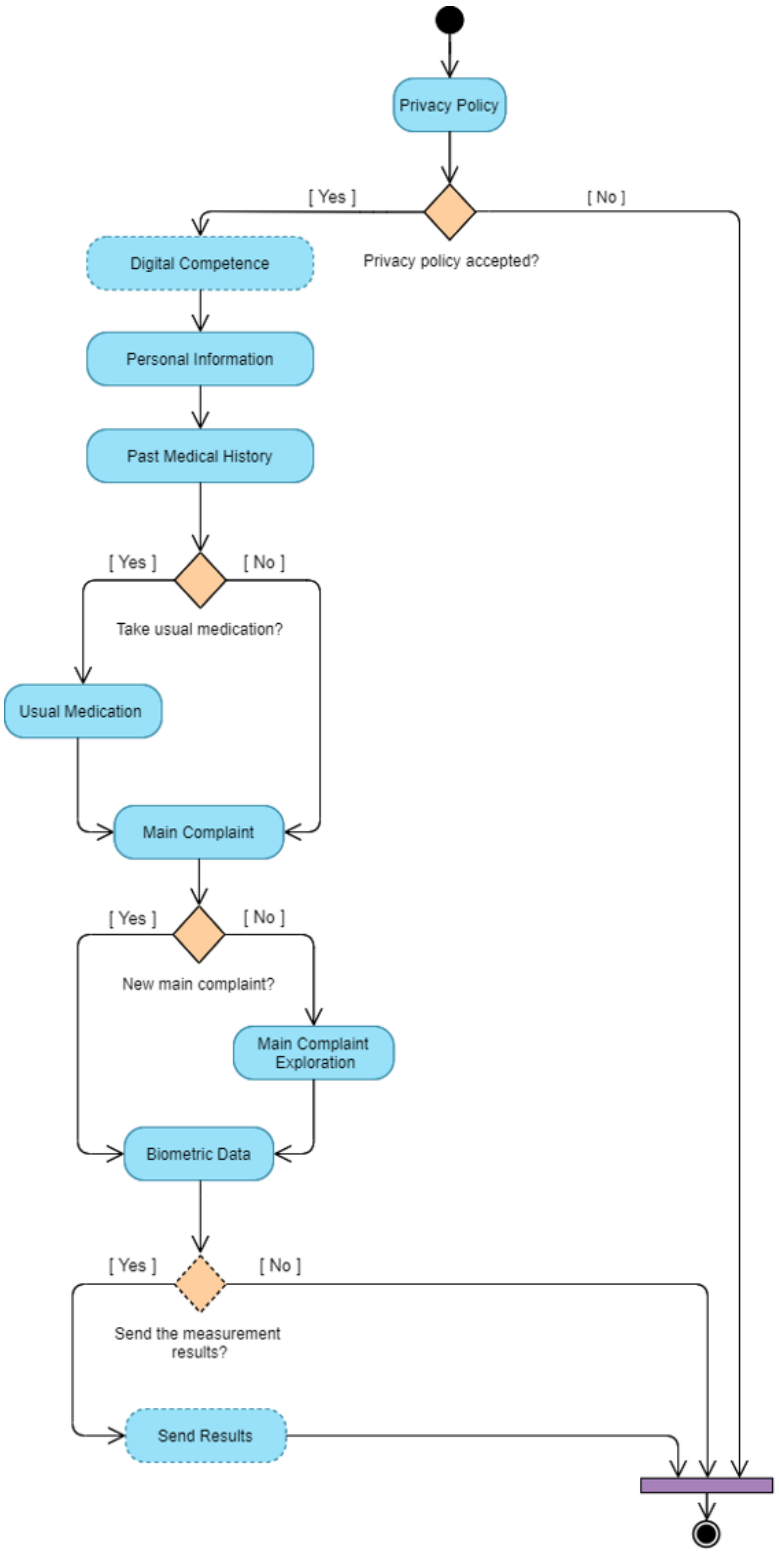


Figure 12: *Application's states flow diagram*

Since the web platform will make patients' clinical data available to physicians and will be used in a hospital environment, it makes sense that authentication is required to access the web platform. The main functionality of this platform is to consult the registers made by patients. This functionality first requires a patient search to allow the consultation. The structured and organised copy of the patient's clinical data is another action that can be performed. After the physician has determined the patient's final diagnosis, the physician can register that diagnosis. The Logout functionality becomes essential to safeguard the patients' clinical data.

After defining the particularities of this system, the Web platform's UI was planned and is presented in table 4.

Table 4: *Web platform's UI*

Interface	Description
Login	The first page of the application allows the physician to authenticate himself.
Patient Search	The desired patient search is performed at this interface.
Consult	In this interface, the physician can consult the patient's clinical data as well as copy them.
Register Diagnosis	Here, the physician can register the patient's diagnosis.

Mockups are low-fidelity graphical prototypes commonly used, as a "quick and dirty" way of gathering and specifying requirements for a software or application to be developed. These requirements can have different types, including those related to the appearance, the behaviour, and the data of a product from an end-user perspective. One of the features that motivate the building of mockups is the clear understandability of their concepts, for both developers and end-users. This feature is due to the use of visual metaphors (e.g., windows, buttons, links, text boxes, and pop-ups) that are familiar to end-users, and at the same time understandable by developers Rivero et al. (2019).

Digital mockups can be created using design software such as Axure and Adobe XD to design the real interface. Axure was the software used to create the mockup for the first version of the kiosk application. The design of the mockups for the kiosk application's second version and the web platform had the collaboration of an Instituto Politécnico do Cávado e do Ave graphic design student, who advised the use of Adobe XD software. This collaboration helped us in the graphical layout's development and provided us with visual

and interactive elements designed by the student.

The mockup of the kiosk application's first version, have different interfaces for the same functionalities, to discuss which interface elements should be used for a better interaction user-system.

A symptom evaluators survey was conducted for the mockup's design of the kiosk application's second version. These symptom evaluators 36 (2020 (accessed September 29, 2020); 37 (2020 (accessed September 29, 2020); 38 (2019 (accessed September 29, 2020); 39; Fitzgerald (2018 (accessed September 29, 2020); 41; 42 helped us during the graphical layout design, through the visual and interactive elements used for each functionality.

The web platform's mockup was developed in compliance with the *Centro Hospitalar Universitário de São João (CHUSJ)*[1] physician needs. He intended a platform that would allow a fast and efficient search of patients, a selective, structured and uniform presentation of clinical patient data and a quick transfer of clinical patient data to another platform.

The mockups of the UI developed for the self-service kiosk and the web platform are presented in the Appendix section C.

3.5 E-ANAMNESIS DESIGN

Medical anamnesis is one of the key functions to reveal health problems. The correct assessment and handoff of this information are the preconditions for a specific and cost-saving diagnostic and therapy. This process is based on the collection of past medical history, usual medication, main complaint exploration, including the location of the pain, how long the pain has been present, and the pain level. These answers, plus the patient's biometric data, allow the physician to get a more accurate diagnosis. Gruene (2016).

All the research work carried out for E-anamnesis design was reviewed by a specialist physician.

3.5.1 *Past Medical History*

The past medical history corresponds to the total sum of a patient's health status before presenting the main complaint. Includes major illnesses, any previous surgery or operations and any current ongoing illness (e.g., diabetes) Swartz (2020). Many patients forget their

1 https://portal-chsj.min-saude.pt/.

medical events and report little past history during their interview with their physicians. These patients are generally not purposefully concealing information, only need to be prompted by the right questions Goldberg (2018 (accessed September 7, 2020). Thus, a survey of the diseases that most affect the Portuguese was conducted.

Portrait of Health in Portugal

In 2015, brain-cardiovascular diseases were responsible for 29.7% of deaths in Portugal. Oncological diseases have seen a very significant increase among the Portuguese population, is already the second cause of death.

Hypertension is one of the cardiovascular risk factors, affecting 36% of the Portuguese aged between 25 and 74. As for total cholesterol, 63.3% of the Portuguese (25-74 years old) have high levels. As for diabetes, it affects 10% of the Portuguese population, between 25 and 74 years, especially men and older age ranges.

Obesity is one of the risk factors with the most impact in diseases in Portugal and 28.7% of Portuguese people aged between 25 and 74 suffer from obesity, mainly women (32.1%).

Mental health mortality is low, occurring mainly in people with severe mental illnesses, most of them treatable (major depression and bipolar disorder).

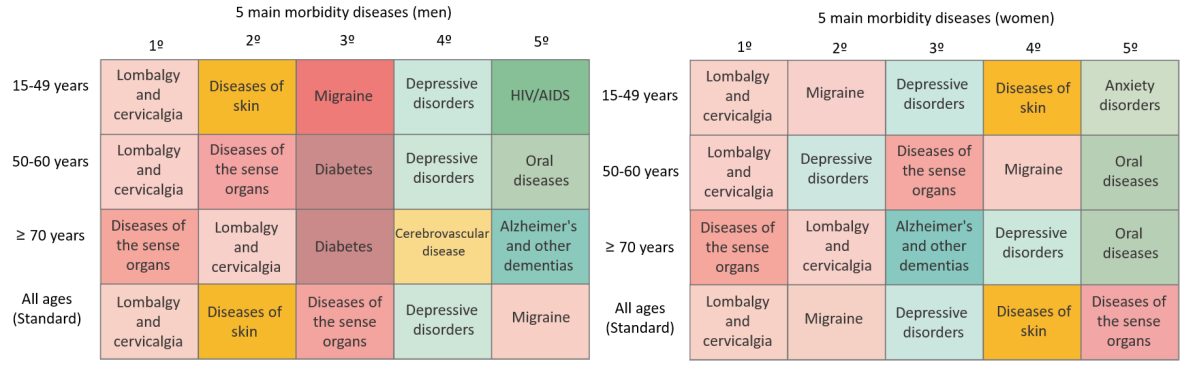
According to the latest report by the Organisation for Economic Co-operation and Development, Portugal is among the countries with the lowest asthma mortality. The analysis of standardized asthma mortality shows that mortality occurs mainly in age ranges above 65 years of age with values, in 2015, of 4.0/100,000 inhabitants. Tuberculosis in Portugal has achieved significant improvements. In the last decade, the reporting's rate and the incidence of tuberculosis have dropped by about 40%. In 2017, according to provisional data, there were fewer than 16 cases per 100,000 inhabitants.

By the end of 2016, 56,000 cases of *Human Immunodeficiency Virus (HIV)* infection had been diagnosed and reported in Portugal, of which more than 21,000 developed into *Acquired Immune Deficiency Syndrome (AIDS)*. Viral hepatitis, a long-standing health problem, has only recently become a global threat to public health. Today, Portugal registers 20 to 30 new cases per year, most of them in age ranges over 35 and not covered by vaccination.

Given the ageing population, the prevalence of chronic diseases, and the emerging need to ensure quality and cost-effective care, specific policies have been defined which favour an

integrated approach to chronic diseases such as kidney failure. In Portugal, there are also more than 5,000 people with Rare Disease.

As for the quality of the Portuguese's life, this is mainly affected by musculoskeletal diseases, depression, skin diseases, and migraines 46 (2018). The five main causes of morbidity by age range, women and men in Portugal are presented in figure 13.



Note: Adapted [reprinted] from "Retrato da Saúde 2018", Ministério da Saúde Lisboa, 2018

Figure 13: *Five main causes of morbidity by age range (Years Lived with Disabilities per 100,000 inhabitants), women and men aged 15 and over, Portugal, 2016*

The most common health problems in Portugal were selected, after analysis, and table 5 was obtained. In order to remind patients of their health problems, the selected ones will be presented to them by bypassing the oblivion of their past medical history.

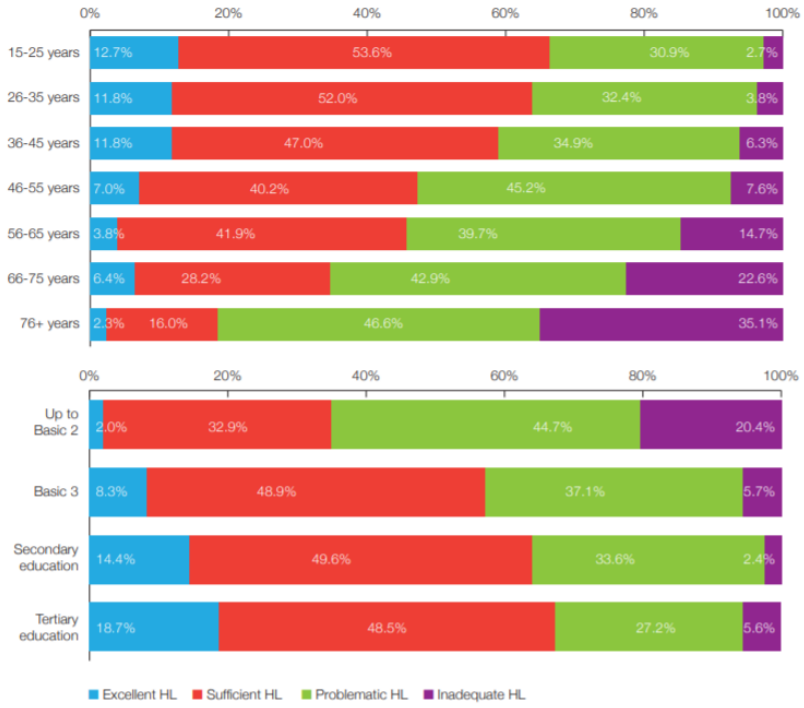
When health literacy is compared across different European countries, Portugal appears in a less favourable position. However, two distinct groups can be identified in Portugal when it comes to health literacy: elderly people with lower education and a highly educated young population. These two groups need different strategies as a health literacy target (elderly people with lower incomes and educational resources are the most vulnerable group) in the use of health information in their daily routines. Figure 14 shows health literacy levels by age and education levels da Saúde (2018).

Since the elderly will essentially be the population expected in the ED, and they have a low level of health literacy, the several health problems were defined avoiding doubts regarding their names.

The definitions of the health problems are presented in the Appendix section D.

Table 5: *Most common health problems in Portugal*

Disease Groups	**Disease**
Brain-Cardiovascular	Thrombosis
	Heart Attack
	Heart disease
	Hypertension
Risk Factors	Diabetes
	High Cholesterol
	Obesity
Mental Health	Depression
	Bipolar Disorder
	Anxiety
	Migraines
Respiratory	Asthma
	Tuberculosis
Other diseases	Cancer
	HIV/AIDS
	Hepatitis
	Kidney Failure
	Rare Disease
	Musculoskeletal disease
	Skin disease
	Alzheimer's and others dementias



Note: Adapted [reprinted] from "Health System Review – Portugal Phase 1 Final Report", by Organização Mundial da Saúde, 2018

Figure 14: *Health literacy levels by age and educational levels*

3.5.2 *Usual Medication*

Obtaining an accurate usual medication is the first step in the process of collecting medicines from patients. This usual medication usually consists of a list of all medicines (prescribed and purchased) that a patient was taking prior to his admission to the hospital. Without an accurate usual medication, prescribers may inadvertently make incorrect decisions about a patient's treatment, causing harm if previously discontinued medicines are restarted, or if current medicines are omitted or prescribed at the wrong dose for the patient.

Although physicians usually obtain usual medication during their initial patient interview, there is evidence that those obtained by pharmacists are more accurate. The cause for this is that the physician besides collecting the usual medication from the patient will have to gather a full clinical history, examine the patient, order investigations, formulate an initial diagnosis and prescribe a patient's medicines. Another factor that can influence the collection of usual medication is that when physicians review a patient on admission, the patient may not be able to provide an accurate list of medicines, especially if the patient is confused or particularly distressed by the cause of his admission Nickless and Davies (2020).

Medication non-compliance/confusion is a major clinical problem, particularly when regimens are complex, patients older, cognitively impaired or simply disinterested Goldberg (2018 (accessed September 7, 2020).

In this way, specific questions were defined concerning the patient's usual medication. The questions that will obtain a precise usual medication are the following:

- What is your usual medication?
- What is the medicine dosage?
- How often do you take it?
- What are the periods of the day when you take it?
- Which route of administration?

The medicines' name should be presented to the patient, since forgetting them is quite common, especially for patients with complex regimens. This decision will make it easier to remember medicine's names, avoiding, for example, the omission of them.

Therefore, research of medicines databases, that provide information on medicines marketed in Portugal, was made.

Infarmed provides the national database of medicinal products for human use, Infomed. This database contains information on medicinal products for human use, including the name, active substances, dosage, pharmaceutical form, presentations, retail price, reimbursement rate, storage conditions, etc 49. Since this database is private, the transfer of Infomed would entail monetary costs, making it impossible for us to use it 50.

Following the idea of obtaining a free medicines database, Article 57 database was found. This database is submitted by *Holders of Marketing Authorizations (MAHs)* for medicines in the *European Union (EU)* and the *European Economic Area (EEA)*. MAHss must submit information to the *European Medicines Agency (EMA)* on authorized medicines and keep this information up-to-date in accordance with EU pharmaceutical regulation. This database contains a complete inventory of all medicines authorized for use in the EU and EEA, including medicines authorized centrally via the EMA and those authorized at national level 51 (2020 (accessed September 7, 2020). The Article 57 database was thus filtered so that only medicines marketed in Portugal could be obtained.

After filtration, we obtained information on medicines, including product name, active

substance, route of administration, marketing authorization holder, pharmacovigilance system master file location, pharmacovigilance inquiries E-mail address, and pharmacovigilance inquiries telephone number. However, only the three columns, product name, active substance, and route of administration were used to obtain the necessary information of the medication.

Through this information, the medicine's names and the route of administration will be presented. The route of administration's presentation is of extreme relevance since some patients may not consider non-oral medications (e.g., inhalers, eye drops, creams, or patches) as medicines. They also may fail to mention medicines that they do not consider relevant, such as oral contraceptives or hormone replacement therapy, or other products they may be regularly taking (e.g., herbal medicines, or dietary supplements) Nickless and Davies (2020).

The presentation of the medicine's doses would also help to remind the patient of them. However, the Article 57 database does not provide this information, leading to possible omissions of the dose. As for the frequency of the medicines' intake, a choice was made to understand the possible frequencies (e.g., every day, or once a week). The choice of the periods of the day was based on the meals, having chosen breakfast, lunch, snack, dinner, and supper. These periods of the day were selected since the meals are more conducive for the patient to take his medicine.

3.5.3 *Main Complaint Exploration*

The main complaint is the patient's description of the reason for consultation, i.e., the most painful symptoms and signs, as well as their duration, which prompt the patient to seek medical attention. Its succinct generalization includes the main symptoms, signs, and urgent needs of the patient in the current consultation. A normal main complaint must have two elements, namely, symptoms/signs and duration. Symptoms/signs are generally known as the main symptoms and are not more than three in number. The duration is calculated from the time of the initial onset of symptoms/signs. If the symptoms or signs involved in the main complaint are related to certain body parts, the body parts should be included Xiao-Qing et al. (2020).

The patient will be questioned about the body part related to their main complaint, since the main complaint's choice may be tough to decide. After choosing the body part, the patient will be presented with the several associated main complaints names. For example, if a patient chooses the chest as a body part, the system will present the following main complaints: shortness of breath, cough, and skin inflammation. The associations of body

parts to the main complaints are presented in the Appendix section E.

The main complaints to be explored were deduced according to the most common diagnoses of patients with the blue and green bracelets in the CHUSJ ED. Figure 15 presents the most common diagnoses associated with the blue and green bracelets in CHUSJ. After analysing these diagnoses, the list of main complaints to be explored was determined.

Rótulos de Linha	Urgência - Nº de Urgências
Lumbago	102
Dor Nos Membros	40
Infeccao Do Tracto Urinario, Local Nao Especificado	30
Dor Abdominal - Erros - Classificações em Codigos Agregadores	29
Dor Articular - Erros - Classificações em Codigos Agregadores	25
Amigdalite Aguda	22
Individuo Que Apresenta Queixa Que O Preocupa Em Quem Nenhum Diagnostico Foi Fei	18
Infeccoes Agudas Das Vias Respiratorias Superiores De Local Nao Especificado	18
Cervicalgia	16
Cefaleia	16
Observacao A Seguir A Acidente De Trabalho	15
Tosse	14
Ciatica	11
Obstipacao - Erros - Classificações em Codigos Agregadores	11
Entesopatia De Local Nao Especificado	11
Transtorno Generalizado De Ansiedade	10
Dermatite De Contacto/Outros Eczemas Por Causa Nao Especificada	10
Dor Abdominal, Epigastrica	10
Total Geral	**1 186**

Rótulos de Linha	Urgência - Nº de Urgências
Lumbago	104
Dor Nos Membros	65
Dor Abdominal - Erros - Classificações em Codigos Agregadores	42
Infeccao Do Tracto Urinario, Local Nao Especificado	33
Dor Articular - Erros - Classificações em Codigos Agregadores	32
Infeccoes Agudas Das Vias Respiratorias Superiores De Local Nao Especificado	29
Cervicalgia	27
Tosse	23
Entesopatia De Local Nao Especificado	21
Dermatite De Contacto/Outros Eczemas Por Causa Nao Especificada	19
Ciatica	18
Alergia Nao Especificada	18
Amigdalite Aguda	17
Observacao A Seguir A Acidente De Trabalho	17
Individuo Que Apresenta Queixa Que O Preocupa Em Quem Nenhum Diagnostico Foi Fei	15
Dor Toracica - Erros - Classificações em Codigos Agregadores	14
Cefaleia	14
Dor Toracica Nao Especificada	14
Osteoartrose S/Especificacao De General. Ou Localiz. Na Perna	14
Total Geral	**1 519**

Figure 15: *The most common diagnoses in patients with the blue and green bracelets in CHUSJ*

List of main complaints

- Headache
- Earache
- Sore throat
- Muscular pain
- Cervical pain
- Chest pain
- Abdominal ache
- Painful urination
- Pain in the limbs
- Joint pain
- Sciatica pain
- Lumbar pain
- Shortness of breath

- Cough
- Vomiting
- Diarrhoea
- Constipation
- Itchy
- Inflammation of the skin

After choosing the main complaint, the patient will answer several questions about the main complaint symptoms as well as indicate the relief and aggravation factors that allow to relieve or worsen the pain.

The "When did the main complaint begin?" question is common to all main complaints, with the answers being only "Less than 7 days" and "7 or more days ago". These answers were based on the questions "Light pain for less than 7 days?" or "Light pain for 7 days or more?" used in the complaint flowcharts of the Manchester Triage System de Triagem (2010).

Since not all main complaints have pain, the question of the pain level will only be asked in certain main complaints. As there are no objective practical methods of measuring pain, this information has to be obtained through scales. The determination of pain intensity is always subjective. However, scales allow the physician to get a better idea of the patient's perception Ragab (2003); Younger et al. (2009); Downie et al. (1978); Josephine Teo (2016).

The Visual Analogue Scale 16 consists of a horizontal or vertical line, 10 centimetres long, which has a "No Pain" rating at one end and a "Maximum Pain" rating at the other. The patient will have to make a cross or a line perpendicular to the line at the point representing the pain intensity. Subsequently, the distance between the beginning of the line (which corresponds to zero) and the marked location is measured in centimetres, and a numerical rating is obtained Miguel (2003).

Figure 16: *Visual analogue scale*

On the Qualitative Scale 17, the patient is asked to classify the pain intensity according to the following adjectives: "No Pain"; "Slight Pain"; "Moderate Pain"; "Severe Pain"; "Maximum Pain" Miguel (2003).

Figure 17: *Qualitative scale*

The numerical scale 18 consists of a ruler divided into eleven equal parts, numbered successively from 0 to 10. The patient is expected to make the equivalence between the pain intensity and a numerical classification, with 0 correspondings to the classification "No Pain" and 10 to the classification "Maximum Pain" (pain of maximum intensity imaginable) Miguel (2003).

Figure 18: *Numerical scale*

On the Face Scale 19, the patient is asked to classify the pain intensity according to the expression represented on each drawn face. The expression of happiness corresponds to the classification "No Pain", and the expression of maximum sadness corresponds to the classification "Maximum Pain" Miguel (2003).

Figure 19: *Face scale*

The Face Scale was the scale chosen since it is a concrete scale and therefore easier to understand. This scale is currently one of the most used and recommended scales by the International Association for the Study of Pain. Although the quantitative scale is popular among the elderly, its disadvantages are the memory effect, and the qualification of pain rather than its quantification Batalha (2016).

Following the main complaint exploration, questions concerning the main symptoms of the patients were explored. Initially, research was done on the warning signs of each main complaint to deduce the questions. The MSD Manuals 60 and the CUF 61 (1969) were the

main sources of research. The MSD Manuals and the CUF provide reliable, clear, and easy to understand information on various medical questions, all of which prepared by specialist physicians. Simple answers were defined to these questions to allow a quick and concise answer. The answers vary between "Yes", "No" and "I don't know". No decision tree was built as all the questions developed were necessary for the main complaint exploration.

As mentioned above, the elderly will essentially be the population expected in the ED. Since they have a low literacy level, some medical terms are not known by them. It is, therefore, important to rewrite the questions presented to the patient with a common vocabulary. This process of rewriting the questions was held by reading them to older people with little medical knowledge. After reading the questions, the participants were questioned on what terms they didn't understand, revealing the terms that had to be changed. Since it would also be essential to understand which were the best terms to use for the questions, the terms were explained to the participants, so that other terms of better understanding could be suggested. Since some terms could not be replaced by more easily understood terms, these were defined in a short explanation, so that the patient can consult it in case of doubt.

The questions of each main complaint and the explanation of the complex terms of these questions are presented in the Appendix section F and in the Appendix section G, respectively.

The factors of relief and aggravation, allow us to perceive what relieves and aggravates the patient's pain, such as change of position, heat, cold, movement, cough, respiration, or rest Dos Enfermeiros (2009). For a complete evaluation of the pain, the relief and aggravation factors of each main complaint were researched, using the same research's sources as the questions concerning the main symptoms.

The relief and aggravation factors of each main complaint are presented in the Appendix section H.

3.5.4 *Vital Signs*

Vital signs are an important part of the ED medical consultation. Their "vital" nature and their importance to the medical consultation, make them essential in helping to assess a patient's overall physical health Gabayan et al. (2017). The four primary vital signs are body temperature, BP, HR, and respiratory rate. However, the vital signs may include other measurements called the "fifth vital sign" or "sixth vital sign".

Body temperature results from the balance between the heat produced and the heat spent by the human body. The normal body temperature is between 36 and 37° C. However, it depends on the person and his age, the activity performed, the time of day, and the part of the body where the temperature is being assessed. There are also several options for measuring temperature, such as rectal, axillary, tympanic, and oral 64 (2020 (accessed September 14, 2020). It is now possible to take temperature measurements without body contact, using thermometers with infrared technology. These thermometers allow a temperature measurement, with safe and hygienic results in only one-second 65 (2019 (accessed September 2, 2020).

BP is the measurement of the pressure or force with which blood passes through artery walls, and consists of two values:

- Systolic: it appears in the first place and measures the force with which the heart contracts and "expels" the blood from its interior.
- Diastolic: is the second value and concerns the measurement of pressure when the heart relaxes between each beat.

When the BP is too high, it means that the blood circulates exerting exaggerated pressure on the arteries, and therefore the heart has to make more effort than normal. There are three types of BP categories, the low-risk category (120/80 mm Hg), the medium-risk category (121-139/80 - 89 mm Hg) and the high-risk category (140+/90 mm Hg). The BP is measured through a BP monitor and is most commonly performed above the patient's elbow, and can also be performed on the wrist 61 (1969); 65 (2019 (accessed September 2, 2020).

HR is defined as the number of heartbeats occurring per minute, and the average resting HR for an adult human is between 60, and 90 beats Gonzalez-Sanchez et al. (2017). However, HRs may vary according to age, activities, general health, gender, emotions, pain, and medications. The rate is lower when sleeping and higher when active or exercising. Rates for infants and children is higher than adults. Well-conditioned athletes have a lower than average resting rate because their cardiovascular system has been developed to function more efficiently Lindh et al. (2013).

Respiratory rate is the number of respirations per minute. The normal respiratory rate varies with age, activities, illness, emotions, and medicines. The average respiration rate to pulse rate is 1:4 one respiration to four pulse beats. This signal is measured by counting breaths for 30 seconds and doubling the amount. This procedure will give the number of respirations per minute Lindh et al. (2013).

Pulse oximetry's reliability and simplicity have led some to promote its use as a "fifth vital sign". The pulse oximetry has been advocated as an accurate, simple, and noninvasive measuring method SPO2. Pulse oximetry can accurately measure SPO2 and reliably detect desaturation under various conditions. It also may improve the ability to assess the cardiorespiratory status of patients Mower et al. (1998). The pulse oximeter is the device that allows the measurement of oxygen saturation (this must be above 95%) 61 (1969).

All the vital signs mentioned above were those chosen for the kiosk, except the respiratory rate. This vital sign was not included because it is not extremely necessary for medical consultation.

4

E-ANAMNESIS PLATFORM IMPLEMENTATION

In order to improve the quality of the user's interaction and perceptions with the E-anamnesis platform, all decisions to implement the UI elements and functionalities were thought out and justified. The clinical business intelligence indicators were defined to analyse the data collected.

4.1 SELF-SERVICE KIOSK COMPONENTS

The self-service kiosk will be introduced to patients via a touchscreen monitor, along with biometric sensors to collect their biometric data. The sensors communicate via Bluetooth LE. This communication completely wireless facilitates the installation and repositioning of the kiosk. The touch monitor and biometric sensors mentioned are described below:

- **Touchscreen monitor**: The PROLITE T2735MSC-B2 is a 27-inch touchscreen monitor and is easily adjustable 69. Interaction with the Android application is done through this monitor.
- **Oximeter**: The Oximeter (MyOxy BW-OX1 Model), measures SPO2 and HR and uses a lithium battery (280mAh) that provides autonomy for 400 readings. The device is fairly easy to use: the user only has to place one of his ngers on the device and wait until the measurement is taken.
- **Thermometer**: The Thermometer (MyThermo BW-CX10 Model), measures a person's body temperature in 28 milliseconds, with a precision of +/- 0.2°C. This device has a lithium battery (DC3.7V) with longevity for approximately 40000 readings. To perform an accurate measurement, the user must position the device at a distance between 1 and 2 inches from the right temporal artery. A relevant feature of this device is that it does not require body contact with the user, which simplies the hygienization between different users.
- **BP Monitor**: The BP (MyTensio Wrist BW-BW1 Model), can measure three different parameters: systolic pressure, diastolic pressure and HR. The device has a digital

monitor, a wristband cuff, and also uses a lithium battery (300mAh), which provides power to perform between 100 and 150 measures. For an accurate measurement, the user must place the wristband with 1 or 2 ngers below the palm of the left hand, with the monitor button positioned on the right side. Unlike standard BP monitors that require users to roll up their sleeve to insert the cuff above the elbow, this device works on the wrist, making it much easier to use, especially in public environments. Contrary to the other devices, that have a discrete measurement model, the BP Monitor provides continuous measurement, sending a stream of real-time monitoring values.

Each biometric sensor has an associated application programming interface, provided by the company BewellConnect 65 (2019 (accessed September 2, 2020), which allows communication with the Android application. The recognition, connection and retrieval of each device measurement data is carried out through the Visiomed Bluetooth LE framework. This framework supports simultaneous connections, making it much easier to manage the connection and life-cycle of a LE device. Other devices, also associated with self-service kiosk are the webcam, TBee Box and keyboard.

- **Webcam**: The webcam allows the collection of personal information from the patient through the scanner of his CC. Together with the Regula Document Reader framework provided by Regula 70 (2020 (accessed December 26, 2020), the entire data extraction process will be carried out.

- **TBee Box**: The tbee box is a box, which gives access to Google Play for applications. 71 (2020 (accessed September 2, 2020). It features an Android 7.1.1 (Nougat) operating system with a Quad Core ARM Cortex A53 processor (Amlogic S905-X) and a WIFI of 2.4 GHz, and 5.0GHz. This box also has 2G DDR3 RAM and 16GB eMMC Flash storage. Although this box has an HD 720p camera, it does not have autofocus, and a webcam is required. The main advantage of the tbee box is that it allows the Android application to run on a large touchscreen monitor.

- **Keyboard**: The Ultra Slim 2.4G USB Wireless Keyboard, shows an advanced 2.4GHz wireless technology for up to 10m operation range (barrier-free) with good anti-interference ability and stable signal. It has Round and flat keys with an ultra-silent design for keyboard, comfortable to touch and operate. This keyboard also features a professional optical positioning technology that achieves more precise positioning and intelligent power-saving technology. The keyboard enters sleep mode if no operation for some time and will wake up when clicking in any key on the keyboard. With a low-battery warning function, the indicator light will turn on 72.

A sketch of the kiosk's appearance is shown in figure 20.

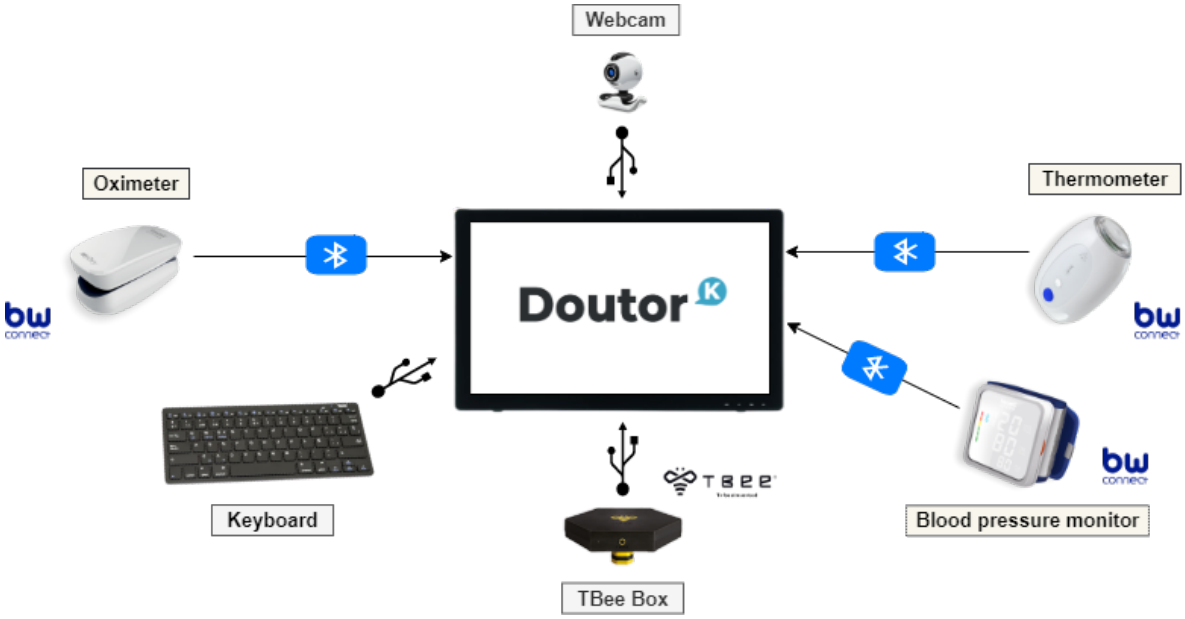


Figure 20: *E-anamnesis platform*

4.2 UI and Functionalities of the First Self-Service Kiosk Prototype

A prototype was developed, based on the development of a simplistic Android application with a structure close to a form. The main objective of this prototype is to gather a set of indicators. After analysis, these indicators allow the identification of difficulties encountered by users when interacting with the application. This prototype was developed only for an experimental study in a non-hospital environment.

The prototype architecture is shown in figure 21, which depicts a built-in Android application that interacts with three biometric devices. The Android application follows the Model-View-Controller architectural standard, which allows it to divide the application into layers with well-defined responsibilities. The data collected was stored into the application's local database, SQLite.

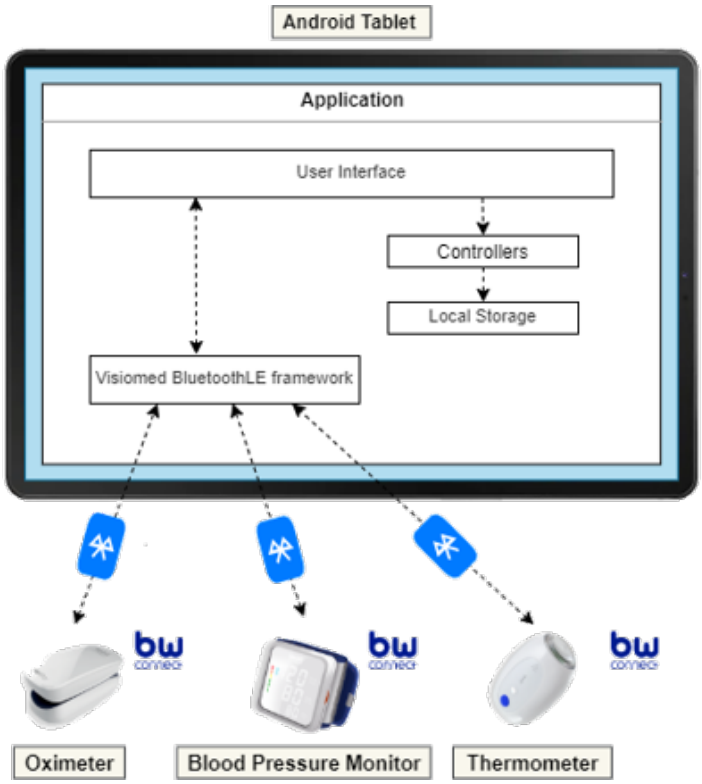


Figure 21: *Prototype architecture*

The kiosk prototype interface is divided into five groups of screens. The first screens group corresponds to the welcome screen and the personal information screen. On the welcome screen, the data privacy policy is displayed, as can be seen in figures 22 a and b. On the personal information screen, the users' personal information (age range, gender and education level) is questioned (22 c). The privacy policy was implemented to inform patients about how the application will collect, handle and process their data. An alert dialog was used to present the privacy policy. This element corresponds to a small window that asks the user to make a decision or enter additional information. It is advised for modal events that require users to act for continuing, as is the case. The alert dialog can be of the modal window or message box type. Once the privacy policy is accepted, the user moves to the personal information screen.

The personal information screen offers pre-defined answers via buttons, resulting in more concise and quick answers. The checkboxes suggested in the mockup were not used because they could lead the patient to select more than one option. The gender selection buttons feature colourful female and male images to allow a faster and more intuitive selection. Levels of education were not presented by cycle (e.g., first cycle, and second cycle), due these terms are less known in the elderly population. To avoid personal information being

forgotten, an alert dialog will appear informing that the selection is not complete, as can be seen in figure 22 d.

The "Continue" button allows to move forward in the session. This button has a green colour giving the idea to continue, like the traffic light, which shows the green to move forward. Typically, it also presents a motion animation to attract the user's attention, informing he may move forward.

The second group concern the past medical history screens. The main health problems in Portugal are presented for selection to drive the interaction. The user has the possibility of selecting health problems in each screen, as well as to add new ones whenever these are not listed. A brief explanation of each health problem can also be consulted by patients, thereby clarifying any doubts and reducing reporting mistakes. In figure 22 e, one can see that the past medical history's screens are divided into two parts. On the left side are presented the health problems, through radio buttons. These radio buttons allow selecting the options from the set of health problems. Next to each health problem, there is an icon of doubt. This icon will display a description with an image of the health problem on the right side when pressed. The "Other problems" button allow proceeding to the next screens of the past medical history. It was chosen to place this button instead of the "Continue" button as the button would reinforce the idea that the patient is still in the group of screens of the past medical history.

When the patient proceeds to the last screen of past medical history, the system will present an alert dialog questioning whether or not the patient has health problems other than those mentioned above, as shown in figure 22 f. If so, the number of health problems will be questioned through radio buttons in the alert dialog presented in figure 22 g, if not, the patient advances to the usual medication. If the patient does not select a quantity and wants to proceed, the system will prompt the patient with the alert dialog, shown in figure 22 h. After selecting the number of health problems, the new screen is launched, and the patient enters the health problems name into the text fields, shown in figure 22 i. The quantity of these interface elements on the screen corresponds to the number of health problems previously selected.

The alert dialogs used were different elements from those projected in the mockup. Initially, it was thought to present a speech balloon with buttons associated with each answer. However, the alert dialog offers a more suitable UI element and is designed for user decision making.

The third screens group consists of collecting the usual medication. Similar to the previous group, the system will present an alert dialog questioning whether or not the patient takes usual medication. If so, the patient will have to quantify the number of medicines, else proceeds to the main complaint exploration, the figures 22 j and 22 k represent these actions, respectively. This quantification will provide the number of screens to describe the medication. On each screen, the patient can enter the medicine's name and its dose and select the periods of the day of taking, as shown in figure 22 l. A dropdown was added to help patients to remember the medicine's names and avoid human errors when typing them. This dropdown includes all the medicines' names sold in Portugal, of Article 57 database. The dose will be inserted in a text field, and the selection of the periods of the day will be through buttons. The buttons are associated with images of periods of the day to facilitate the patient's choice.

In the fourth screens group, a screen with several main complaints buttons is displayed, where patients can select the main complaint or insert other complaints not listed, as presented in figure 22 m. In the mockup, two types of interface were designed for the selection of the main complaint. This interface was chosen because it was intended simple and direct interfaces, close to the form concept.

Once the main complaint is selected, several screens with yes or no questions about possible symptoms are displayed. As in group two, this group also provides brief explanations for some of the questions' terms about the symptoms. An icon of doubt is next to the answers, so the patient in case of doubt can see a brief explanation in the board presented on the right side. After the patient answers all the questions, two screens relating to the relief and aggravation factors are displayed. In these screens will be selected the factors what relieves or worsens the main complaint.

Figure 22 n shows an alert dialog, where the patient will have to insert the main complaint, not corresponding to any of the above mentioned, in a text field. Since this main complaint will be new, the system advances directly to the screens for collecting vital signs.

When the patient selects one of the main complaints mentioned, an alert dialog, shown in figure 22 o, is presented to him. This alert dialog will question when the main complaint started. After selecting the answer through the button, the patient can proceed to the main complaint exploration, depending on the main complaint selected. If the main complaint selected could cause pain, the system shows an alert dialog in which the patient indicates whether or not the pain exists. If so, a new alert dialog will be presented to select the pain level, if not, the patient will proceed to the main complaint' exploration, as can be seen

in figures 22 p and 22 q. The pain level selection is presented through a set of buttons with faces that allow selecting the pain level since the face scale was the chosen one for determining the pain level. The description below each button aims to help the patient in his choice.

One of the screens where the main complaint exploration is carried out is presented in figure 22 r. This screen presents a set of questions related to the symptoms of the main complaint. The answers to these questions are presented through buttons "Yes" or "No" with green and red colour, respectively. The colour green and red are often associated with a positive and negative result, respectively. Thus, these colours were used in each button to make the patient's answer as intuitive as possible. The buttons also feature a shadow and a darker colour associated with each answer selected. This feature creates a depth effect, allowing patients to know which questions they have already answered and review their answers.

The questions are presented simultaneously, unlike what was planned in the mockup, where one question at a time would be presented. This presentation was chosen since it would be tiring and more time consuming to answer one question at a time.

The "Next Symptoms" button permits to proceed to the next screens of the main complaint exploration. As in group two, this button was chosen instead of the "Continue" button, since it reinforces the idea that the patient is still in the group of the main complaint exploration's screens. In figure 22 s several relief factors are presented through radio buttons.

The last group permits the collection of the patient's vital signs. An alert dialog, figure 22 t, is shown to the patient to indicate that the measurement of a vital sign is about to start. This group has three different phases: video tutorial, data collection and result reporting. These three phases are repeated for each measurement. The video tutorial demonstrates the various steps that the patient must follow to perform the measurement successfully, as shown in figure 22 u. An alert dialog will be displayed when the video is fully viewed, allowing the patient to choose to watch it again or start the measurement (figure 22 v). In the data collection phase, the measurements are performed and the respective values sent to the application. Throughout the measurement, information will be provided on the measurement status. In the result reporting phase, the values of each measurement are accompanied by feedback. This feedback is provided by green, yellow and red coloured smiles, indicating normal results, attention or danger, respectively. The result reporting for the oximeter is presented in figure 22 w. Finally, it is given the possibility to receive the result reporting by E-mail, through an alert dialog in which the patient writes down the E-mail address, as shown in figure 22 x.

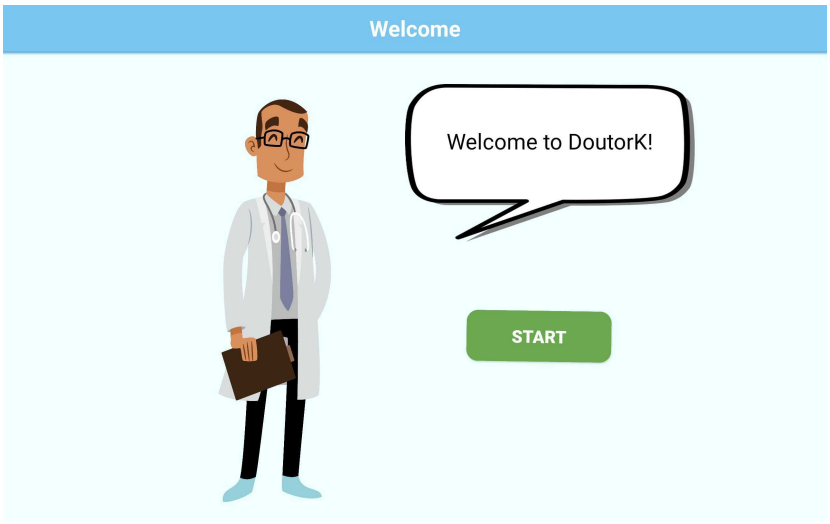
Errors that may occur during measurements were anticipated and cautioned, namely incorrect placement of the oximeter on the finger or instability of the hand at the time of measurement, incorrect placement of the cuff on the wrist, and invalid body temperatures (below 32ºC and above 43ºC). For errors caused by a patient during the use of the devices, error messages are shown along with the instructions that must be followed to correct it. Figure 22 y shows one of these error messages.

On the final screen, one thank the patient and wish his a recovery, as can be seen in figure 22 z.

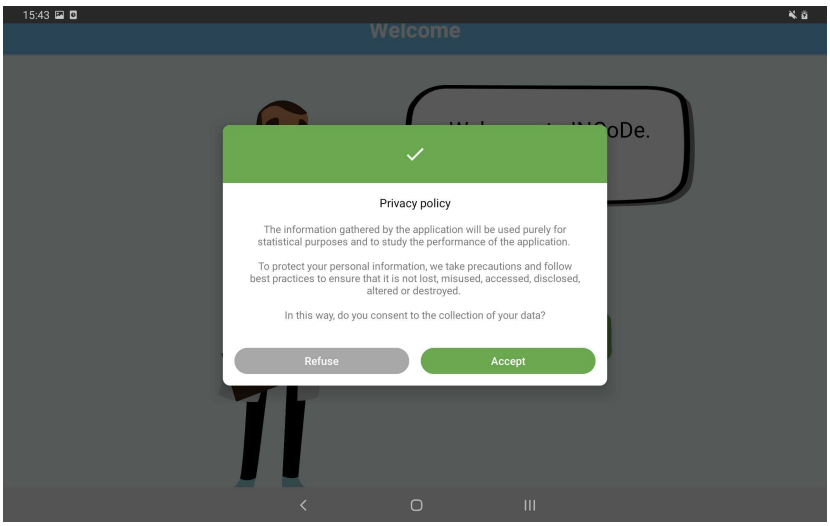
Since the user can leave the kiosk and forget to end the session, a timeout of approximately sixteen minutes was added to each interface. Whenever an interface does not present any interaction for sixteen minutes, the session will end, and a new session will restart.

The "Back" and "Exit" buttons displayed on all screens allow to go back to the previous activity and end the kiosk session, respectively. Both buttons present an illustration associated with each action, to facilitate the perception and avoid possible unintended clicks. The "Exit" button is essential so that the patient leaves the session without the need to finish it. When this button is pressed, the session data will be deleted, offering security in case of withdrawal. Its red colour symbolises the danger, as if the patient presses it, the session and all the data collected so far will be lost.

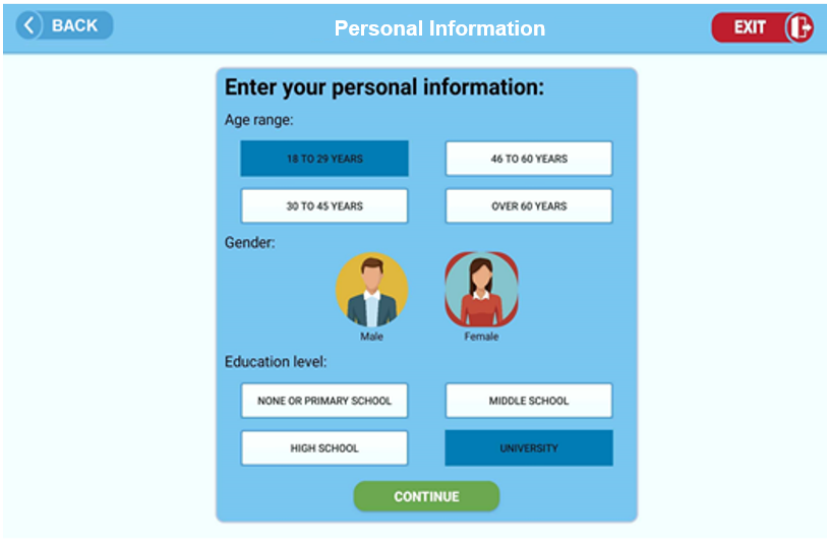
The main function of design and colours in hospital environments is to cause feelings of tranquillity, calm and relief, which can eliminate the tension of patients and thus contribute to their recovery. In this way, all the application's base colour is blue, which has a calming psychic effect, leading the patient to associate something safe with blue.



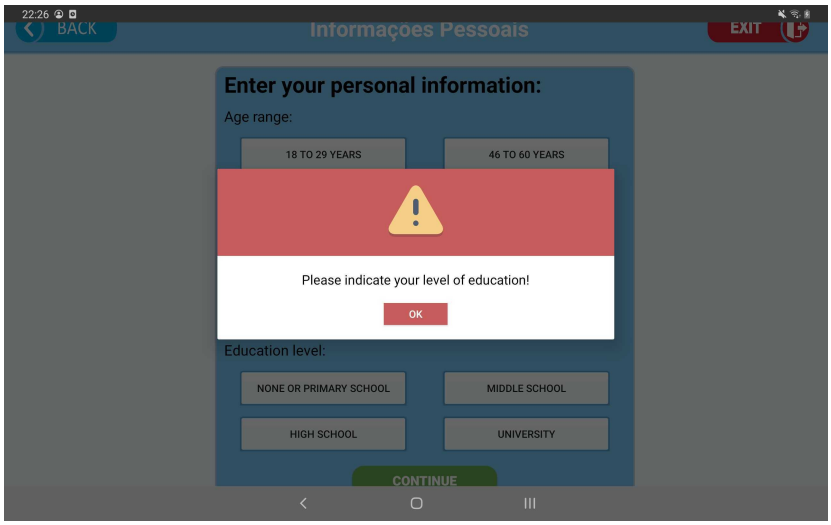
(a) *Welcome interface*



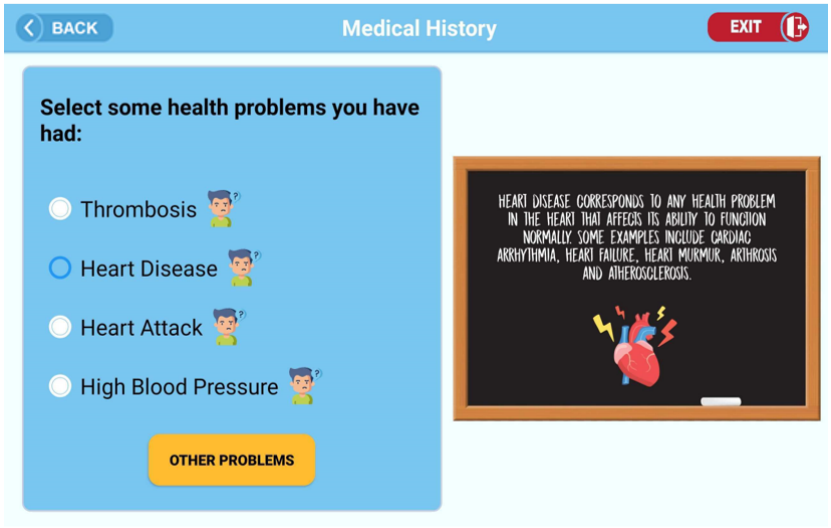
(b) *Privacy policy alert dialog*



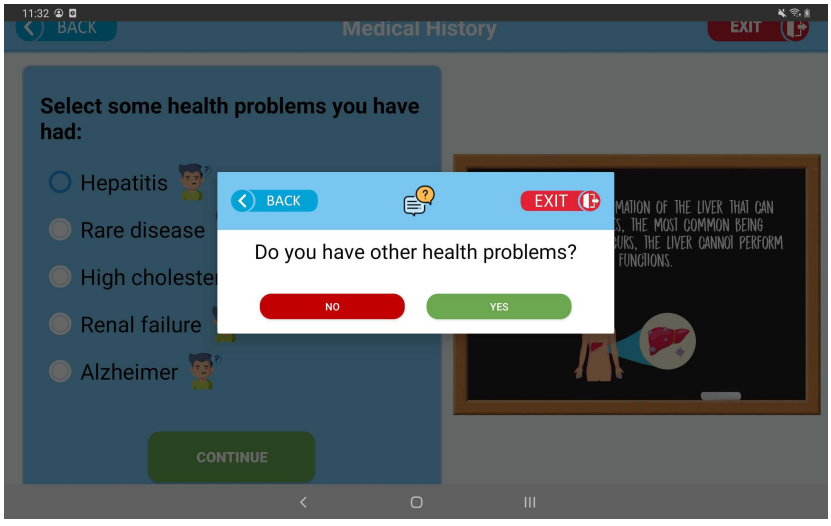
(c) *Personal information interface*



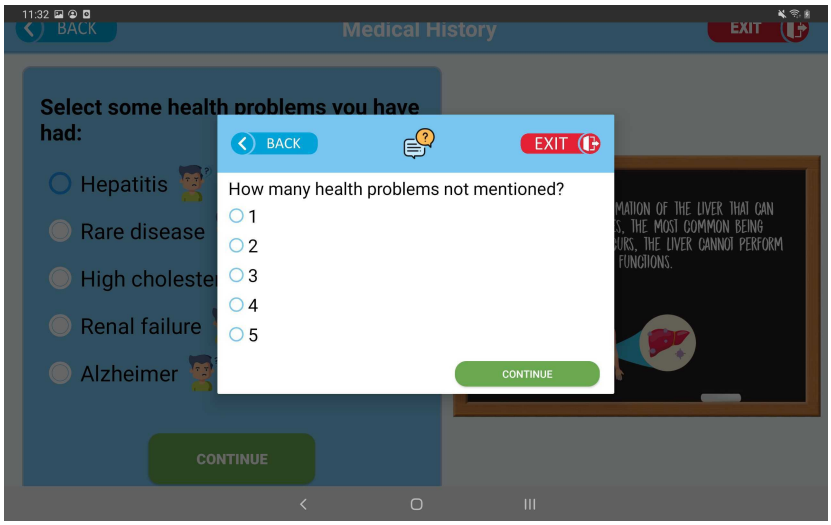
(d) *Personal information alert dialog*



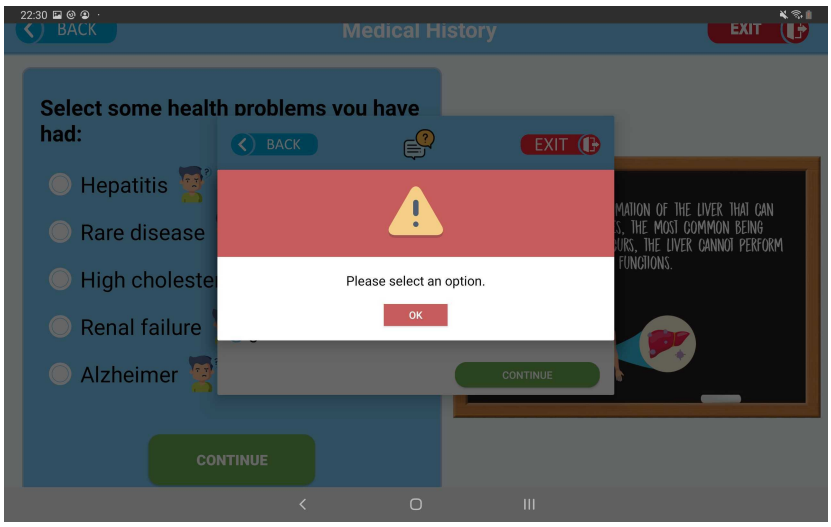
(e) *Past medical history interface*



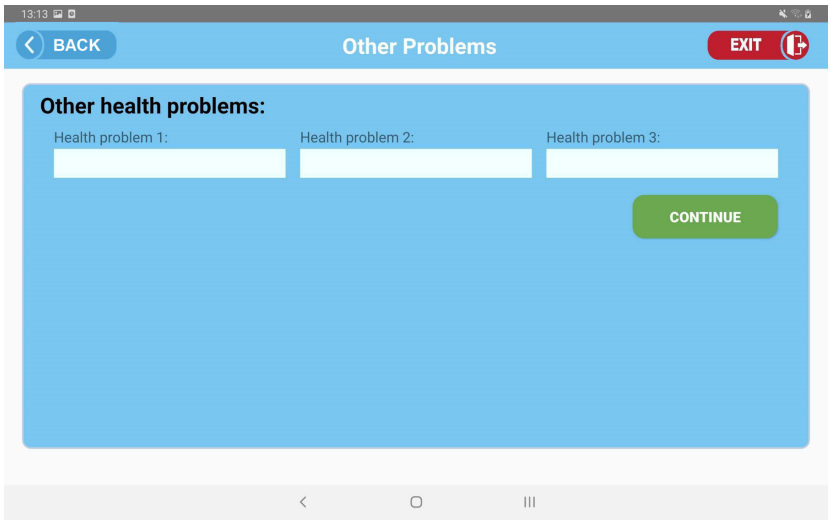
(f) *Other health problems alert dialog*



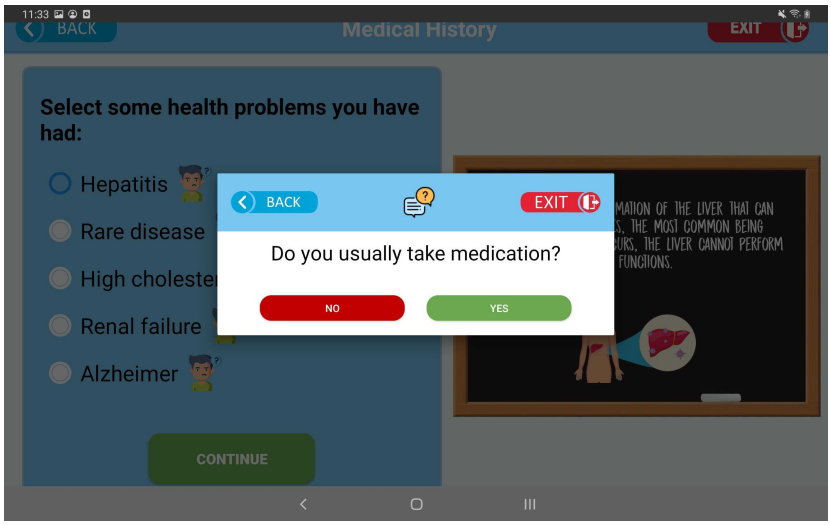
(g) *Number of health problems alert dialog*



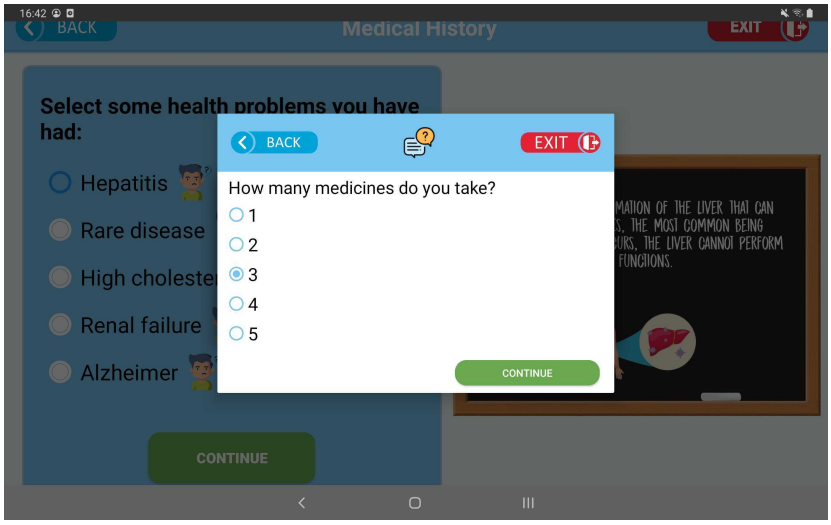
(h) *Select one of the options alert dialog*



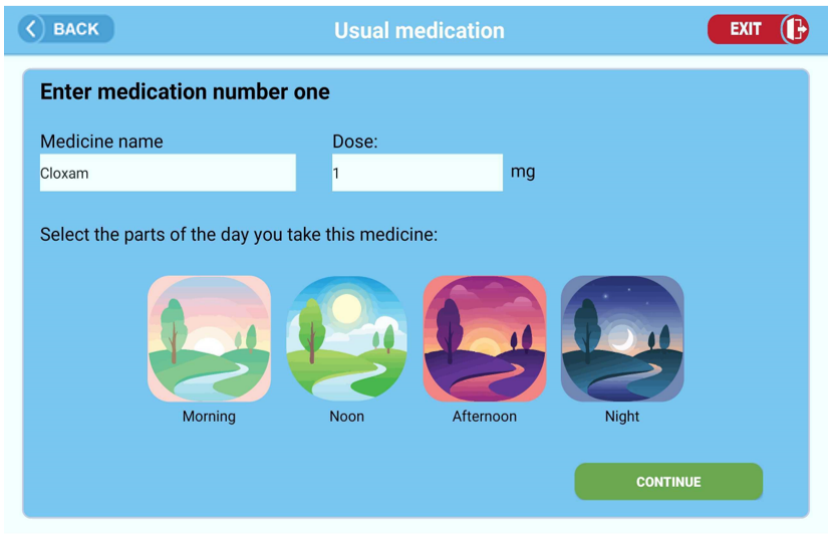
(i) *Other health problems interface*



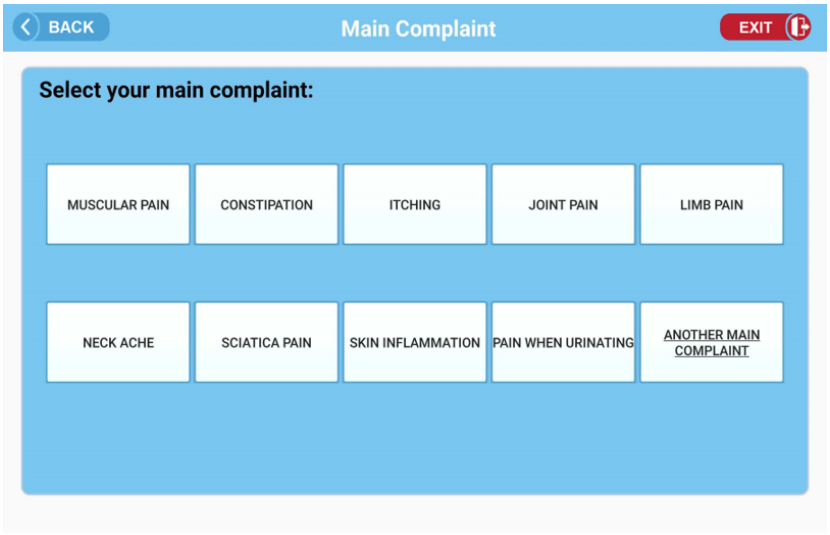
(j) *Usual medication alert dialog*



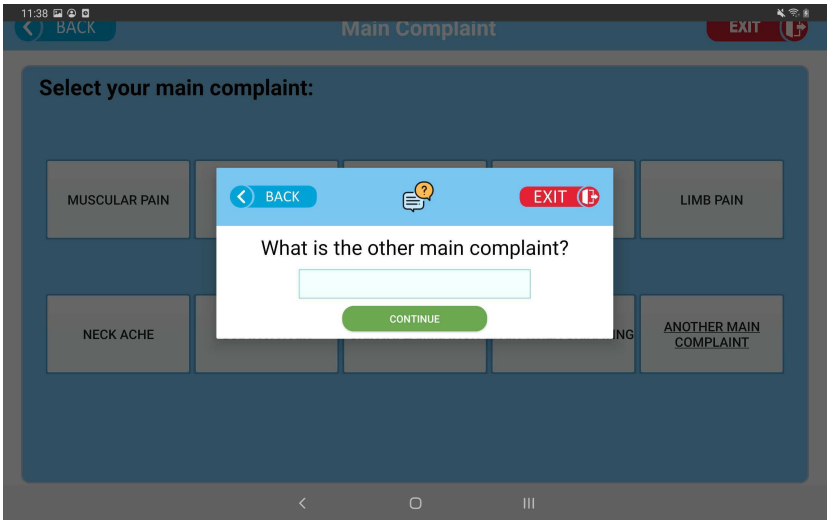
(k) *Number of medicines alert dialog*



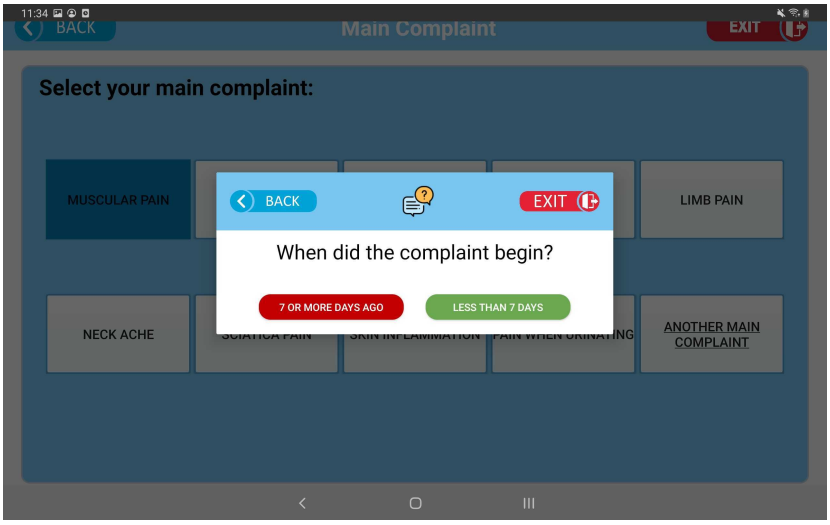
(l) *Usual medication interface*



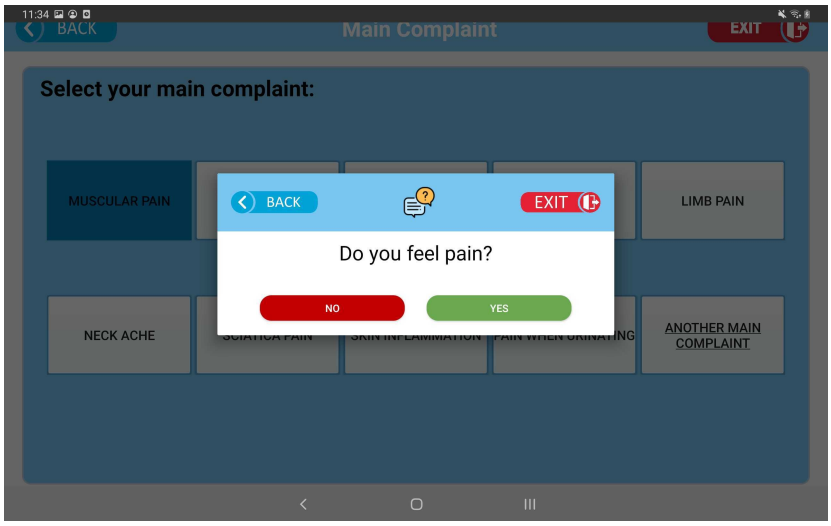
(m) *Main complaint interface*



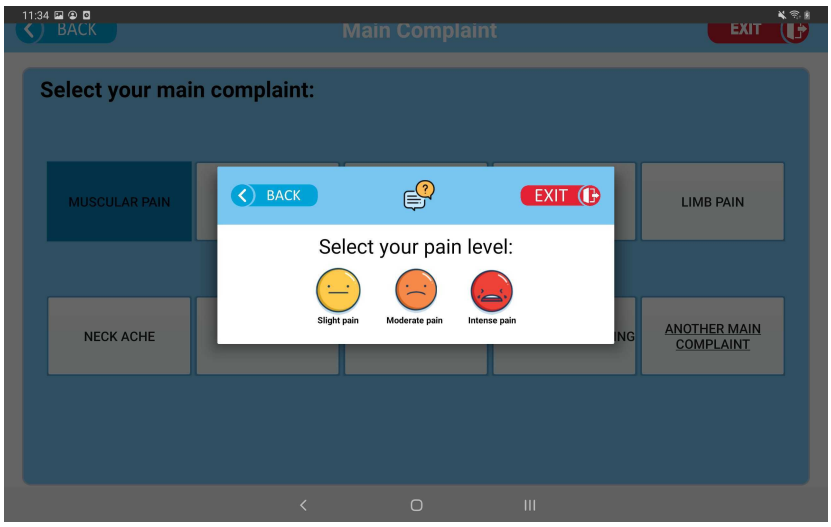
(n) *Other main complaint alert dialog*



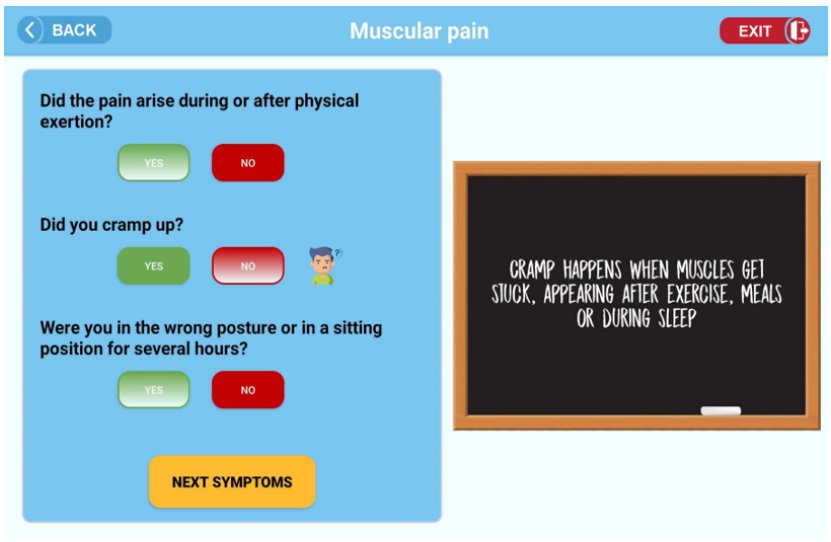
(o) *Start of the main complaint alert dialog*



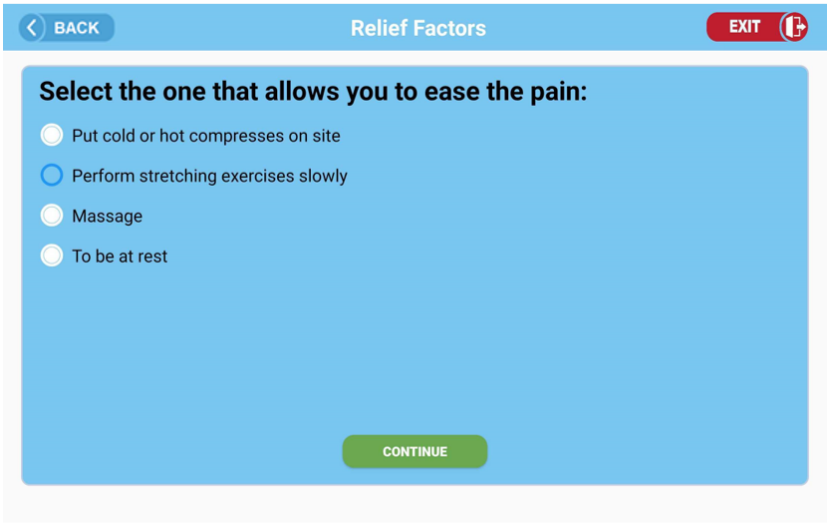
(p) *Feel pain alert dialog*



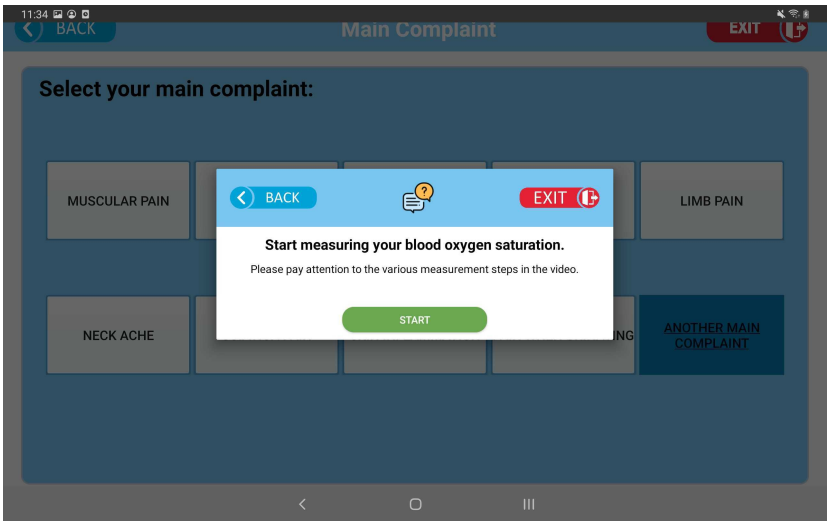
(q) *Pain level alert dialog*



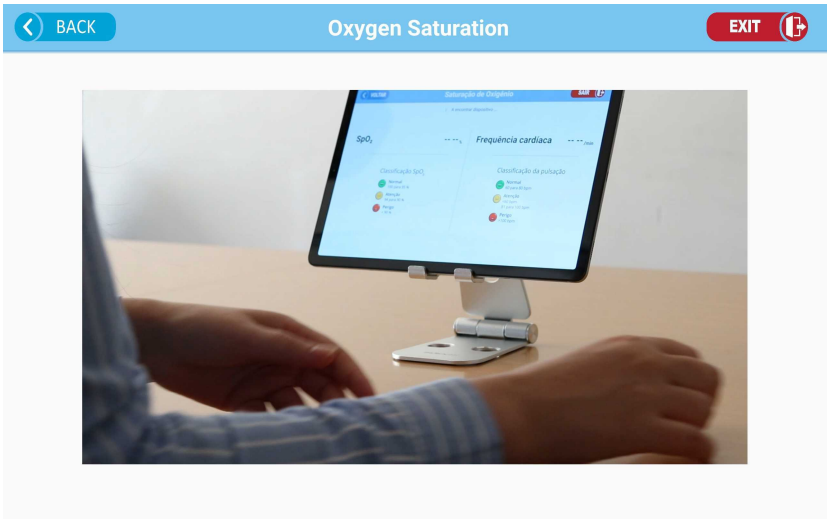
(r) *Main complaint exploration interface*



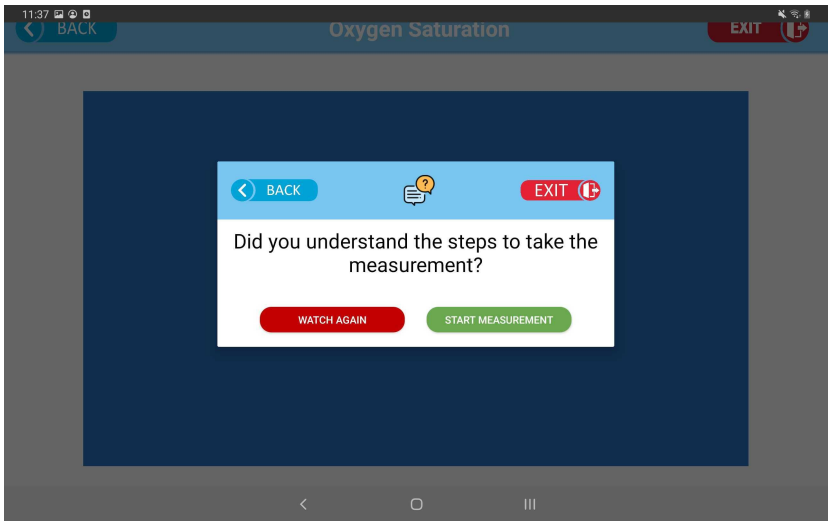
(s) *Relief factors interface*



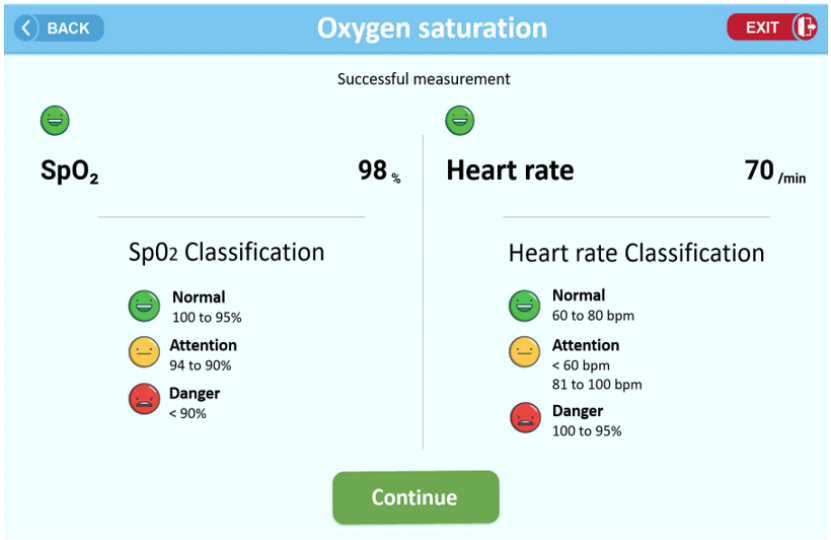
(t) *Start measurement alert dialog*



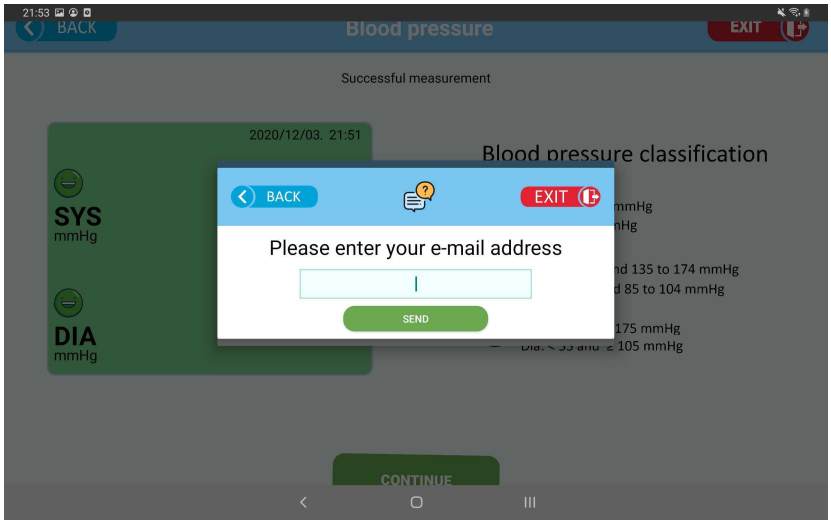
(u) *Video tutorial interface*



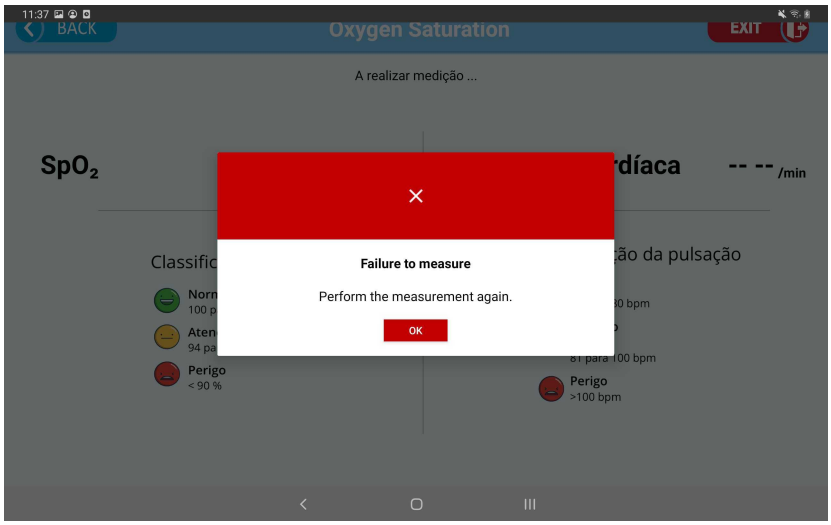
(v) *Understand the steps alert dialog*



(w) *Result reporting for the oximeter interface*



(x) *Send results alert dialog*



(y) *Error message alert dialog*

(z) *Final interface*

Figure 22: *(a; b; c; d; e; f; g; h; i; j; k; l; m; n; o; p; q; r; s; t; u; v; w; x; y; z) UI of the Android application's first prototype*

4.3 UI and Functionalities of the Second Self-Service Kiosk Prototype

The first prototype testing phase provided helpful insights into developing self-service health applications, mainly in terms of usability and human-computer interaction. These lessons facilitated the UI construction of the second Android application prototype. In this way, the division into five groups of screens was maintained, but with differences from the first prototype, both in terms of the UI and functionalities.

In the welcome screen (figure 23 a), the data privacy policy is displayed through an alert dialog, as shown in figure 23 b. The user only proceeds to the digital competence screen after accepting the privacy policy terms.

The digital competence and educational level questions will be crucial to find out the type of user. Through the identification patterns, it will be possible to build an intelligent UI/UX system. This system responds to the needs of each type of user, improving human-computer interaction. Each question will appear one by one, to avoid visual confusion and oblivion any question. By looking at figure 23 c, it is possible to see that the question will have associated to itself a set of answers presented in radio buttons so that the user only chooses one option of those mentioned.

Still, in this first group, the user's personal information will be collected by scanning the patient's CC using a webcam. As this prototype will be tested in a hospital environment, it is necessary to collect more personal information than in the first prototype (name, date of birth, nationality, civil identification number, and profile photo). This collection way will ease and accelerate the identification process by reducing patient interaction with the system, avoiding minutes-long form-filling manually, which could sometimes be tedious and exhaustive, leading the user to feel like giving up. During the collection, the user will only have to place his CC in front of the camera. The system will inform the patient of the approach or distance required for successful scanning, as shown in figure 23 d.

In the second group, all main health problems in Portugal will be presented on one screen, contrarily to the previous past medical history screens of the first prototype. This change will avoid the need to move between screens to look up other health problems, which can sometimes become fatiguing, especially for patients who do not have health problems or do not remember them. Like the first prototype, the patient may also add other health problems apart from those mentioned, without needing to respond to alert dialogs, which ultimately increases the session time and is dispensable. The users did not show difficulties in understanding the health problems in the first version. Thus, the health problems' explanations were removed in this version. When users know their health problem's name, they know what it refers to, the main difficulty they experience is remembering their health problem's name.

As can see in figure 23 e, there are two checkboxes with the answer "I don't have any" and "I don't know". These checkboxes allow going ahead in the session, even if the patient has no health problem or doesn't remember any, and cannot be selected simultaneously. It is important to point out that when a patient selects one of this two checkboxes and

later on registers a health problem without changing the answer, the system intelligently and automatically unchecks the selected checkbox, facilitating the interaction of the most distracted users.

The health problems are divided into disease groups to allow a faster and less confusing search of the health problems. The checkboxes where the health problems are presented were the elements chosen. These elements enable selecting one or more options from a set, contrarily the radio buttons. Their shape is close to a button, since the button is a more common element among users, especially for users with less digital competence. Additionally, the users know that by pressing it something will be selected. After selection, the checkbox will display a blue colour and an icon with a green checkmark to draw attention to the patient's selection. The symptom evaluator 36 (2020 (accessed September 29, 2020) also uses this type of checkboxes to select symptoms, further encouraging its use.

The patient can also add other health problems, other than those mentioned, by typing the problem name into a text field and adding it pressing on the add button. After adding the health problem, the text field will be clean for a new insertion. This button has an addition sign icon to reinforce its function so that patients have no doubts about its functionality. Health problems mentioned on the screen or health problems already entered cannot be added.

After selecting or adding a health problem, it will be registered in an answers' history, represented on the right side of figure 23 e. This answers' history allows patients to review the answers and edit them in case of a mistake, more quickly and easily. On this screen, by pressing the health problem's button placed in history, the patient can remove any health problem. This button contains the health problem and displays an icon with an X to reinforce the deletion's idea, helping the patient visually understand its functionality. However, the patient can also uncheck the selected checkbox, and the health problem will also be removed.

The answers' history includes the patient's age and gender. The history allows editing any answer via the "Edit" buttons associated with each question. When pressed, the system launches the respective question screen so that the patient changes the answer. This history presents a scroll so that all the answers given can be reviewed. Automatic scrolling always occurs after each answer, allowing the history to follow the patient throughout the session without the need for interaction. Several symptom evaluators already have this answers' history as 36 (2020 (accessed September 29, 2020); 37 (2020 (accessed September 29, 2020); 41; 42, reinforcing the importance of this component which may help more distracted or forgotten users.

The "Next" button is shown when the patient selects one of the presented checkboxes or adds a new health problem. Thus, the patient only advances in the application after checking some checkbox or add a new health problem. This will avoid forgetting or distracting the user from the application functionalities. All the interfaces of the application feature this behaviour.

The third group initiates by questioning whether or not the patient takes medication habitually. If so, the patient proceeds to the medication screen, otherwise to the main complaint exploration. The answers to the question are given by radio buttons since only one answer will be considered, as can be seen in figure 23 f.

The users experienced difficulty to remember their medication and to write it correctly in the latest version, even with the help of the dropdown. Thus, was decided to create a search system tailored to any patient's type. This search method allows the patient to type the letters of the medication name in a search field, and from the third letter typed the application presents only the checkboxes with the medicines containing those same letters as a substring (figure 23 g). When patients' finds it difficult to remember the medicine's full name, this system can be useful, by showing the medicines' names with only 3 letters typed. If the number of letters was less than three, the checkboxes' list would be too long to be seen by the user in this context. As with group two, these checkboxes allow the selection of more than one medicine and looks like buttons. After the selection of the medicine, the search field will be clear for a new insertion.

Before any search, the system displays the "I don't remember any" checkbox option, represented in figure 23 h, so that patients can proceed with the session if they forget the medicines' names. When a patient selects this checkbox and later on registers a medicine without changing the answer, the system intelligently and automatically unchecks the checkbox, facilitating the interaction with the application. All selected answers can be removed by pressing the medicine's button placed in answers' history.

Since there are quite extensive medicine names (with more than thirty-three characters), checkboxes with a larger size were created for these medicines. These checkboxes will appear at the end of the filtration results list, to avoid unnecessary long readings at the beginning of the search. The same happens with the history's buttons. If the selected medicine had a number of characters greater than seventeen, the button's size will also be different (figure 23 i).

After the selection of the medicines' names, the patient will describe each one. Initially, the patient will type medicine's dose in a text field element. However, it is not compulsory to insert it as can be easily forgotten. This element will also inform the patient that the dose needs to be typed in milligrams, as shown in figure 23 j.

For the medicine's frequency of taking, a radio button with the option "Every day" is displayed, since it is the most common answer. If this is not the medicine's frequency of taking, the patient can press the "Other" button to view and select another frequency. This button presents an addition icon to give the idea that there are more possibilities of frequencies.

The selection of the periods of the day in which the medicine is taken is similar to the last version. However, the buttons' images and descriptions are associated with the day's meals, as represented in figure 23 k. The day's periods selection can be performed either by pressing the button or the description, facilitating the interaction. More than one period of the day can be chosen, being the green colour chosen to represent the selection, once it is considered a confirmation colour.

The route of administration's question was left for last, because it will not always be carried out, since some medications present only one route of administration, being unnecessary to question. The question will present the medicine's routes of administration through radio buttons.

In the mockup, the usual medication description would be done by inserting the information in text fields. However, this option was discarded because it would require the user to remember the answers and type them instead of selecting them.

If the user has not entered the dose's value, it will appear "Not filled".

In the fourth group, the main complaint will be explored after being selected on the screen depicted in figure 23 l. On this screen, a front and back human body is displayed, so that the patient can select the body part related to the main complaint. To define the clickable areas of the human body images, the library ClickableAreasImage was used. After body part selection, the system will present a list of main complaints' names associated with that body part, through an alert dialog, for the patient selects one or even insert a new one. This human body will easily permit to identify and find the name of the main complaints. Symptom evaluators 36 (2020 (accessed September 29, 2020); 37 (2020 (accessed September 29, 2020); 38 (2019 (accessed September 29, 2020) also use this human body component to

help the user choose the main complaint or symptoms associated with a particular body part.

By entering a new complaint, not contained in the system, the main complaint exploration will not take place, and the patient proceeds to the vital signs collection. The layout for adding a new main complaint is the same as adding a new health problem to maintain internal consistency. Unlike the previous version, the main complaints are not in capital letters, allowing a faster reading of the whole list.

As in the first prototype, the main complaint exploration will be done through a set of questions related to the symptoms of the main complaint chosen. As can be seen in figure 23 m, the patient is informed about the main complaint previously chosen. Each question will essentially have as possible answers "Yes", "No" and "I don't know". The symptom evaluators Fitzgerald (2018 (accessed September 29, 2020); 38 (2019 (accessed September 29, 2020) use the same set of answers to explore the main complaint, especially the latter, which also includes the hypothesis of an answer "I don't know". This answer was not in the last version. However, it is of extreme importance since the patient may not know or remember any symptom that is questioned, for example. The answers will be presented in radio buttons so that the patient can only choose one answer.

Similar to the first prototype, some questions, with more complex terms, will be accompanied by a doubt icon. When the icon is pressed, it will provide a brief explanation of the term. This brief explanation will be provided in a tool tip, commonly used in symptom evaluators 41; 42, so that a patient can always answer despite not having a high level of health literacy. The icon chosen is different from the other of the last version because it has a simpler appearance. This icon only presents an interrogation point which is, generally, used as a help symbol in other day-to-day applications.

Each question will appear one by one, to avoid any question being ignored. Additionally, allow a more paused follow-up of each question avoiding visual confusion. As the patient answers a question, a new question will appear, and the scroll down will follow the rhythm of the patient's answer. All the answers given will be displayed in the answers' history and when the patient wants to change any of them, only needs to press the "Edit" button of the desired question, and the system will provide him with a screen with only that question. Only one question was chosen to appear, instead of all the questions, so that there is no confusion or errors when changing the answer of a question.

At the end of the main complaint exploration, several factors of relief and aggravation are presented. Thus, not being mandatory, patients can choose what relieves and aggravates

the pain, as shown in figure 23 n. The checkboxes were the elements chosen to present the relief and aggravation factors since these elements permit to select one or more factors.

When the main complaint is changed, the patient needs to carry out again all the exploration of the main complaint. In the case that this new main complaint is not included in the system, all the answers given during the main complaint exploration will be deleted, and the patient proceeds to the vital signs' collection.

In the last group, as opposed to the first version, there are only two phases, which happen simultaneously. These two phases are tutorial of measurement instructions and data collection. The tutorial of measurement consists of a set of gifs and instructions with steps that the patient needs to perform throughout the measurement. While the patient performs the steps, the system provides new gifs and steps to follow until the measurement is completed. Figure 23 o shows the layout of the tutorial. The gifs and steps complement each other as they will provide visual and textual support of what has to be done throughout the measurement so it is successfully completed. This type of tutorial replaces the video one used in the first version, allowing a follow-up of the measurement. This method prevents a patient from forgetting certain actions that are necessary to perform during the measurement. The sensor positioning and the interaction with the device itself are presented along with the gifs, avoiding unnecessary usage errors.

The results of the measurements will be displayed at the end of each measurement and shown in the answers' history. Unlike the other groups, this group will not allow navigating to it again. After a successful measurement, the patient will not be able to retake the measurements, to avoid an increase in the session duration. A maximum of three attempts are allowed per sensor, to avoid giving up the session, in case the user cannot perform it successfully. After these three attempts, the patient proceeds to the following measurement.

The result reporting was excluded in this version since a less positive result may affect the patient, by interfering with the next measurements or even with the session's withdrawal itself. The term SPO2 was replaced by oxygen saturation, enabling patients with low health literacy levels to have no difficulty in understanding which measurement they will take.

Although users of the first version were interested in receiving the results by E-mail, it was decided to withdraw this possibility, since it is not crucial to the anamnesis procedure.

Errors during measurements had been anticipated, including device misplacement errors and invalid values. Alert dialogs with error messages will be presented to the patient with

the instructions that must be followed to correct the error, as shown in figure 23 p. These error messages should not be devalued since good instructions for error correction will be the key factor for not giving up the session.

On the final screen, instructions will be presented concerning the following step after the session is finished to keep the patient oriented within the ED, as can be seen in figure 23 q.

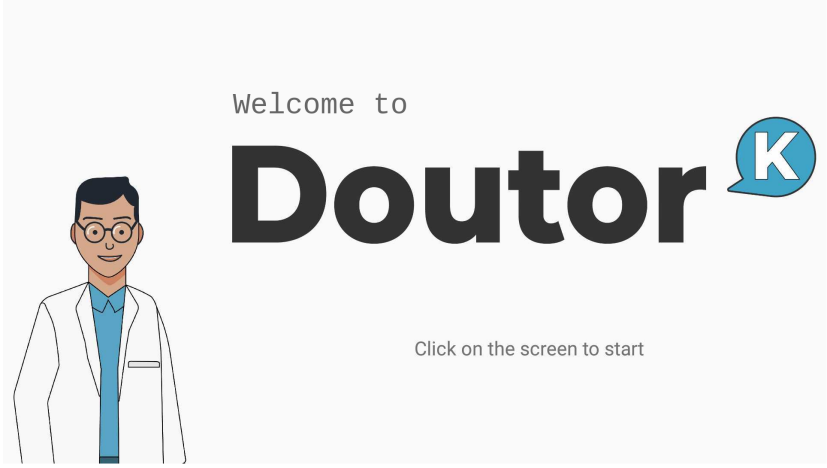
As the patient can leave the kiosk at any time and forget to end the session, a time-out of approximately sixteen minutes was set up for each interface, just like in the previous version.

To navigate between screens, the patient can either press the "Back" and "Next" buttons, or the "Edit" buttons of the answers' history, offering an internal consistency to the system. Unlike the first version, the "Next" button will not feature any motion animation, as animations can cause motion sickness or leading to select it, even if the interaction with the screen is not yet completed. Therefore, the "Next" button will appear animation-free once the patient performs all the screen's steps. The "Exit" button, presented in all screens, displays a distinct format than the first version, with a switch-off icon which is often associated with the idea of ending the session. Due to the established neutral colour of the icon, not drawing the patient's attention, unnecessary clicks are avoid.

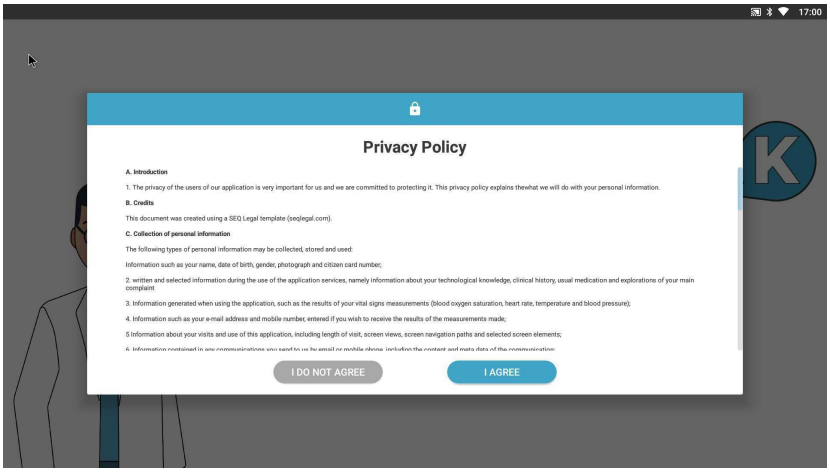
A progress bar was added to this new version, providing information about the patient's session status in the overall interface process. By allowing the patient to view and estimate the end of the kiosk's session, the motivation to proceed might increase, avoiding dropouts. This progress bar is divided into four of the five groups explained so far, which are past medical history, usual medication, main complaint and biometric data. The beginning of each phase will be marked on the progress bar. Each phase is represented by an image in the progress bar elucidating about its content.

This application's version was readjusted for a larger screen size, to enable a better visualization and organization of the information. The visual and tactile inabilities possibly experienced by some patients also contributed for this change.

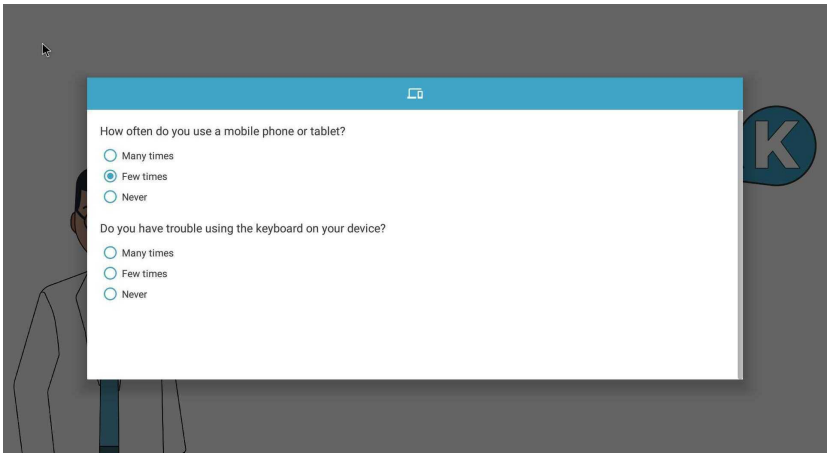
Since users with less digital competence or lacking contact with touch devices have less difficulty typing information in a physical keyboard, the virtual keyboard firstly used was replaced.



(a) *Welcome interface*

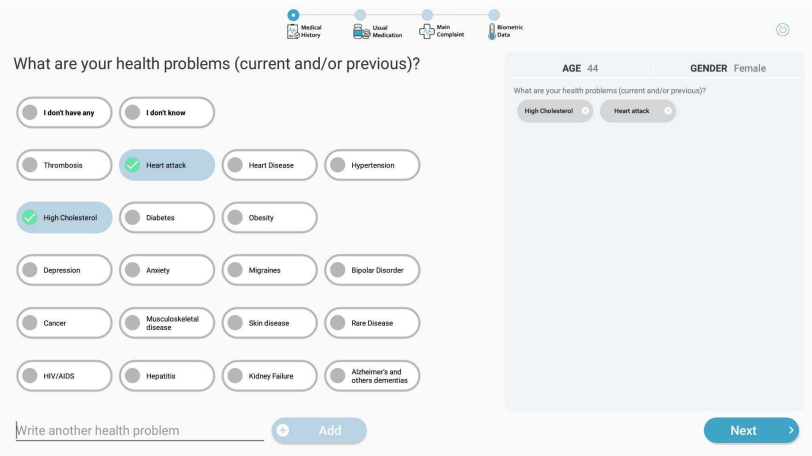


(b) *Privacy policy alert dialog*

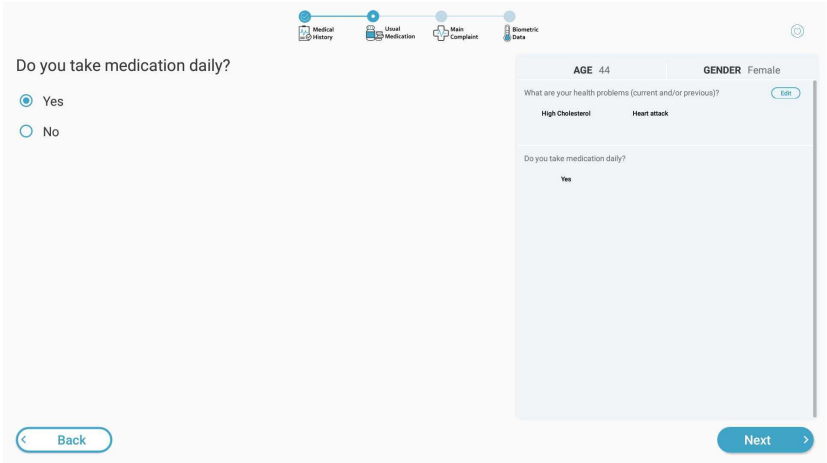


(c) *Digital competence alert dialog*

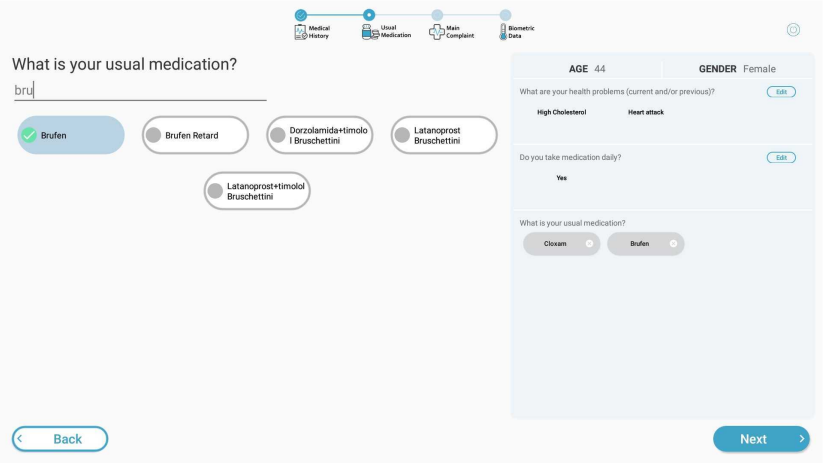
(d) *Personal information interface*



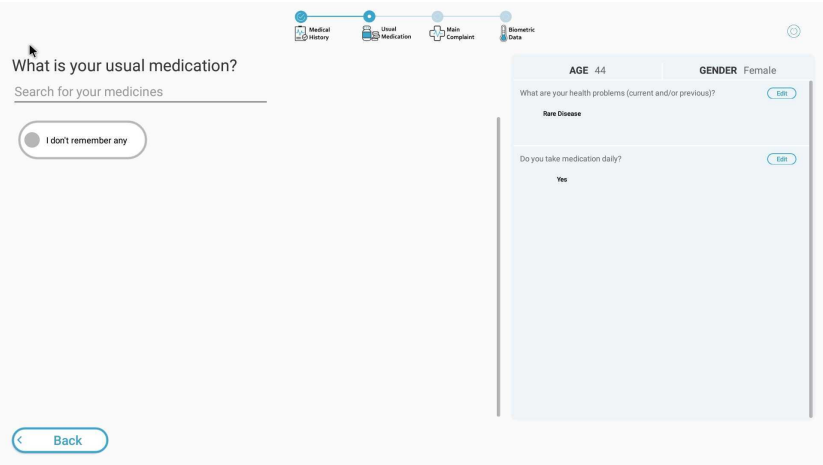
(e) *Past medical history interface*



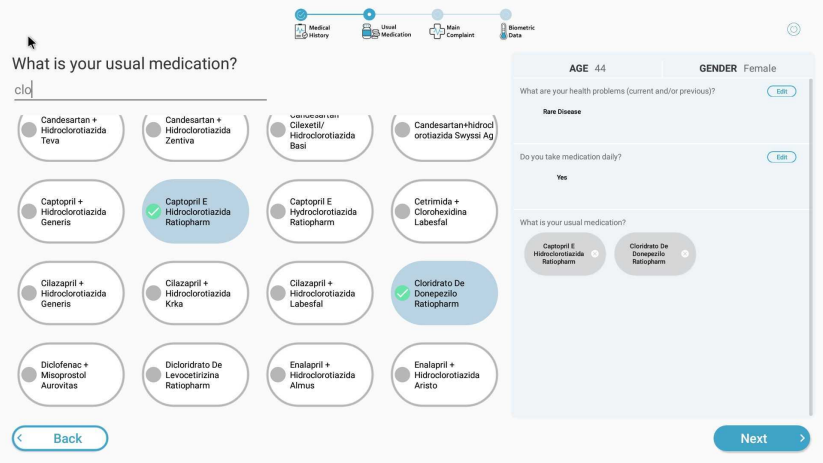
(f) *Take medication interface*



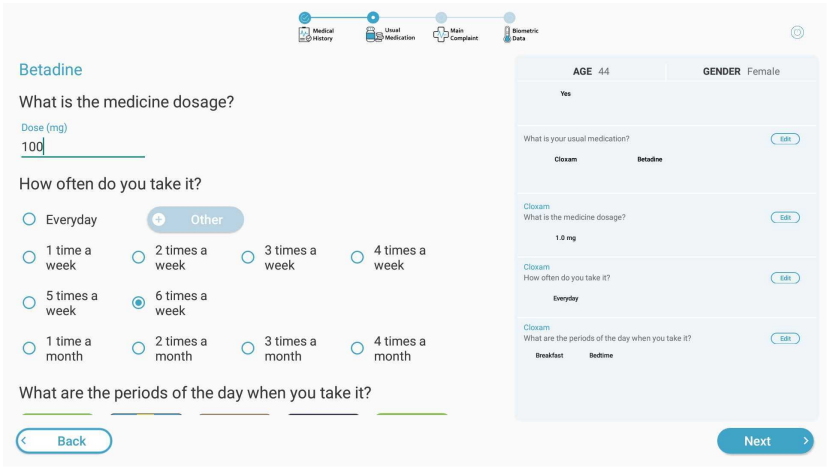
(g) *Medicines interface*



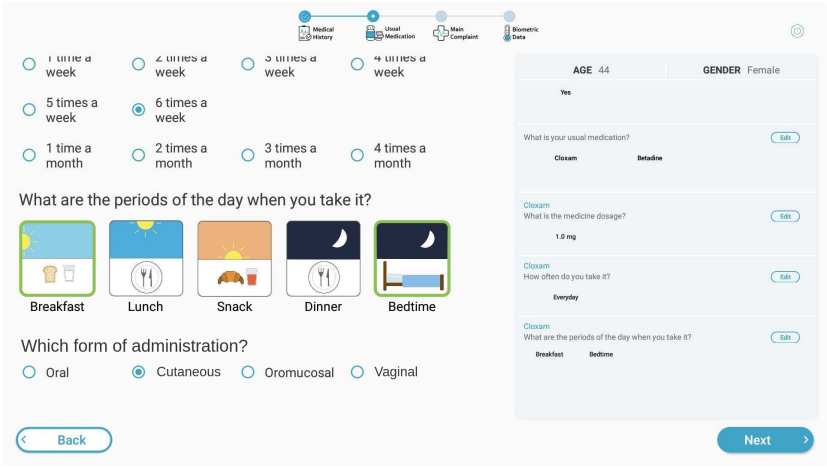
(h) *Medicines interface with checkbox "I don't remember any"*



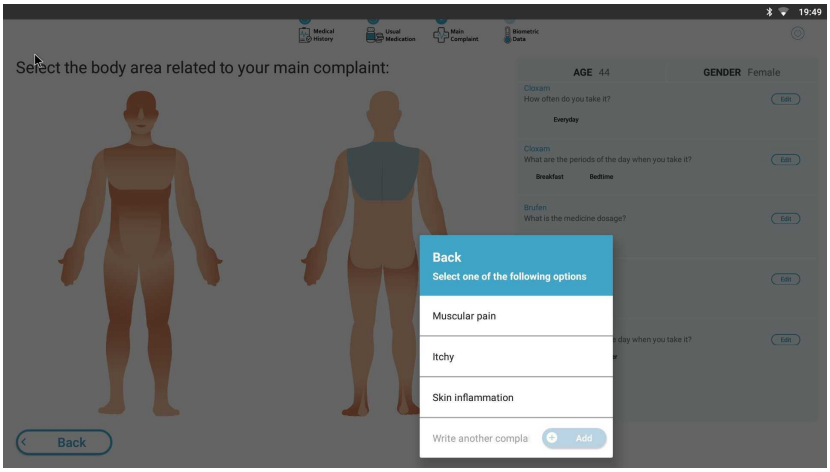
(i) *Medicines interface with checkboxes and buttons with a larger size*



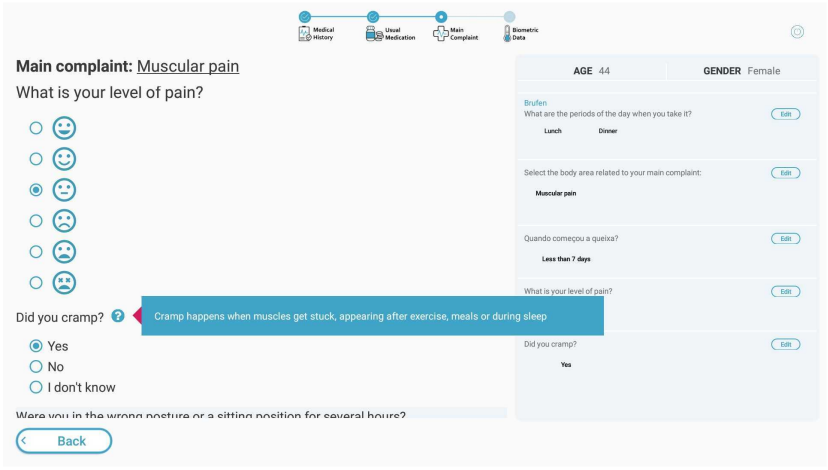
(j) *Description of the medication interface - Part 1*



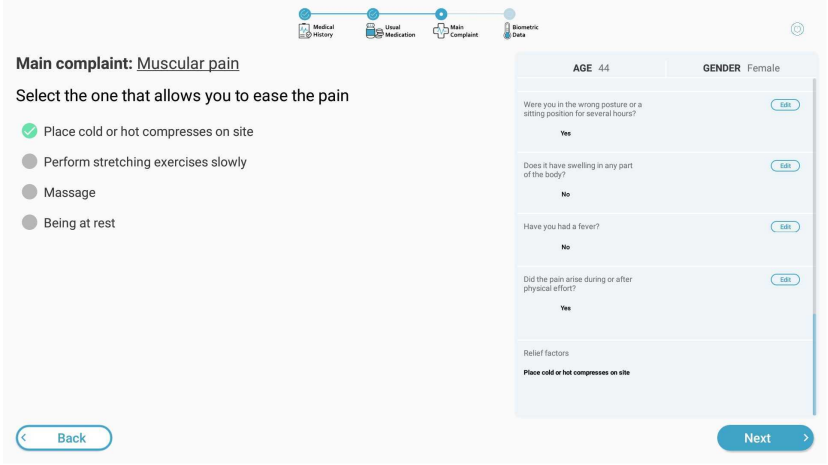
(k) *Description of the medication interface - Part 2*



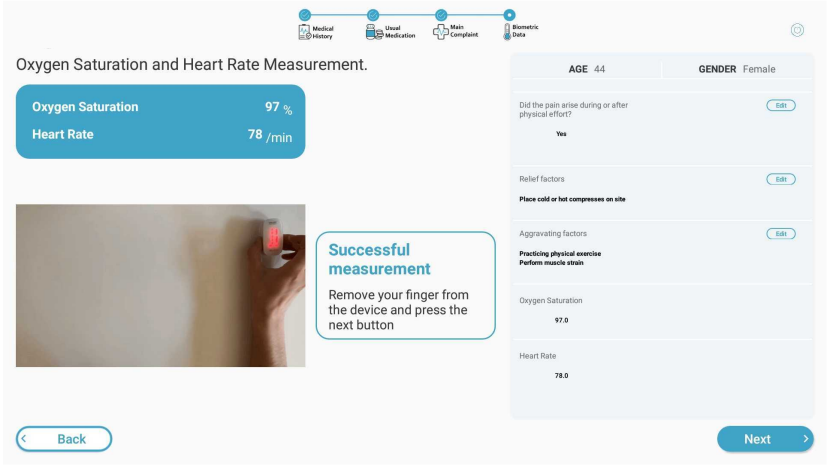
(l) *Main complaint interface*



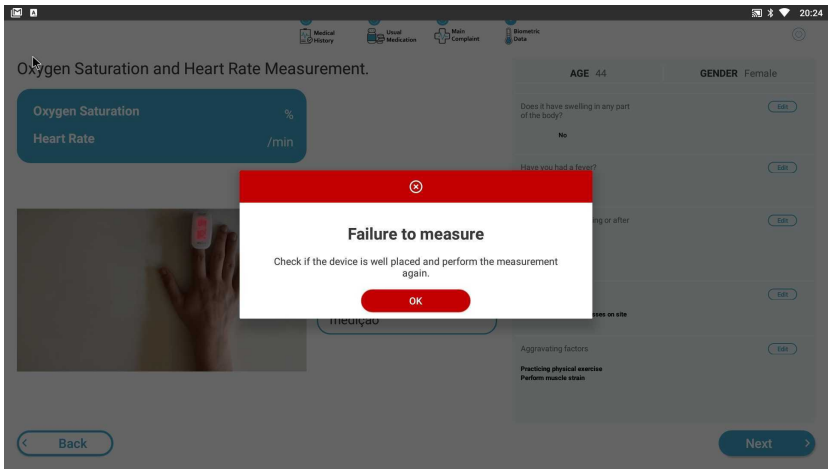
(m) *Main complaint exploration interface*



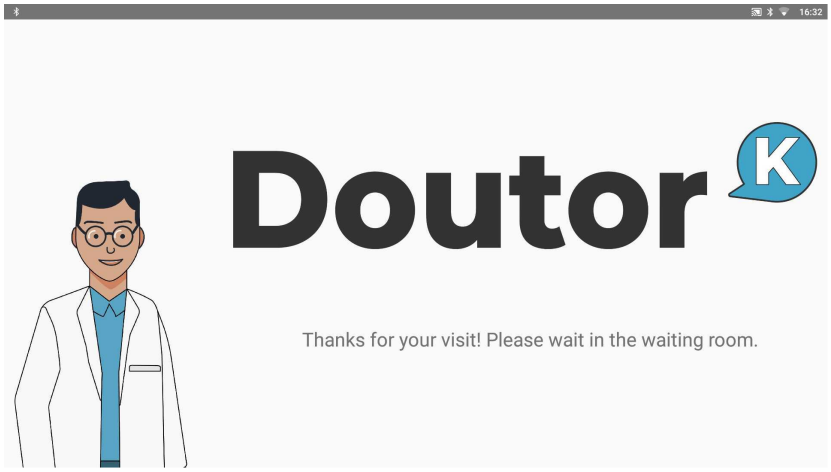
(n) *Relief factors interface*



(o) *Tutorial oxygen saturation measurement interface*



(p) *Error message alert dialog*



(q) *Final interface*

Figure 23: *(a; b; c; d; e; f; g; h; i; j; k; l; m; n; o; p; q) UI of the Android application's second prototype*

4.4 UI AND FUNCTIONALITIES OF THE WEB PLATFORM

The web platform prototype was implemented in React and is divided into three web pages. The first web page corresponds to the login page, where the physician must enter the access code to access the platform and use its functionalities (24 a). This login is important, as it will prevent people other than physicians from CHUSJ EDs from entering the platform. The login ensures the privacy and security of patients' clinical registers collected at the kiosk.

This page's interface contains a password-type text field where the physician enters the access code. In addition, there is an eye icon in the text field that allows physicians to make the access code visible when pressed. The eye icon was added to reduce possible errors that

might be caused by the complexity of the access codes. To complete the login process, the physician will have to press the "Login" button, accessing the next pages. A spinner may appear during access as it may take some time to check the access code. The spinner offers a simple message of approximate waiting time, preventing the continuous "Login" button press.

After the login, the Patients page of the web platform is displayed, where it is possible to search patients and navigate to their clinical registers. In figure 24 b, one can see a search input where the physician can enter the name or the CC number of the patient to be found. This search input contains a search icon on the left so that the physician can intuitively see that this is where the search can be performed. When a letter or number is entered into the search input, the cards containing these characters as substrings of either the name or the CC number will appear, facilitating the filtering selection (figure 24 c). Each card contains a name, number and profile photo of the patient's CC. This information was chosen for presentation, as the physician can identify the patient by face, name or CC number found in the hospital's clinical registers. The search is not compulsory as the page can be scrolled to view all the patients' cards through a manual search. When selected, each card redirects to the corresponding patient's clinical register page.

The Patients page contains a web platform logo in the upper left corner and a navigation menu in the upper right corner, which shows to physicians that they are located on this page, as the word Patients is underlined in blue to highlight it. This Patients item will allow the physician to return to the Patients page, when on different pages. The physician will also be able to logout and leave the web platform. The logout is presented in a grey colour, passing unnoticed to the physician, avoiding unnecessary session endings. When the mouse overlays it, the logout word becomes coloured and underlined in blue, to emphasize that when pressed, the logout is carried out. Along with it, there is an exit icon to reinforce the end of the session.

As mentioned above, after selecting a patient's card, the physician will be redirected to the patient's clinical register page. However, the physician may have to wait for the page to load. In case this happens, several spinners associated with the personal information, past medical history, usual medication, biometric data, and main complaint exploration appears. Once loaded, the physician can view the entire patient's clinical register collected at the kiosk and copy it. As we can see in figure 24 d in the left corner, the component with the patient's personal information (name, age, nationality, civil identification number, and profile photo) will be shown. Since age and nationality are indicators that might reflect the patient's health condition, these help assessing the patient's diagnosis. In addition to the personal

information, two buttons are displayed, the "Copy All" and the "Register Diagnosis".

The "Copy All" button allows to copy all the information from the patient's clinical register, whereas the "Register Diagnosis" button allows entering the patient's diagnosis in a dialog box, as shown in figure 24 e. A dropdown list will be shown with different diagnoses names, containing the characters typed as substring, so that they can register more easily and prevent potential typing errors. These diagnoses names on the dropdown correspond to the most common CHUSJ diagnoses. To complete this diagnostics's register, the physician will have to press the "Register" button, and the dialog box will immediately disappear. Since the diagnostics's register will be the last action performed by the physician, the card associated with the patient will be deleted from the Patients page. This deletion minimizes the effort of searching patients between cards and prevents physician entries in the clinical registers of patients consulted. This "Register Diagnosis" button was an added functionality, as this information can be essential in, for instance, identifying patterns between health problems and diagnoses. This button is coloured red to draw the physicians attention to prevent them from forgetting to register the patient's diagnosis. The dialog box can be of the modal window or message box type.

In the right corner, several components with the registers of the past medical history, usual medication, biometric data and main complaint exploration of the patient are presented. They all have a title and a scroll associated, as there might be a lot of data associated with each theme. Both the "Copy All" and the "Copy" buttons were suggested as functionality by a CHUSJ physician, as not all the information in a patient's clinical register is stored in the hospital centre's clinical registers. These functionalities will allow the physician to quickly and efficiently copy the information from the web platform to the CHUSJ patient clinical registers platform. The "Copy" buttons were placed below each component. Thus, when analysing the component, the physician can copy the information immediately.

In the past medical history component, the names of the patient's health problems are presented. In the usual medication, the physician can find detailed information of each medicine taken via sentences, for quick reading. To highlight the distinction between phrases, the name of each medicine appears in bold. Some biometric data results are accompanied by danger icons so that the physician is aware of the results beyond the normal range. The data from the main complaint exploration is presented through the main complaint, the body part, and the answers to the main complaint exploration's questions.

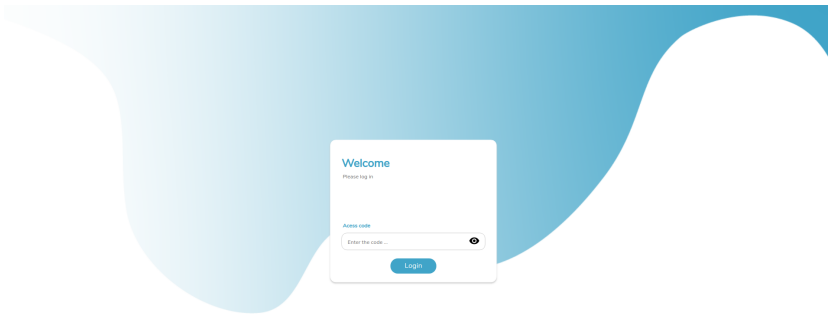
The main complaint and the body part are presented in blue and bold, as these are crucial information, and the answers to the questions vary between the colours grey, green, red and

orange. The grey-coloured information concerns the pain level and the start of the complaint answers. The "No" answers are associated with red, a colour linked with negative results, whereas "Yes" answers are presented in green, a colour related to positive results. The "I don't know" answers, coloured in orange, associate with doubt results. What allows to relieve and aggravate the patient's pain will be presented in the two components of relief and aggravation factors. In case no information is registered on any of these topics at the kiosk, a sentence informing the physician that there is no content is presented, as can be seen in figure 24 f.

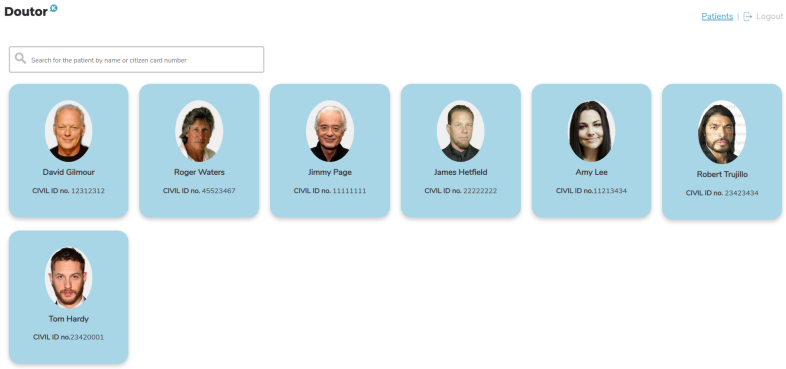
Like in the Patients page, this page also displays the side menu and the logo in the upper right and left corners, respectively. If the physician wishes to return to the Patients page and has not registered the patient's diagnosis, an dialog box will be displayed. This dialog box aims to inform the physician that the patient's diagnosis has not been registered and to ask if he still wants to go to the Patients page, as can be seen in figure 24 g. If the physician presses "Yes" the application redirects them to the Patients page. In case the answer is "No", the dialog box will disappear and keep the physician on the patient's clinical register page so that the diagnosis's register is performed.

All components of the clinical register were selected to be displayed on a single page, so that the physician can see them without having to conduct a manual search. The web platform is responsive, adjusting correctly when both the web and the CHUSJ platforms are opened simultaneously. When the web platform is minimized, the components are presented as a list, to keep the information organized in a smaller space, as can be seen in figure 24 h.

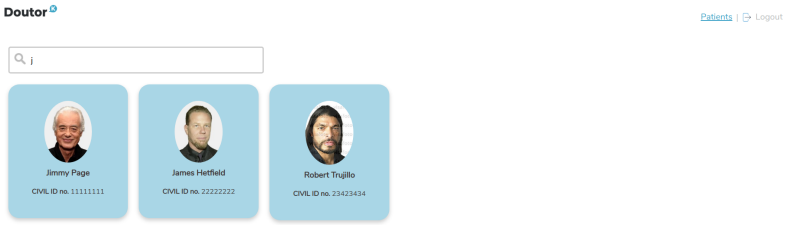
When the mouse hovers the "Copy", "Copy All" and "Register Diagnosis" buttons, these will show a shadow and darker colour than the previous one, highlighting their functionality. The cards on the Patients page also have a different presentation when the mouse hover them, indicating to physicians that they are clickable components.
In order to maintain the colour consistency between the web platform and the kiosk application, blue was used as the main colour throughout the web platform.



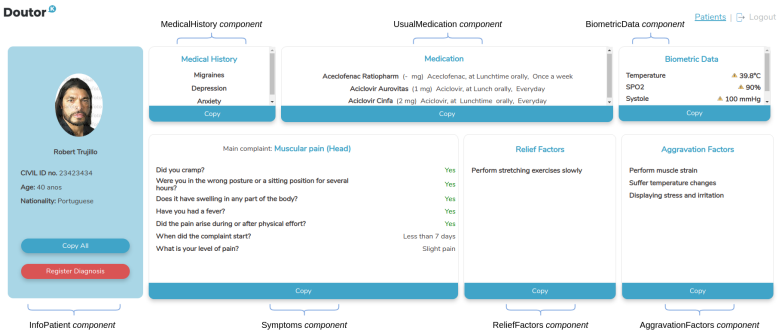
(a) *Login interface*



(b) *Patients interface*

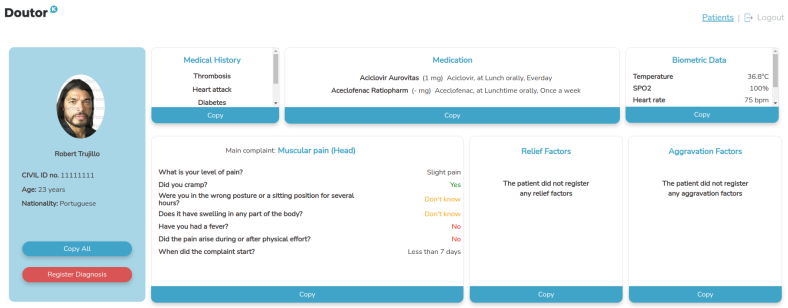


(c) *Patients interface with cards obtained from the search*



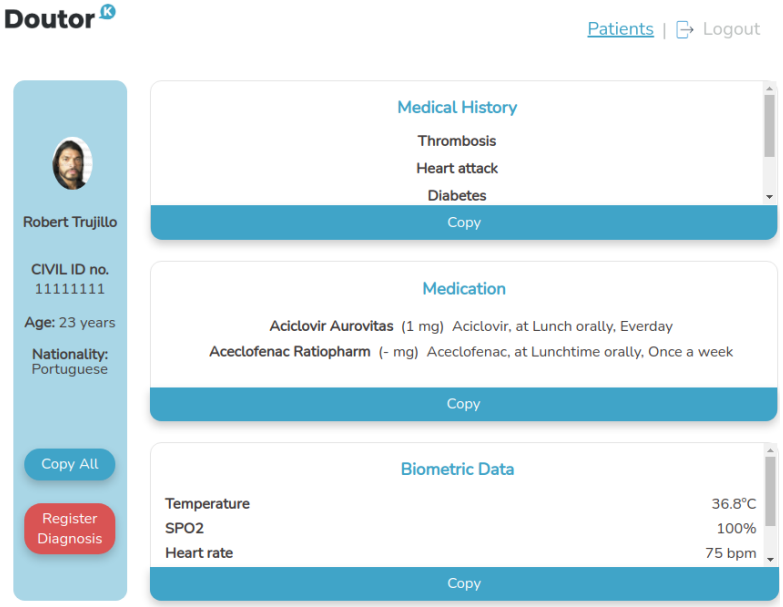
(d) *Clinical register interface*

(e) *Diagnostic register dialog box*



(f) *Clinical register interface without relief factors*

(g) *Attention dialog box*



(h) *Responsive interface*

Figure 24: *(a; b; c; d; e; f; g; h) UI of the web platform*

4.5 CLINICAL BUSINESS INTELLIGENCE

Clinical business intelligence corresponds to the business intelligence methods applied to the health sector. This process refers to a broad category of information technologies, that analyses clinical information to help health professionals make better decisions, as well as help institutions, improve performance in terms of cost and quality. Regarding benefits, it allows improving the healthcare process management, through clinical performance

measures; to support clinical decision-making, through predictive analysis and performance improvement processes, allowing a continuous improvement in the quality of institutions 73 (2020 (accessed November 16, 2020); 74 (2020 (accessed November 16, 2020). Provided by Microsoft Corporation, the Power BI tool enables data analysis to improve decision-making and recognise patterns in disease diagnosis and other parameters associated with pathologies or even demographic data. This tool allows transforming data, from Excel spreadsheets, or information stored in MySQL databases into coherent, visually engaging and interactive information. The power BI allows real-time modelling and analysis of data, always updated, at any time maggiesMSFT.

During the planning phase, several points were defined as important, to which the data warehouse implemented by Pacheco (2021) was intended to respond, resulting in the following indicators:

What is the average time of kiosk usage?

This indicator will allow knowing whether the kiosk was used longer or shorter than the first version of the self-service kiosk.

Which age range and gender have the longest kiosk usage times?

This indicator can provide us with evidence on which age ranges and gender have the greatest difficulty when using the kiosk.

What is the age range and gender that presents the results of dangerous measurements of SPO2, body temperature, HR and BP?

This indicator can be used to determine which age ranges and gender should receive more attention since they present results of dangerous measurements. Monitoring vital signs in these age ranges and gender outside the hospital environment may be a possibility, preventing future health problems.

What are the most common health problems for each age range and gender?

This indicator becomes essential for the identification of patterns between health problems with the age and gender.

How many health problems do each age range,and gender have on average?

Determining which age range and gender have the most health problems may allow us to see which patients probably visited the ED most due to their health problems.

What are the most commonly taken medications for each age range and gender?

This indicator can be useful for hospital pharmacies, informing them of the medicines they should have in stock for each age range and gender. This indicator may also provide for the identification of patterns between medicines with age and gender.

How many medicines does the patient take on average for each age range and gender in his usual medication?

A high number of medicines in the usual medication can make the patient's taking of each medicine confusing and lead to forgetting to take some medicine. Determining the age ranges and gender that take a high number of medicines is essential for increased vigilance in the correct compliance with the usual medication.

What are the most common main complaint and diagnosis by age range and gender?

This indicator will allow the identification of patterns between main complaints and diagnoses with age ranges and gender. It will also provide support to the physician in determining the diagnosis of a patient with a certain age range and gender.

What health problems are associated with the results of dangerous measurements of SPO2, body temperature, HR and BP?

The association of health problems with this category of measurement results highlights which patients with certain health problems should be monitored for their vital signs. This monitoring allows preventing aggravation of these health problems or the appearance of others. This indicator also allows the identification of patterns between health problems with dangerous measurement results.

What are the main complaints and diagnoses that are most associated with the results of dangerous measurements of SPO2, body temperature, HR and BP ?

Results of dangerous measurements can be associated with certain main complaints and diagnoses. When this association is determined, support can be offered to the physician's

decision making in determining the patient's diagnosis.

What are the health problems and the main complaints most associated with each diagnosis?

The support for the physician's decision making in determining the patient's diagnosis is essential. The identification of patterns between health problems and the main complaint with the diagnosis can provide this support.

What are the most common health problems, medicines, main complaints and diagnoses?

This indicator will provide the health problems, medicines, main complaints and diagnoses most common of patients visiting the ED.

What is the day of the week with more patients in the ED?

This indicator will allow the hospital to know which day of the week is the most crowded. This contribution will help the hospital to manage the number of visits to the ED.

Which month has the highest number of visits to the ED?

Knowing which month is the most crowded will allow hospitals to manage the number of visits to the ED in an appropriate and timely manner.

What is the most common main complaint and diagnosis per month?

Determining the most common main complaint and diagnosis per month will help hospitals and physicians. For example, in those months, hospitals may prepare their pharmacies with stocks of medicines prescribed for these diagnoses. This indicator will also provide decision making support for the physician in determining the diagnosis.

What is the most common education level per age range?

This indicator will provide information for the age ranges with the lowest education level.

What is the average time of kiosk usage by age range and education level?

This indicator makes it possible to check whether the age range and education level attain-

ment influence the average time of kiosk usage.

What is the average time of kiosk usage for each answer given to questions about digital competence?

This indicator makes it possible to check whether the digital competence influences the average time of kiosk usage.

Which age range and education level have the least digital competence?

This indicator makes it possible to check whether the age range and education level influence the digital competence of each patient.

Which interfaces have the most interaction time?

This indicator allows us to see which interfaces the patient found most difficult to interact.

Which interfaces have the longest interaction time per age range and education level?

Determining whether the age range and level of education are associated with the time of use of each interface is essential for the construction of interfaces suited to each type of patient.

5

E-ANAMNESIS PLATFORM TEST AND EVALUATION

The evaluation of the self-service kiosk occurs in two moments. In the first moment, the Android application's first prototype was tested in Univerdade do Minho and in a National Digital Competences Conference (Forum INCoDe.2030[1]. At the end of each kiosk session, users were invited to conduct a system usability questionnaire. Due to the pandemic, it was not possible to perform the second evaluation moment. The second prototype of the Android application would have been evaluated at the ED of CHUSJ with patients and some nurses. They would have been invited to conduct a system usability questionnaire. The prototype of the web platform would have been evaluated by physicians from the hospital centre. After using the web platform in medical consultations, the physicians would have been invited to conduct a questionnaire about the system.

5.1 TESTING METHODOLOGY

In order to evaluate the E-anamnesis platform usability, various testing methodologies were defined for each kiosk prototype and web platform.

5.1.1 *First Prototype of the Self-Service Kiosk*

The evaluation of the kiosk's usability was carried out taking into account the following indicators: (I) average time per screen, (II) average time of a complete kiosk session, (III) application design, (IV) devices interaction, and (V) interaction with the system. These last three indicators will be evaluated through methods (B) and (C), presented below, following a methodology similar to the one presented in Silva et al. (2017). To obtain these indicators, we divided the usability test into three parts: (A) kiosk usage time, (B) final questionnaire, and (C) observation report. To facilitate data analysis Power BI and Google forms were used to generate statistical graphs.

1 https://www.incode2030.gov.pt/.

A. Kiosk Usage Time

The usage time of the kiosk will be analyzed taking into account the usage time per screen and the time of a complete session. The time used per screen allows taking into account which screens the user found more difficulty in terms of interaction since these will have longer times. The time of a full session will help to reach the overall objective of reducing the session time as much as possible, which can be accomplished both in terms of application design and interaction with the sensor devices.

B. Questionnaire

At the end of each kiosk session, users were invited to conduct a system usability questionnaire. The initial questions consist of determining the user's age range, gender, education level and zip code. These questions are particularly relevant because the system is intended to be used, and was tested, by a very diversified range of users, from which one intends to understand how different factors influence the ability to use the system. To this extent, there is a particularly interested in understanding how age and education level influences kiosk usage, and how effective can system design options be in overcoming general usage barriers of digital systems.

The following questions were adapted from the *Post-Study System Usability Questionnaire (PSSUQ)*. It was specifically designed for use at the completion of usability studies Dabbs et al. (2009). The PSSUQ assesses overall user satisfaction with 16 aspects of the system and interface, such as system utility, information quality and interface quality. The answer scale ranges from 7 answer options (fully agree, agree, partly agree, neither agree nor disagree, partly disagree, disagree, fully disagree) and not all questions have to be answered, as there may be non-applicable questions.

Questionnaires to users conducted in Forum INCoDe.2030 are presented in section H.1 of Appendix I.

C. Observation Reports

During the test phase of the kiosk, there were two observers watching and creating reports on user interaction with the system. These observations and reports provide valuable information about participants behaviour that cannot be captured by questionnaires nor interface digital monitoring alone. These were particularly insightful to identify and provide a deeper understanding of system interaction problems, difficulties in understanding the content provided on the screens, problems with the use of the devices, and user suggestions, among other issues.

5.1.2 *Second Prototype of the Self-Service Kiosk*

The evaluation of the kiosk's usability will carry out, taking into account the same indicators, as in the previous version. However, another method (D) was added to evaluate user interaction with the device, following a methodology similar to the one presented in Silva et al. (2017). To obtain the indicators intended, one will divide the usability test into four parts: (A) kiosk usage time, (B) final questionnaire, (C) observation report, and (D) coordinates of the user clicks. In the (A) kiosk usage time and (C) observation report methods, the same methodology will use as in the previous version. To facilitate data analysis, Power BI and Google forms will use to generate statistical graphs.

B. Questionnaire

Like the previous version, users will be invited to conduct a system usability questionnaire after the kiosk's session. This questionnaire is, essentially, made up of a set of questions related to the application's functionalities, but it also contains questions adapted from the PSSUQ. In order to verify if the functionalities implemented in the system helped and facilitated the user interaction with the system, questions were added to the questionnaire, which were not present in the methodology of the previous version. The number of questions, adapted from the PSSUQ, was reduced. The system's and interface's aspects were taken into account, keeping questions associated with the system's usefulness, information quality and interface quality.

The answer scale varies between three answer options (agree, neither agree nor disagree, disagree). This scale was reduced from the previous version to obtain more concise and accurate answers. Since all questions are mandatory, the possibility of "Not applicable" answers for questions not applicable to the user was added.

This questionnaire will be conducted to two different types of users since in addition to the ED patients, nurses will also interact with the self-service kiosk. The questionnaire conducted to the nurse differs from the one conducted to the patient in only one question, where one is asked if all the information collected by the system is sufficient. The nurses as health professionals were considered extremely important users, providing us with a professional point of view about the system, which the patient could not transmit.

Questionnaires to patients and nurses in the ED are presented in section H.2 of Appendix I.

D. Coordinates of the User Clicks

During the kiosk session, the user will interact with the application through a touchscreen interface. The kiosk application was instrumented to register clicks' coordinates made by the user so that later it will be possible to represent them in the system interface that corresponds. These register of clicks' coordinates by the user will allow us to verify if the

user interaction with the application meets the design expectations, i.e., check whether users have any problems with the interaction or the application's flow. Registers of interactions that should not exist or that were not foreseen reflect the frustrations and difficulties felt by the user regarding certain interface's elements.
This evaluation of the interface's usability will improve the application's flow, solving user interaction's problems with unintentional parts of the interface.

5.1.3 *Web Platform Prototype*

The evaluation of the web platform usability will carry out taking into account the following indicators: (I) effectiveness evaluation of the interface, (II) interface design, and (III) interaction with the system. To obtain these indicators, will conduct a questionnaire to ED physicians who used the web platform during their consultations. Power BI and Google forms were used to generate statistical graphs, to facilitate data analysis.

After using the web platform in consultations, the physicians will be invited to conduct a questionnaire about the system. This questionnaire is divided into two parts. Initially, a set of questions about the effectiveness evaluation of the interface is performed to register information in a correct and complete way from the clinical register collected of the patient. Subsequently, another set of questions related to the satisfaction of this web platform usage will be carried out, containing questions related to the functionalities of the system and the presentation of the information collected in the platform. As in the usability questionnaires carried out to the self-service kiosk users, this questionnaire also contains questions adapted from the PSSUQ.
The answer scale varies between 3 answer options (agree, neither agree nor disagree, disagree). Since all questions are mandatory, the possibility of "Not applicable" answers for questions not applicable to the user was added.
Questionnaire to the physicians in the ED is presented in section H.3 of Appendix I.

A flyer was created, provided to patients in triage, to inform them about the purpose of the self-service kiosk and its functionalities. This flyer would encourage patients to use this technology during the waiting time when offered by the nurse.
Besides, a poster was also created, for the physicians, which explains the main functionalities of the web platform so that they learn how to use the platform more quickly.
The flyer and poster are presented in Appendix section J. The tests protocol defined for the second phase of usability testing is presented in the Appendix section K.

5.2 RESULTS

As previously mentioned, due to the pandemic, it was not possible to perform the testing phase in CHUSJ. Thus, no data was collected to allow to create dashboards based on the defined indicators through the Power BI tool and complete the process of developing the intelligent UI/UX system.

The usability evaluation of the first self-service kiosk prototype was performed through (A) kiosk usage time, (B) final questionnaire and (C) observation reporting.

A. Kiosk Usage Time

Screen usage values, presented in figure 25, show that the average time of use was significantly different for each screen.

The screens with the interface to collect biometric data from the user are the ones with the longest time of use, since the measurement devices require a fixed and often significant amount of time. Here, one has to account not only for normal time that each device takes to make a measurement but also on error attempts. The BP monitor clearly shows this problem, since it is the device with the most measurement errors, as explained in Observation Reports.

The average time of a complete kiosk session from the initial screen to the final screen was 399 seconds. This average time did not include the time of the videos explaining the use of the devices for collecting vital signs.

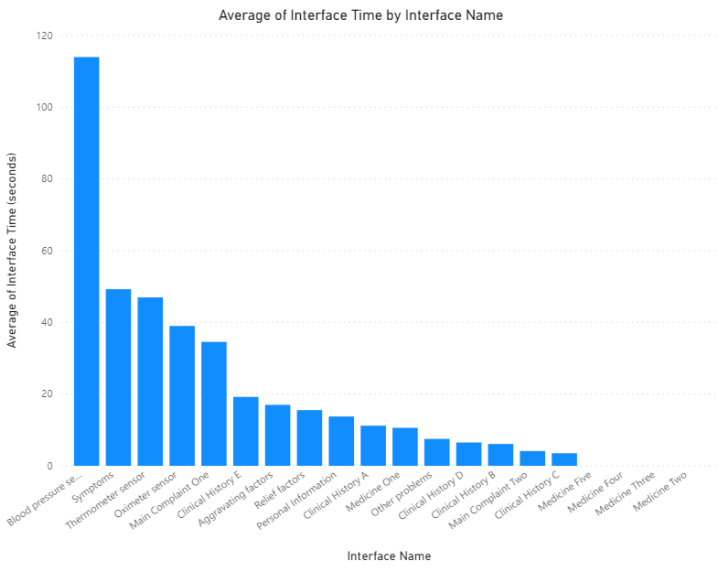


Figure 25: *Interface time average by interface name*

B. Questionnaire

When asked to fill-in the final questionnaire, only a small number of participants (19 participants) answered, arguing time unavailability.

The answers given to the questionnaire were essentially from higher education participants (17 participants), with a probably high digital competence.

More than 50% of the participants are between 18 and 29 years old.

About 80% of the participants fully agreed or agreed that the system is simple and easy to use, observing that all tasks could be performed quickly. Only 14 participants responded to have made errors while using the system. All of these participants fully agreed or agreed that the system provided clarity in correcting the problems and it was easy and quick to correct them.

The information presented in the system was clear and easy to find in agreement with 95% of the participants. In addition, about 80% of the participants agreed that the information was well organised and that it actually helped. Everyone found the interface of the system pleasant and were satisfied with the system developed, as the results in figure 26 show.

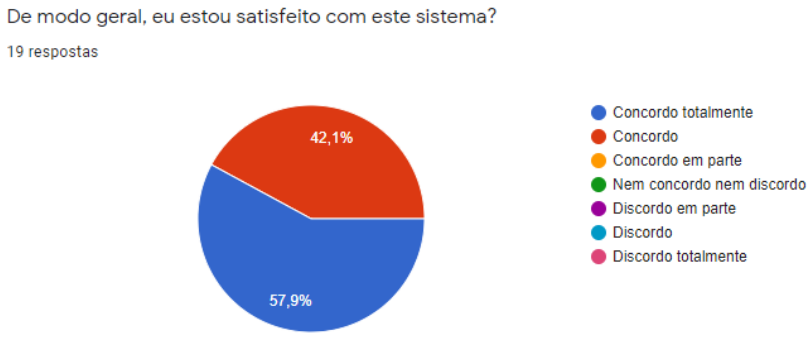


Figure 26: *Overall satisfaction answers of the system*

C. Observation Reports

Observers during the test phase detected difficulties in gender selection by the users, who justified it by saying that the button seemed unnoticeable as it was different from the buttons of age range and education level.

In contrast, on the past medical history screens, users did not experience difficulty in understanding the health problems presented. Users who did not have health problems mentioned that the "Other problems" button, which followed the next health problems, should not be compulsory and raised the possibility of including a button to move on to the next phase, the usual medication.

In the usual medication, it was observed that there was a difficulty on the part of the users to remember their medication and to write it correctly, even with the help of the dropdown, which was little or not used by users with a low education level. Users with a

low educational level also showed doubts about introducing the number of medicines they were taking or the dose of each medicine.
In the parts of the day, the same users clicked on the textual description of the image button instead of the button itself.
No complaint of difficulty was perceived by the observers in both the main complaint screen and the symptom screens.
Several difficulties were found in the sensor device screens. In the use of the oximeter, questions arose regarding the meaning of the term SPO2 by low education users, which finger to insert and the correct orientation of the device for finger insertion.
On the thermometer, users experienced difficulty in placing the device at the correct distance, as well as when they should press a second button to have the measurement data sent to the application.
The BP monitor was the device that presented the most error messages, due to the difficulty in placing the device correctly. In one case, a user gave up the use of the device after successive unsuccessful attempts. However, this device still showed some advantages during the trial, since the measurement is performed on the wrist and users do not have to take any clothes off. This was particularly convenient in the conference trials that were carried during winter season.
The videos explaining the use of each device were not shown because of time unavailability by the participants. Thus, the instructions were given by the observers to the users and in some cases it was necessary to repeat the same explanation, since users forgot the steps to be performed.
Regarding the results of the measurements, all users showed interest in knowing if their vital data was under normal levels and almost everyone wanted to receive this information by E-mail.
On the screens where it was necessary to use the tablet keyboard, it was found that users with a low education level felt difficulty using it, an example of this was when they wanted to delete a letter without knowing which key to press.
For the final screen, some users suggested that in an ED situation it should inform the patient about the next steps to take.
In general, we received several important general suggestions regarding the interface design.
In the main complaint exploration screens, users suggested to replace the colours of the "Yes" and "No" buttons with the same colour and to replace the "Exit" button colour to red with less contrast.
The all capitals labels used in the main complaint buttons was reported to affected users' reading, and it was also suggested to increase the font size when changing to sentence case.
The lack of the progress bar was also an element pointed out by users, referring that when a task contains many steps and necessary actions, it is better to divide these tasks into several

subtasks.
In the past medical history and usual medication screens, different buttons were used (e.g., "Continue" button) from the buttons used in the rest of the application. This caused some confusion to users, alerting for the need to maintain internal consistency.

5.3 DISCUSSION

The discussion of the results will be presented according to the division used in the results section: (A) kiosk usage time, (B) final questionnaire and (C) observation reporting).

A. Kiosk Usage Time
The relation between average time of a complete kiosk session, the age range and education level (figure 27 and figure 28), shows that participants with age ranges between 30 and 60 have the longest time for a complete session as well as illiterate participants and participants who have completed primary and middle school. This difficulty in using the system is probably due to the low level of digital competence of users, which is known to be highly correlated with education level. Surprisingly, we can see that for an age range over 60, the time for a full session of the kiosk was the shortest, contrary to what one would expect. However, these are outlier values, given that the number of participants in this age range is only two and their education level is much higher (middle school and university levels) than the mean education level for this age range.
Considering the data available, the age range variable has little statistic significance and can not be used to extract any correlations with the kiosk usability. Contrary to this indicator, the educational level allowed to identify systematic relations with the kiosk's ease of use. Participants with an university educational level had a lower than average time of complete kiosk session, while all other educational levels where below it.
The devices used during the biometric data collection phase must be fast during measurement so that as little time as possible is lost. Therefore the choice of a thermometer with infrared technology is the best option as it allows measurement in a few seconds with the same accuracy. Another factor to take into account is the simplicity of the devices. A BP monitor with a single key to automatically start the measurement will allow the user to have no doubts about where to press the key, offering a faster measurement. In the oximeter, this simplicity factor should also be present, and it should be a device in which only the finger needs to be inserted in it and it automatically performs the measurement without the need to press any key.
The measurement errors also affect the time of the measurement and an error message should always be displayed for the user with which error, its cause and the way to correct it.

This way the frustration caused by the error will be eliminated and the user will be able to solve the error more easily and quickly.

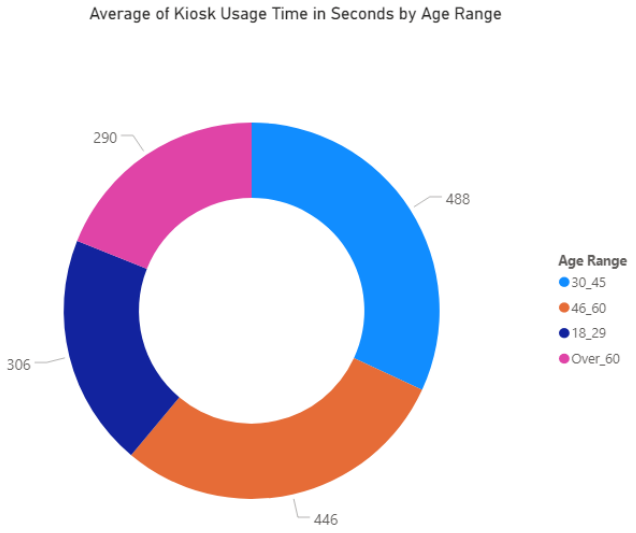


Figure 27: *Average of kiosk usage time in seconds by age range*

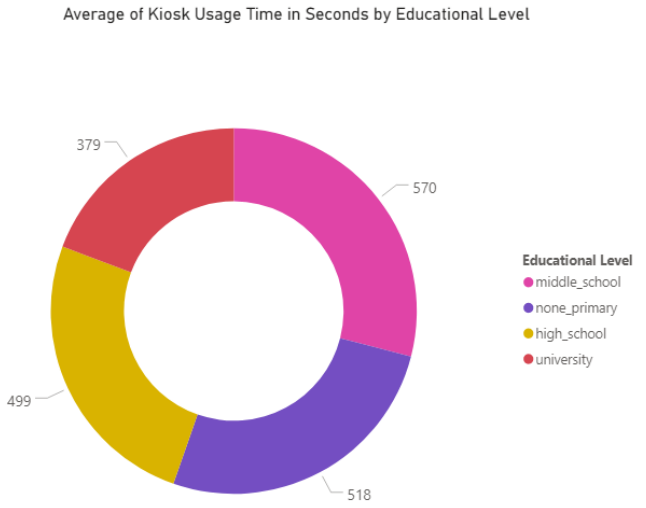


Figure 28: *Average of kiosk usage time in seconds by educational level*

B. Questionnaire

The positive and encouraging answers obtained may be due to the majority of participants presenting a university education level and an age range between 18-29. One factor to consider in the future is to add a "Not applicable" option to all questions. This would allow to register user doubts and accelerate the questionnaire answering, since users would no long have to look for alternative answers to move to the next question.

C. Observation Reports

Considering that users were forgetting the steps to be taken in using the sensor devices, we may conclude that videos are not an effective single way to explain the use of the devices, since the steps would be easily forgotten. George Miller work supports this 77 (2014 (accessed September 28, 2020), where he found that people are only able to keep five to nine items in the short-term memory before they forget or start making mistakes.

The green and red colour associated with each button of the answers to the questions made in the main complaint exploration, can influence user's answers, because the expansion effect that warmer colours have, when placed next to colder colours, makes them literally spill out and take dominance 78. So, users will be more likely to click the "No" button associated with a warm colour than click the "Yes" button associated with a cold colour.

The "Exit" button used in all screens also showed the colour red, obtaining a highlight that could induce users to click on it unnecessarily. The suggestion was to replace the colours of the "Yes" and "No" buttons with the same colour, since similar colours infer a similarity between the objects, and the "Exit" button to a red with less contrast, in order to avoid drawing the user's attention 79.

Replace the all capitals case to sentence case and increase font size in the main complaint buttons in order to allow for faster reading, given that reading speed is slowed about 13% to 20% when text is set in all capital letters Minhas (2020 (accessed September 28, 2020).

The progress bar suggested by some users would allow a step-by-step checkout flow, breaking down a complex checkout task into bite-sized chunks, each requiring user small user actions is a developer and Author (2018 (accessed September 28, 2020). This subdivision of interface tasks provides constant information to the user about his progress in the overall interface process, allowing him to envision and estimate the end of the kiosk session, an aspect that motivates users and increases the number of sessions carried out to the end.

The internal consistency in the past medical history and usual medication was suggested by users. This is important, to create patterns in language, layout and design throughout the app to help facilitate efficiency. Once a user learns how to do something, he should be able to transfer that skill to other parts of the app 82 (2014 (accessed September 28, 2020). This way keeping the same layout and design on the "Continue" buttons on these screens will make it easier for the user to learn.

In the past medical history, the most common health problems in Portugal are presented for selection, instead of text boxes in which the user would have to type his health problems. This choice is because when a patient comes to a physician's appointment and the physician questions him about his health problems he answers that he does not present any. This answer from the patient is because he do not remember his health problems or do not consider that he has a health problem even if he is taking medication associated with the problem. Showing the user possible health problems will remind him of his problems, allowing him not to skip this phase.
In the usual medication, a dropdown was added to the text box where the user enters the name of his medication to avoid mistakes and help him remember the name of his medication. However, we realize that the dropdown has not been able to help participants with a higher age range and low levels of education. The possible reason for this will be the lack of digital competence and not being used to using this type of elements. Simpler and more common elements such as buttons may be a more feasible option for these cases.
During the main complaint exploration, several questions are asked to the user regarding his main complaint. As certain medical terms are not common knowledge in society, it is important that the questions asked to the user are rewritten in a simple way with a common vocabulary. When questions, even rewritten, may cause the user to have doubts, the user should be given the opportunity to know more about the terms in doubt, through a simple click and an AlertDialog, for example.

5.4 System Improvement of the First Prototype of the Self-Service Kiosk

The system improvements presented in this section were directly drawn from the analysis of the obtained results and they amount both to the digital interface as well as to the medical sensor devices. Table 6 summarizes the differences between the current system and future system improvements. One such improvement involves the use of a CC reader to extract personal information quickly, thus replacing the need for the user to enter this data.
The past medical history screens will be reduced to one, allowing the user to view and select all possible health problems he may have, and taking him immediately to the usual medication phase. The implementation of this improvement demands a larger tablet for the necessary visualization and organization of the information.
In the usual medication, the writing of the name of the medication will undergo a process of correction and automatic search without the use of a dropdown. Dose writing will be replaced by a set of buttons associated with the various possible doses of each medicine, so that less proficient users understand the information they are asked for. The parts of the day will be associated with the description as a part of the button.
On the device screens, instructions will be displayed at the same time as the measurement,

so that the user has always access to the next step to take, thus reducing errors of use due to forgetfulness of steps during measurement. The BP monitor will also be changed to a device that reduces measurement errors.
To allow a larger number of participants to receive their measurement results, the possibility of sending an *Short Message Service (SMS)* will also be added.
The device's keyboard will also be replaced by a simpler and easier to use keyboard so that users with less digital competence will not be in doubt.

Table 6: *Current system versus system improvement*

Current System	**System Improvement**
Manual entry of the personal information	Extract personal information by CC
Smaller tablet	Larger tablet
Four clinical history screens	Only one clinical history screen
Manual medication search	Automatic medication search and medication names correction
Manual dose entry	Select dose button
Device instructions before measurement	Device instructions during measurement
MyTensio Wrist BW-BW1 Model	A new one with less measurement errors
E-mail measurement results	E-mail and SMS measurement results
Tablet keyboard	Simple and easier to use keyboard

5.5 INTELLIGENT UI/UX SYSTEM

No two users are the same, each has different habits, preferences and ways of working. An intelligent UI can take into consideration these differences and provide personalized interaction methods. Since an intelligent UI might know each user preferences, it is feasible to use that knowledge to set the best communication channel with that particular user. A "normal" UI is defined as a communication between a user and a machine. An extension of this definition for an intelligent interface is that the computer uses some component that tries to reproduce human intelligence to complete the human-computer communication. Likewise, they are also known as adaptive interfaces, since they can adapt to the user Alvarez-Cortes et al. (2009). Designing a multi-user adaptive interface means designing for a diversity of end-users and contexts of use, and implies making alternative design decisions at various levels of the interaction Gullà et al. (2015a,b). Thus, a self-adaptive UI changes automatically in response to its experience with user. Three types of the self-adaptive UI were distinguished. Those who collect information about the user and tailor the interface responses either during a session or between sessions. Those who identify a user as belonging to a particular category and set the interface's parameters accordingly (once only). And those in which the interface doesn't change but performance improves, for example by dealing with errors more quickly Browne (2016).

It is therefore intended to conceptualize a UI/UX system that intelligently adapts to the user based on the user's profile and the contents' features, allowing the familiarity with the smart device and the usability of the contents is improved. This UI/UX system was developed in the studies Yun et al. (2016); Ji et al. (2018); Lim et al. (2019), that propose a method of analyzing the user's cognitive and behavioural information in a distributed environment, providing a customized UI/UX based on the analysis.

Intelligent UI/UX systems need three major components: user model, contents model, and UI/UX model, to support adaptive UI/UX.

User model is one of the key components in the intelligent UI/UX system that contains information such as cognitive functionality, emotion, knowledge, health, and environment. Features of a user model can be divided into two categories: static features and dynamic features. Static features are the features that are not likely to change, such as gender, age, or education level. On the other hand, dynamic features are ones such as cognitive functionality, emotion, and health status that may change more frequently. Features of a user model are different between users, so it can be used to personalize the system to each user.

Contents model is the set of features of the content being displayed to the user such as subtitles, brightness, volume, size of buttons, interface layout, use of sound, images and virtual assistants. Features that are relevant to the user's usability affect UI/UX and can be adapted to the user's model.

UI/UX model defines the components subject to change based on the user model and contents model Yun et al. (2016).

The user model for this intelligent UI/UX system will be based on static characteristics such as gender, age range, nationality and education level, and dynamic characteristics such as digital competence, health problems and results of user vital signs measurements. The UI/UX model will be based on the user model, the contents model and the user-behaviour one that gathers behavioural data on the user's interaction with the kiosk application.

Initially, one collects the static and dynamic characteristics of users and the behavioural data on the users' interaction with the kiosk application. Then, based on the data collected it is generated a user classifier model and classified clusters. Neither in clustering nor in classification is there a predefined answer for user types, being necessary to use of semi-supervised learning. Semi-supervised machine learning is a supervised and unsupervised machine learning methods combined that allows operating with non-labelled data.

The Elbow method allows the best number of clusters to be obtained, i.e., the optimum number of user types. The Elbow method is a method to find an appropriate number of clusters in a data set based on the consistency of the data in the clusters Ji et al. (2018). After defining the number of clusters for the K-means algorithm, the user clusters are classified using this algorithm. K-means is an unsupervised learning algorithm for clustering, that aims to find similarities between the data and group them according to the number of clusters in the past. K-means is normally used with Euclidean metrics to calculate the distance between the points and the centres of the cluster Jain (2010). The classification of the user clusters allows the data to be labelled, determining the characteristics of each type of user. These characteristics will be essential in the customization of the UI, adapting the set of features of the contents model, for each type of user.

Since one intends a self-adaptive UI that changes automatically in response to the type of user, it will be necessary to choose a classification algorithm to create the user classification model. The choice of classification algorithm may vary according to data size, quality and characteristics. Therefore, this study aims to select the algorithm with the highest precision for the classification model.

Only static characteristics (gender, age range, nationality and education level) and dynamic characteristics (digital competence) of the user model will be used as attributes for each data register. It is intended that the user classification model is used at the beginning of the self-service kiosk session. This model will allow the user to be allocated to a particular category and to define the UI parameters accordingly, only once at the beginning of each session.

The architecture of the UI/UX model is outlined in Fig. 29.

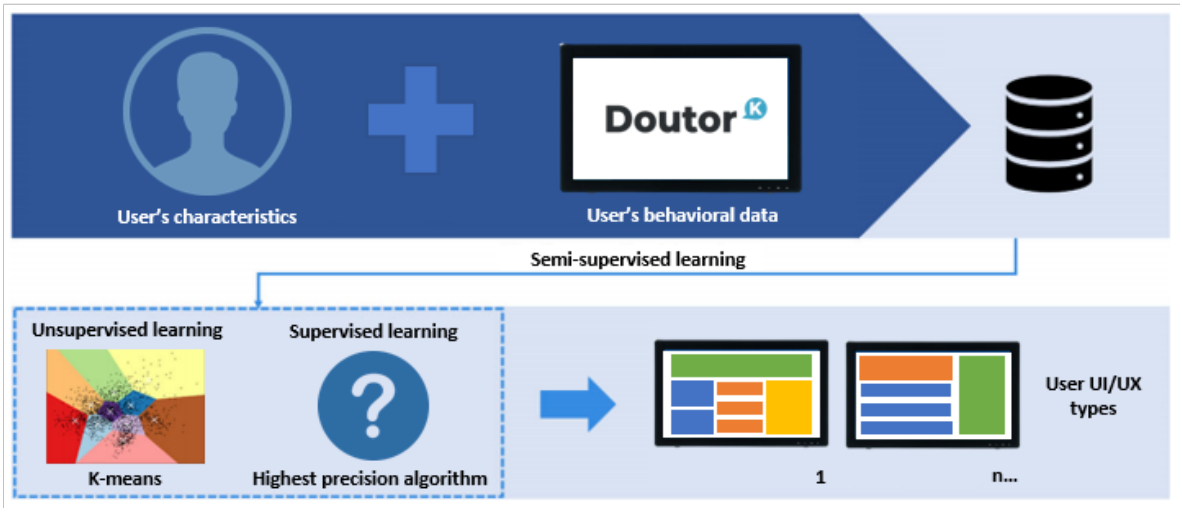


Figure 29: *UI/UX model*

During the process of determining the classification model, the *Cross-Industry Standard Process for Data Mining (CRISP-DM)* methodology is followed. This process is divided into six phases: Business Understanding, Data Understanding, Data Preparation, Modelling, Evaluation e Deployment, as can be seen in to figure 30. This methodology is followed due to its advantages, such as increasing the success of data mining projects, allowing the implementation of data mining models in real environments Morais et al. (2017).

Business Understanding: The business understanding phase focuses on understanding the project's objective from a business perspective, defining a preliminary plan to achieve the goal.

Data Understanding: The data understanding phase starts with an initial data collection and proceeds with activities to get familiar with the data, to identify data quality problems, to discover first insights into the data, or to detect interesting subsets to form hypotheses for

hidden information.

Data Preparation: The data preparation phase covers all activities to construct the final dataset from the initial raw data. Data preparation tasks are likely to be performed multiple times, and not in any prescribed order. Tasks include table, record, and attribute selection, data cleaning, construction of new attributes, and transformation of data for modelling tools.

Modelling: In this phase, various modelling techniques (algorithm of decision tree, support vector machine, neural networks, among other) are selected and applied, and their calibrated parameters for optimization.

Evaluation: At this phase is built one or more models that appear to have high quality, from a data analysis perspective. Before proceeding to the final deployment of the model, it is important to be certain it properly achieves the business objectives.

Deployment: In this phase the knowledge gained by the model was organized and presented in a way that the customer can use Wirth and Hipp (2000).

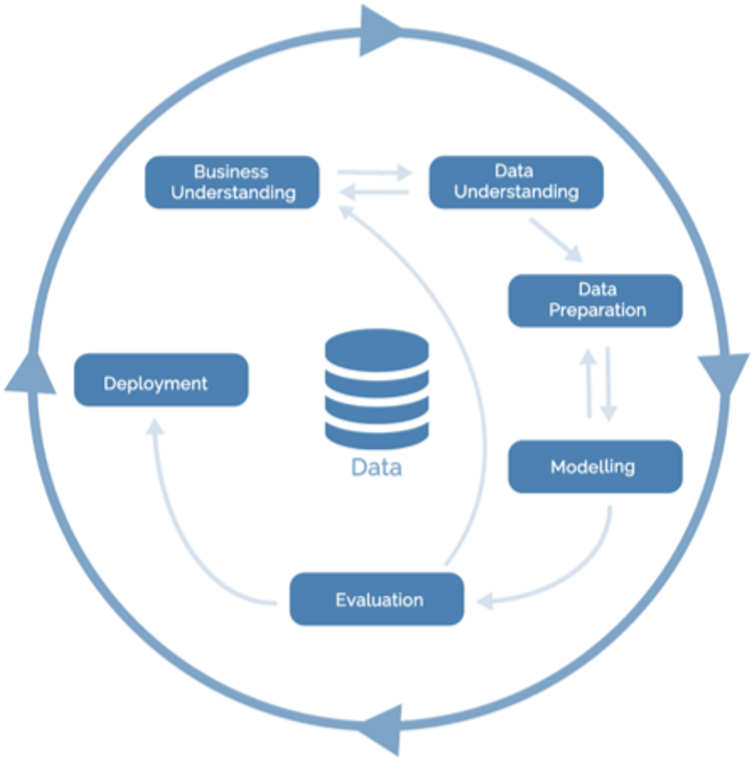


Figure 30: *The CRISP-DM process*

As it was not possible to carry out the data collection, only was conceptualized the intelligent UI/UX system and were described the first two phases of the CRISP-DM process.

Business Understanding

The main objective of this study is to predict the type of user of the self-service kiosk through data mining. The prediction of the type of user will allow the UI to be adapted to each type of user. These self-adaptive interfaces will offer the user a better human-computer interaction as they can adapt to the user, communicate with him and solve his problems.

Data Understanding

Each data record presents a set of nine attributes, which correspond to the label and the user's static and dynamic characteristics. The label corresponds to the type of user and will be defined in a value between one and the optimum number of user types. Although there are no data records yet, the type and description of each attribute was established, as it is presented in the table 7 .

Table 7: *Data description*

Attribute	Type	Description
Age Range	Nominal	Patient's age range
Gender	Nominal	Patient's gender
Nationality	Nominal	Patient's nationality
Education Level	Nominal	Patient's education level
Answer to Question 1	Nominal	Answer to the question "How often do you use a mobile phone or tablet?"
Answer to Question 2	Nominal	Answer to the question "Do you have difficulties using the keyboard of your device?"
Answer to Question 3	Nominal	Answer to the question "How often do you install an application on your device?"
Answer to Question 4	Nominal	Answer to the question "Do you use the Internet?"
User Type	Numeric	User type classification

6

CONCLUSION

ED crowding has been steadily increasing, with a significant share from non-emergent pathologies. This phenomenon negatively affects the delivery of emergency services, impairing the quality of health care and, consequently, the clinical outcome of patients. The project carried out resulted in the development of a self-service digital kiosk to improve both the time and quality of the anamnesis procedure performed by ED medical staff. Two basic requirements were considered:

- The solution has to integrate a self-service kiosk that allows the collection of the patient's anamnesis information in a fast and intuitive way;
- The solution must integrate a web platform providing a selective, structured and uniform presentation of anamnesis information of each patient to the medical staff.

By using the self-service kiosk to collect anamnesis information, patients of low clinical severity will be able to use their waiting time more productively. After this collection, the system provides this information to the physician, before the medical consultation, in order to reduce the clinical observation period and thus improve the response capacity of the ED. These patients with low clinical severity are assigned the colours blue, green or yellow shown on the Manchester Triage Protocol triage scale.

The literature review of health self-service kiosks helped to identify kiosk-based solutions to improve clinical care on health services. UI elements were the most relevant effectiveness aspect in health kiosks design, followed by clear communication and perception by patients of the advantages related to kiosks usage. The high levels of kiosks acceptance and satisfaction encountered support a relevant opportunity for the introduction of self-service kiosks in several healthcare contexts.

The system's specification allowed the planning of the solution and the architecture's choice that best suits the system. The functionalities and requirements of the system were specified and identified. The system architecture consists of a client-server communication

model in which the clients communicate with the same back-end system. The first phases of the UI/UX design process were carried out to get to know the system users better and the system's design. The E-anamnesis design made it possible to determine the questions to be asked during the self-service kiosk session, as well as all the clinical content associated with the past medical history, usual medication and main complaint exploration. The selection of the vital signs to be measured was based on the signs measured in a medical consultation.

The main components of the self-service kiosk correspond to the touch screen monitor and the biometric sensors. These biometric sensors allow the collection of biometric data from patients. All decisions to implement the UI elements and functionalities in each self-service kiosk prototype and web platform were duly justified. UX practices were used for improving the quality of the user's interaction and perceptions with the E-anamnesis platform. Indicators were defined to determine interaction difficulties during the kiosk session, to support clinical decision making and help institutions to improve their management and performance.

The usability evaluation of the self-service kiosk's first prototype allowed us to understand the aspects that should be improved in this first tested prototype. The heterogeneity of participants allowed to understand the difficulties felt while using the system more globally. In general, there was positive acceptability by participants, with a large majority considering the system user-friendly.

All participants were able to complete a kiosk session from start to finish without any help from observers, except in the screens for collecting vital signs for which were found a series of improvements based on the carried analysis. The time for a full kiosk session was less than expected, even though it is necessary to take into account that the kiosk was not tested in a real ED.

Unfortunately, the self-service kiosk's second prototype and web platform were not tested in the CHUSJ due to the pandemic situation. The primary purpose of this solution has not been verified, and the results of the usability assessment were not obtained. As it was not possible to carry out the data collection, dashboards based on the defined indicators were not created, as well as an intelligent UI/UX system that adapts to the type of user.

6.1 Future Work

As future work, it is essential to test the E-anamnesis platform in a hospital environment with ED patients for evaluation and survey of improvement proposals.

The implementation of the conceptualised UI/UX system, since patients of different ages

and digital competence are expected to use the self-service kiosk.

Creating a decision support diagnostic system for physicians could help them to achieve more accurate diagnoses.

The selection of medicines for the patient would be easier if he could select the medicine box's image instead of its name, since the image of the medicine box would raise visual recognition to the patient. Obtaining a database with images of the boxes of medicines sold in Portugal would be ideal, for presentation to the patient at the phase of collecting the usual medication.

Remembering the dose of each medicine is also difficult for the patient during the phase of usual medication. Having a database that would provide the possible doses of each medicine would be quite beneficial. Presenting these doses to the patient for selection would help him remember his dose and prevent him from not filling this field.

The ED can be visited by the same patient more than once, so the self-service kiosk should present the patient's history from previous visits, avoiding the selection's repetition of the same health problems or usual medication for example.

The web platform could also present a dashboard page of each patient's history of anamnesis information so that the physician could view any past patient information more quickly and intuitively and get support in determining the patient's diagnosis.

The determination of patterns between health problems, medicines and demographic indicators through data mining techniques could allow health problems to be suggested to the patient for selection through his demographic data and the selected medication. A CHUSJ physician reported that patients remember their medication easier than their health problems. The implementation of a system that suggests health problems names might assist them during the past medical history collection phase.

A system of main complaint suggestions would also facilitate the patient's interaction with the kiosk application. The patterns' determination between main complaints and past medical history, medication, vital signs, and demographic data through data mining techniques may allow this system's creation.

Replacing punctual measurements in the self-service kiosk with continuous monitoring of the patient's vital signs from the time the patient starts his session in the kiosk until he

leaves the ED, would provide physicians with the relevant biosignals data of each patient in real-time. This continuous monitoring would inform the physicians of possible worsening or improvement of the patients' health status during his stay in the ED. The use of a smart all-in-one device to measure vital signs can be a solution for this continuous monitoring.

A mobile application's creation could be interesting since we live in a time of intensive use of devices such as smartphones, which allow a more familiar and hygienic use.

The implementation of a solution that allows interoperability between the hospital system and the E-anamnesis platform will certainly facilitate the interchange of clinical information of patients between systems. This interoperability will also provide the possibility for the E-anamnesis platform to have access to patients' past clinical registers.

The creation of a modular self-service kiosk is fundamental since it can be easily adapted to different use cases, allowing the clinical staff to choose which functionalities the self-service kiosk should have at any given time.

6.2 CONTRIBUTIONS

The project presented in this dissertation has resulted in a conference publication and a submission of a systematic review to International Journal of Medical Informatics with the following references, respectively:

- Pacheco, P., Santos, F., Coimbra, J., Oliveira, E., Rodrigues, N. F. (2020, August). Designing Effective User Interface Experiences for a Self-Service Kiosk to Reduce Emergency Department Crowding. In 2020 IEEE 8th International Conference on Serious Games and Applications for Health (SeGAH) (pp. 1-8). IEEE.
- Pacheco, P., Santos, F., Coimbra, J., Oliveira, E., Rodrigues, N. F. The role of kiosks on health services: a systematic review (Submitted).

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A

KIOSK REQUIREMENTS

In this appendix, the functional and non-functional requirements of the kiosk are described.

A.1 FUNCTIONAL REQUIREMENTS

Requirement nº: 1
Type of requirement: Functional.
Use case: Register digital competence.
Description: The patient should be able to register of his digital competence.
Reason: In order to provide a user-friendly experience, it is essential to take into account the digital competence of each patient.

Requirement nº: 2
Type of requirement: Functional.
Use case: Register identification data.
Description: The patient must be able to register his identification data.
Reason: As this system collects a set of information on the health of each patient, he must register his identification.

Requirement nº: 3
Type of requirement: Functional.
Use case: Register the past medical history.
Description: The patient should be able to register of his past medical history.
Reason: As the past medical history may have an impact on clinical diagnosis, registration is essential.

Requirement nº: 4
Type of requirement: Functional.
Use case: Register usual medication.

Description: The patient should be able to register his usual medication.
Reason: The patient's usual medication can influence the physician's prescription of new medicines.

Requirement nº: 5
Type of requirement: Functional.
Use case: Register main complaint.
Description: The patient should be able to register his main complaint.
Reason: The patient's main complaint can help to identify the health problem.

Requirement nº: 6
Type of requirement: Functional.
Use case: Collect biometric data.
Description: The patient should be able to collect his biometric data.
Reason: The collection of biometric data from patients is one of the objectives of the system, and they must be able to do so.

Requirement nº: 7
Type of requirement: Functional.
Use case: Collect biometric data.
Description: The patient should be able to measure his BP.
Reason: Since BP is a vital sign, it is convenient for the physician to have its knowledge.

Requirement nº: 8
Type of requirement: Funcional.
Use case: Collect biometric data.
Description: The patient should be able to measure his body temperature.
Reason: Since body temperature is a vital sign, it is convenient for the physician to have its knowledge.

Requirement nº: 9
Type of requirement: Funcional.
Use case: Collect biometric data.
Description: The patient should be able to measure his HR.
Reason: Since heart rhythm is a vital sign, it is convenient for the physician to have its knowledge.

Requirement nº: 10
Type of requirement: Funcional.
Use case: Collect biometric data.
Description: The patient should be able to measure SPO2.
Reason: Since oxygen saturation in the blood is a vital sign, it is convenient for the physician to have its knowledge.

Requirement nº: 11
Type of requirement: Functional.
Use case: End Session.
Description: The patient may end the kiosk session at any time.
Reason: If the patient withdraws, the data registered so far must be deleted.

A.2 Non-Functional Requirements

A.2.1 *Appearance Requirements*

Requirement nº: 12
Type of requirement: Appearance Requirement.
Description: The application should display tutorials alluding to the use of the sensors.
Reason: Show patients the correct way to use biometric sensors.

A.2.2 *Usability Requirements*

Requirement nº: 13
Type of requirement: Usability Requirement.
Description: The system shall use terms appropriate to the context in which the system operates.
Reason: The system must use terms and vocabulary appropriate to the context in which it is inserted to facilitate its understanding by patients.

Requirement nº: 14
Type of requirement: Usability Requirement.
Description: The system should be easy to use.
Reason: It is important that the system is intuitive to facilitate the use by all patients.

Requirement nº: 15
Type of requirement: Usability Requirement.

Description: The system must adapt the different components of the interfaces to each patient's digital competence.
Reason: The system adapts the different interface components for each patient. This adaptation allows the interaction's improvement between the patient and the application.

A.2.3 *Performance Requirements*

Requirement nº: 16
Type of requirement: Performance Requirement.
Description: The process of collecting biometric data should be rapid.
Reason: The collection process should be rapid to reduce the effort exerted on the patient.

Requirement nº: 17
Type of requirement: Performance Requirement.
Description: The system should provide answers to patient requests promptly.
Reason: It is convenient that this interaction of the patient with the system is fluid so that the use of the system is pleasant.

Requirement nº: 18
Type of requirement: Performance Requirement.
Description: The system should always be available.
Reason: The system should always be available so as not to impede its use by patients.

A.2.4 *Security Requirements*

Requirement nº: 19
Type of requirement: Security Requirement.
Description: The application should protect information about patients.
Reason: It is essential that patients feel secure about the protection of their data.

A.2.5 *Legal Requirements*

Requirement nº: 20
Type of requirement: Legal Requirement.
Description: The patient must agree to the data privacy policy.
Reason: It is crucial that the patient, as well as being aware of the measures taken to protect his data, agrees to them.

Requirement nº: 21
Type of requirement: Legal Requirement.
Description: The system must comply with the General Data Protection Regulation, in force since 25 May 2018.
Reason: The system must comply with current laws.

B

WEB PLATFORM REQUIREMENTS

In this appendix, the functional and non-functional requirements of the web platform are described.

B.1 FUNCTIONAL REQUIREMENTS

Requirement nº: 1
Type of requirement: Functional.
Use case: Login.
Description: The system should check whether the credentials entered by the user are valid or not.
Reason: Validation of the data entered by the user is necessary in order to avoid undue access to the system.

Requirement nº: 2
Type of requirement: Functional.
Use case: Patient Search.
Description: The physician may search the patient.
Reason: This action is essential so that the physician can consult the correct patient's clinical register.

Requirement nº: 3
Type of requirement: Functional.
Use case: Consult the patient's clinical data.
Description: The physician should be able to consult the patient's clinical data collected at the kiosk.
Reason: Since a patient's diagnosis is depending on his clinical data, the physician must be able to consult them.

Requirement nº: 4
Type of requirement: Functional.
Use case: Consult the patient's clinical data.
Description: The physician should be able to consult the patient's past medical history.
Reason: A patient's past medical history can have an impact on his diagnosis.

Requirement nº: 5
Type of requirement: Functional.
Use case: Consult the patient's clinical data.
Description: The physician should be able to consult the patient's usual medication.
Reason: A patient's usual medication may have an impact on the prescription.

Requirement nº: 6
Type of requirement: Functional.
Use case: Consult the patient's clinical data.
Description: The physician should be able to consult the patient's main complaint.
Reason: The patient's main complaint can have an impact on his diagnosis.

Requirement nº: 7
Type of requirement: Functional.
Use case: Consult the patient's clinical data.
Description: The physician must be able to consult the patient's BP.
Reason: Knowledge of the patient's BP can influence his diagnosis.

Requirement nº: 8
Type of requirement: Functional.
Use case: Consult the patient's clinical data.
Description: The physician must be able to consult the patient's body temperature.
Reason: Knowledge of the patient's body temperature can influence his diagnosis.

Requirement nº: 9
Type of requirement: Functional.
Use case: Consult the patient's clinical data.
Description: The physician must be able to consult the patient's HR.
Reason: Knowledge of the patient's HR can influence his diagnosis.´

Requirement nº: 10
Type of requirement: Functional.

Use case: Consult the patient's clinical data.
Description: The physician must be able to consult the patient's oxygen saturation.
Reason: Knowledge of the patient's oxygen saturation can influence his diagnosis.

Requirement no. : 11
Requirement type: Functional.
Use case: Copy patient's clinical data.
Description: The physician should be able to copy patient's clinical data.
Reason: Copying the information from patients' clinical data speeds up the medical consultation.

Requirement nº: 12
Type of requirement: Functional.
Use case: Register diagnosis.
Description: The physician should be able to register the patient's diagnosis.
Reason: The diagnosis is registered to identify patterns between the data collected at the kiosk and the diagnosis provided by the physician.

Requirement no. : 13
Requirement type: Functional.
Use case: Logout.
Description: The physician may log out of the system.
Reason: When the physician has no more tasks to do in the system, he may end the session.

B.2 NON-FUNCTIONAL REQUIREMENTS

B.2.1 *Usability Requirements*

Requirement nº: 14
Type of requirement: Usability Requirement.
Description: The system shall use terms appropriate to the context in which the system operates.
Reason: The system must use terms and vocabulary appropriate to the context in which it is inserted to facilitate its understanding by physicians.

Requirement nº: 15
Type of requirement: Usability Requirement.

Description: The system should be easy to use.
Reason: It is important that the system is intuitive to facilitate the use by all physicians.

B.2.2 *Performance Requirements*

Requirement nº: 16
Type of requirement: Performance Requirements.
Description: The system should provide answers to patient requests promptly.
Reason: It is convenient that this interaction of the physician with the system is fluid so that the use of the system is pleasant.

Requirement nº: 17
Type of requirement: Performance Requirements.
Description: The system should always be available.
Reason: The system should always be available so as not to impede its use by physicians.

B.2.3 *Security Requirements*

Requirement nº: 18
Type of requirement: Security Requirements.
Description: The web platform should protect information about patients.
Reason: It is essential that patients feel secure about the protection of their data.

B.2.4 *Legal Requirements*

Requirement nº: 19
Type of requirement: Legal Requirements.
Description: The system must comply with the General Data Protection Regulation, in force since 25 May 2018.
Reason: The system must comply with the laws.

C

MOCKUPS

In this appendix, the UI's mockups developed for the self-service kiosk (figures 31 and 32) and the web platform (figure 33) are presented.

Figure 31: *UI's mockup of the kiosk application's first version*

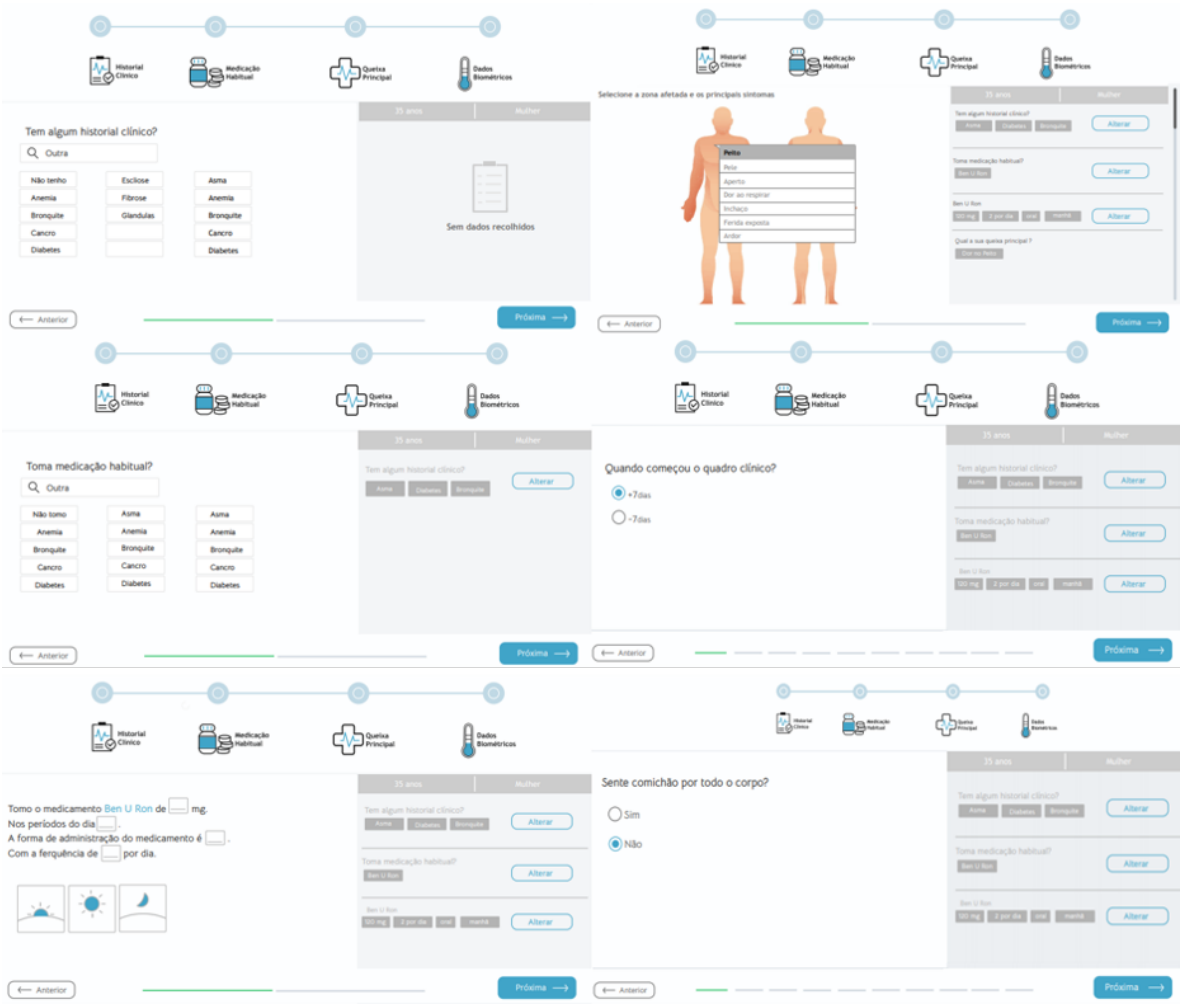

Figure 32: *UI's mockup of the kiosk application's second version*

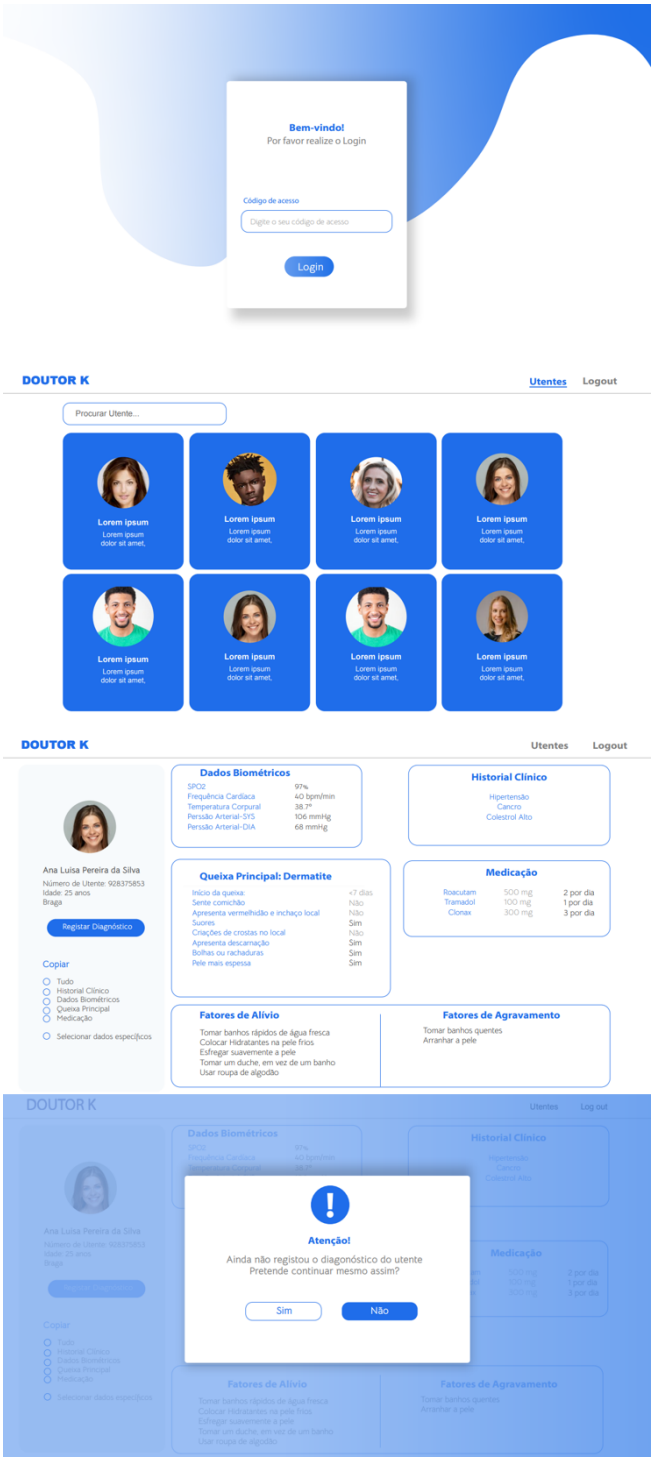

Figure 33: *UI's mockup of the web platform*

D

DEFINITIONS OF THE HEALTH PROBLEMS

In this appendix, the definitions of the health problems are described.

Thrombosis - Thrombosis corresponds to the formation of a blood clot inside a blood vessel, with the blood at that point stopping its circulation. It often occurs in the brain and can lead to a stroke.

Heart Attack - A heart attack occurs when one or more arteries that allow blood to reach the heart are blocked. The medical term for this is myocardial infarction.

Heart disease - Heart disease corresponds to any health problem in the heart that affects its ability to function normally. Some examples may be Heart arrhythmia, Heart failure, Heart murmur, Arthrosis, and Atherosclerosis.

Hypertension - Hypertension corresponds to the permanence of high BP values over several months or sudden increases in BP values.

Diabetes - Diabetes is a disease characterized by increased blood sugar levels. This disease appears in our body when it cannot produce a hormone that helps to control blood sugar levels, insulin.

High Cholesterol - Cholesterol is one of the fats circulating in the blood, which accumulates inside the arteries. Total cholesterol values above 190 mg/dL can mean that the person has high cholesterol.

Obesity - Obesity is a disease characterized by overweight. A body mass index (BMI) value of 30 or more indicates that can be at risk of obesity.

Depression - Depression is a psychiatric illness characterized by prolonged sadness, loss of interest in activities usually felt as pleasant, and loss of energy or easy tiredness.

Bipolar Disorder - Bipolar Disorder is a psychiatric illness characterized by marked variations in mood, where episodes of depression alternate with periods of excitement and enthusiasm.

Anxiety - Anxiety is an emotion characterized by feelings of tension, worry, insecurity, usually accompanied by physical changes such as increased BP and HR, sweating, dry mouth, tremors, and dizziness.

Migraines - Migraines are characterized by localized headaches and are associated with changes in body strength, speech, and vision.

Asthma - Asthma is an inflammatory disease of the airways (nose and mouth), characterized by a reduction in the size of the bronchi, which are found in the lungs, resulting in a sensation of respiratory difficulty.

Tuberculosis - Tuberculosis is an infectious disease, caused by the bacteria Mycobacterium Tuberculosis, which is acquired by air (nose and mouth). The disease usually reaches the lungs but can reach any other organ.

Cancer - Cancer is a disease that occurs when new cells are formed with genetic changes, growing uncontrollably, and spreading to possible organs in our body.

HIV/AIDS - HIV/AIDS is the Human Immunodeficiency Virus. The virus attacks and destroys our body's immune system, that is, it destroys the defence mechanisms that protect us from the disease.

Hepatitis - Hepatitis is an inflammation of the liver that can have several causes, the most common being viruses. When this occurs, the liver cannot perform its functions.

Kidney Failure - Kidney failure is a disease caused by decreased kidney function, the kidneys become sick and the ability to eliminate toxins and water that accumulate in the body is reduced.

Rare Disease - Rare diseases occur infrequently in the general population. They are mostly genetic and are present throughout the patient's life. Some examples of rare diseases are as follows: Gaucher Disease, Hemophilia, Acromegaly, Hereditary Angioedema, and Crohn's Disease.

Musculoskeletal disease - Muscular or joint disease is related to lower back and neck pain. These diseases cause back and neck pain, which can occur after a specific movement, such as lifting a weight or can result from the normal age-related wearing process.

Skin disease - Skin diseases are dermatological problems, usually related to herpes, dermatitis, rosacea, mycosis, psoriasis, and eczema.

Alzheimer's and others dementias - Dementia is a set of diseases, which conditions the loss of autonomy. Alzheimer's is part of this set of diseases, the main symptom of which is the loss of recent memories. However, there are other dementias such as Vascular Dementia, Parkinson's Disease, and Lewy Body Dementia.

E

ASSOCIATIONS OF BODY PARTS WITH THE MAIN COMPLAINTS

In this appendix, the associations of the body parts to the main complaints are presented.

Head

- Headache
- Itchy
- Inflammation of the skin

Nose

- Shortness of breath
- Itchy
- Inflammation of the skin

Mouth

- Shortness of breath
- Vomiting
- Cough
- Itchy
- Inflammation of the skin

Ears

- Earache
- Itchy
- Inflammation of the skin

Neck

- Shortness of breath
- Sore throat
- Muscular pain
- Cough
- Cervical pain
- Itchy
- Inflammation of the skin

Chest

- Shortness of breath
- Cough
- Muscular pain
- Chest pain
- Itchy
- Inflammation of the skin

Belly

- Muscular pain
- Vomiting
- Diarrhoea
- Abdominal ache
- Constipation
- Itchy
- Inflammation of the skin

Belly bottom

- Muscular pain
- Painful urination
- Joint pain
- Itchy
- Inflammation of the skin

Thigh

- Muscular pain
- Pain in the limbs
- Sciatica pain
- Itchy
- Inflammation of the skin

Knees

- Muscular pain
- Pain in the limbs
- Joint pain
- Itchy
- Inflammation of the skin

Leg

- Muscular pain
- Pain in the limbs
- Sciatica pain
- Itchy
- Inflammation of the skin

Shoulders

- Muscular pain
- Pain in the limbs
- Joint pain
- Itchy
- Inflammation of the skin

Arm

- Muscular pain
- Pain in the limbs
- Itchy
- Inflammation of the skin

Hands

- Muscular pain
- Pain in the limbs
- Joint pain
- Itchy
- Inflammation of the skin

Feet

- Muscular pain
- Pain in the limbs
- Sciatica pain
- Joint pain
- Itchy
- Inflammation of the skin

Back

- Muscular pain
- Itchy
- Inflammation of the skin

Bottom of Back

- Muscular pain
- Sciatica pain
- Lumbar pain
- Itchy
- Inflammation of the skin

Buttocks

- Muscular pain
- Diarrhoea
- Sciatica pain
- Joint pain
- Itchy
- Inflammation of the skin

Elbows

- Muscular pain
- Pain in the limbs
- Joint pain
- Itchy
- Inflammation of the skin

F

QUESTIONS OF THE MAIN SYMPTOMS

In this appendix, the questions concerning the main symptoms of each main complaint are presented.

Lumbar pain

- When did the complaint start?
- What is your pain level?
- Did you suffer a back trauma?
- Do you have difficulty walking?
- Do you feel colic?
- Does it hurt your stomach?
- Do you have any loss of consciousness or heart palpitations?
- Do you feel numbness or weakness in one or both legs?
- Do you have difficulty urinating?
- Do you feel a loss of bladder or bowel control?
- Have you suffered weight loss?
- Do you feel intense pain during the night?
- Are you having trouble breathing?
- Do you have sudden dizziness or sweat?
- Do you vomit?
- Does it have black or bloody stools?

- Is there blood in the urine?
- Have you had a fever?

Sore throat

- When did the complaint start?
- What is your pain level?
- Have you travelled abroad recently?
- Did the pain suddenly appear?
- Do you feel a wheeze when breathing?
- Are you having trouble breathing?
- Do you feel the voice muffled?
- Do you have a cough and difficulty swallowing, speaking, or breathing?
- Do you feel an impression in your ears when you swallow?
- Have you had a fever?

Earache

- When did the complaint start?
- What is your pain level?
- Do you have any fluid coming out of your ear?
- Have you got dizziness?
- Have you recently had a hearing loss?
- Do you have constant vomiting?
- Does it show redness and inflammation behind the ear?
- Does it present hoarseness, difficulty in swallowing, or blocked nose?
- Have you had a fever?

Headache

- When did the complaint start?
- What is your pain level?
- Have you had sudden changes in sensations or vision?
- Do you feel weakness?
- Do you have difficulty controlling your movements correctly?
- Does it convulse?
- Do you have difficulty speaking?
- Is it difficult to understand what others are saying?
- Are you feeling confused or sleepy?
- Feel your neck stuck?
- Do you feel pain when combing your hair or chewing?
- Have you suffered any weight loss?
- Do you have bright red eyes in bright places?
- Have you experienced any vision difficulties lately?
- Do you vomit?
- Is this headache similar to others you have had in the past?
- The headache comes and goes?
- Is the headache all over the head?
- Have you had a fever?

Muscular Pain

- When did the complaint start?
- What is your pain level?
- Did the pain arise during or after physical effort?
- Did you cramp?

- Were you in the wrong posture or a sitting position for several hours?
- Do you feel a pain that worsens with movement?
- Does it have swelling in any part of the body?
- Have you had a fever?

Shortness of breath

- When did the complaint start?
- Do you feel shortness of breath at rest?
- Are you feeling confused or dizzy?
- Do you experience chest discomfort or heart palpitations?
- Have you suffered weight loss?
- Do you have night sweats?
- Sudden shortness of breath?
- Do you sleep with more than one pillow?
- Do you wake up at night breathless?
- Are your feet swollen?
- Do you have sputum?
- Have you had a fever?
- Do you have muscle pain?

Painful urination

- When did the complaint start?
- What is your pain level?
- Do you have constant vomiting?
- Is there little or no urine?
- Do you have sweats and chills?
- Is there blood in the urine?

- Feeling heavy?
- Do you feel that your bladder is never empty?
- Is there a constant urge to urinate?
- Does urine smell strong?
- Feeling an itch on the spot?
- Does it show redness on the spot?
- Do you have pain in your lower back?
- Have you had a fever?

Vomiting

- When did the complaint start?
- What is your pain level?
- Thirsty or dry mouth?
- Is there little or no urine?
- Does it show weakness and tiredness?
- Do you have a headache?
- Feel your neck stuck?
- Are you feeling confused or losing attention?
- Do you feel constant pain in your stomach?
- Are you sensitive when you touch your abdominal?
- Does it have a swollen belly?
- Have you had a fever?

Diarrhoea

- When did the complaint start?
- What is your pain level?
- Do you have a stomachache or vomiting?

- Does it have blood, pus, oil, fat, or mucus in the stool?
- Does it show changes in colour or consistency in the stool?
- Is there little or no urine?
- Are you thirsty and dry?
- Have you suffered weight loss or appetite?
- Do you feel the urgent need to defecate or to defecate several times?
- Does it present with prolonged diarrhoea?
- Does it present diarrhoea during the night?
- Have you had a fever?

Itchy

- When did the complaint start?
- Do you feel itchy all over your body?
- Have you suffered weight loss?
- Feeling tired?
- Do you have night sweats?
- Do you feel weakness, numbness, or tingling?
- Do you have a abdominal ache?
- Does it have a yellowish colour on the skin and eyes?
- Are you very thirsty?
- Does it increase the amount of urine?

Cough

- When did the complaint start?
- What is your pain level?
- Are you short of breath?
- Does it have a sputum thick yellowish or greenish colour?

- Does it have blood sputum?
- Have you suffered weight loss?
- Have you had a fever lasting more than a week?
- Does it have a stuffy nose and sore throat?
- Do you have a prolonged cough?

Chest pain

- When did the complaint start?
- What is your pain level?
- Does it present pain with a sensation of crushing or pressure?
- Are you short of breath?
- Does it present sweats?
- Are you nauseous or vomiting?
- Does it hurt when chewing, on your back, neck, belly, or one of your shoulders or arms?
- Have you got dizziness?
- Does it have fast or irregular heartbeats?
- Have you had a fever?

Joint pain

- When did the complaint start?
- What is your pain level?
- Does it have swelling, a burning sensation, and redness in the joint?
- Does it have sores, stains, or purple spots on the joint?
- Do you have sores in your mouth, nose, or sexual organs?
- Do you feel pain in your chest?
- Do you feel pain in your stomach?
- Do you have difficulty breathing or coughing?

- Have you had a fever?
- Do you have sweats or chills?
- Have you suffered weight loss?
- Does it show redness or pain in the eyes?

Pain in the limbs

- When did the complaint start?
- What is your pain level?
- Is pain always present?
- The pain suddenly appears and is it strong?
- Do you feel a cold touch or a white colour?
- Do you feel pain in your chest?
- Does it present sweats?
- Do you have shortness of breath or heart palpitations?
- Have you had a fever?
- Has your limb suddenly swollen, with blisters or black spots?
- Does the affected member have weakness or numbness?

Abdominal ache

- When did the complaint start?
- What is your pain level?
- Does it have an accelerated heartbeat?
- Does it present sweats?
- Have you had a fever?
- Does it have swelling in the belly?
- Do you feel heartburn or nausea?
- Do you have vomiting or diarrhoea?

- Does it have blood in the stool or urine?
- Do you have a cough with blood?
- Have you suffered weight loss?
- Do you feel pain from the belly to the shoulder?

Cervical pain

- When did the complaint start?
- What is your pain level?
- Does it have a burning sensation or shock-like pain when you touch the skin?
- Does it present pain during the night?
- Do you feel weakness in your arms or legs?
- Do you feel tingling or reduced sensitivity in your arms or legs?
- Have you had a fever?
- Feeling tired?
- Have you suffered weight loss?
- Do you have headaches?

Sciatica pain

- When did the complaint start?
- What is your pain level?
- Is pain always present in only one side?
- Does it feel tingling or numb?
- Do you feel weakness or numbness when moving your leg or foot?
- Do you feel a sudden pain in your leg?
- Do you feel pain and other symptoms on your toes?
- Have you had a fever?

Constipation

- When did the complaint start?
- What is your pain level?
- Does it have hard, separate stools?
- Do you feel uneasiness and discomfort in your belly?
- Have you had a fever?
- Does it have a swollen belly?
- Do you have gases?
- Do you feel sick and vomit?
- Do you have trouble evacuating?
- Do you still feel like evacuating after you have done it?

Inflammation of the skin

- When did the complaint start?
- Feeling itchy?
- Does it show redness and swelling in place?
- Does it present sweats?
- Do you present crust creations on-site?
- Does it present peeling?
- Does it have blisters or cracks?
- Has thicker skin?

G

EXPLANATION OF THE COMPLEX TERMS OF QUESTIONS CONCERNING THE MAIN SYMPTOMS

In this appendix, the explanations of the complex terms of questions concerning the main symptoms are presented.

Heart Palpitations - The sensation that the heart is racing, accelerated, or that it has skipped a beat.

Intense Pain - Intense pain is a pain that prevents you from performing activities such as watching television, telephoning, or reading.

Vertigo - Vertigo is the sensation that the environment where we are is in a rotating movement.

Fever - Fever can be a normal response to an infection and occurs when the body temperature is above 38º C. Normal body temperature is between 36-37º C.

Wheezing - Wheezing occurs when you put the air out and produces a shrill sound like a whistle or whistle.

Muffled voice - Muffled voice corresponds to a voice that can be heard badly, giving the idea of difficult breathing.

Convulsions - Convulsions correspond to rapid muscle contractions and relaxation in a disorderly manner and are also known as spasms.

Cramp - Cramp occurs when muscles get stuck, appearing after exercise, meals or during sleep.

Dizziness - Dizziness corresponds to a feeling of weakness, imbalance, dazed head, vertigo,

or feeling faint.

Sputum - Sputum is the elimination, through coughing, of secretions produced in the lungs and is known as sputum.

Chills - Chills, also known as shivers, are muscle contractions and relaxation that cause "chicken skin".

Crusts - Crusts correspond to a hard surface, which forms above a wound.

Peeling - Peeling corresponds to the fall or elimination of the upper parts of the skin.

Cracks - Cracks are crevices caused by dry skin.

H

RELIEF AND AGGRAVATION FACTORS

In this appendix, the relief and aggravation factors of each main complaint are presented.

H.1 RELIEF FACTORS

Lumbar pain

- Being in a horizontal position;
- Being at rest for 1 or 2 days;
- Alternating between sitting and standing positions;
- Placing hot and cold compresses;
- Massaging the area;
- Performing simple stretching exercises;
- Healthy and balanced diet.

Sore throat

- Little voice effort;
- Ingesting candies, tablets, or throat sprays;
- Drinking warm liquids;
- Gargling warm water and salt;
- Being in humid environments.

Earache

- Drinking liquids;
- Being in open and well-ventilated environments;
- Cleaning the ears and removing excess wax;
- Putting the hot, dry compress on the area;
- Wearing hearing protectors when swimming or diving;
- Nose washing with saline or seawater.

Headache

- Resting;
- Sleeping;
- Maintaining the same routine;
- Practicing yoga and meditation exercises;
- Drinking liquids;
- Being in a quiet environment;
- Being in a dark environment;
- Massaging the back and neck;
- Applying ice to the head;
- Exercising pressure in the area that hurts;
- Taking a hot bath.

Muscular pain

- Placing cold or hot compresses on the area;
- Performing stretching exercises slowly;
- Massaging;
- Being at rest.

Shortness of breath

- Being at rest;
- Being in the right posture;
- Not making too much effort, avoiding meals that are difficult to chew;
- Wearing comfortable clothes.

Painful urination

- Relaxing;
- Practicing yoga exercises, meditation and pilates;
- Drinking water;
- Practicing hip-oriented exercise;
- Use of heat on the area;
- Urinating whenever you feel the need.

Vomiting

- Drinking water;
- Having small meals at shorter intervals, in calm and airy environments;
- Raising the head end of the bed during sleep;
- Eating food at room temperature or cold;
- Having good oral hygiene.

Diarrhoea

- Drinking plenty of liquids;
- Practicing physical exercise.

Itchy

- Practicing relaxation exercises;
- Massaging;
- Pinching;
- Tapping lightly;

- Taking short baths;
- Using soft towels;
- Moisturizing the skin with cold creams;
- Using cold or warm water;
- Using soap;
- Being in humid environments.

Cough

- Inhaling hot and humid air;
- Having a good nose hygiene;
- Wrapping up;
- Drinking more liquids;
- Use of physiological serum;
- Being at rest.

Chest pain

- Undoing the clothes, especially on the neck, chest and waist;
- Staying in airy places;
- Breathing deeply;
- Sitting or lying down;
- Resting;
- Massaging the chest;
- Lying down and hugging your knees with your legs bent.

Joint pain

- Immobilising joint with a splint;
- Placing hot or cold compresses;
- Relaxing the muscle;

- Massaging;
- Performing stretching;
- Weight control;
- Being at rest.

Pain in the limbs

- Placing warm compresses on site;
- Massaging;
- Being at rest;
- Performing stretching.

Abdominal ache

- Relaxing;
- Drinking lots of water;
- Walking;
- Eating cooked vegetables, fresh fruit, and whole grains;
- Placing hot water compress on site;
- Massaging;
- Breathing deeply;
- Performing stretching;
- Practicing yoga and meditation exercises.

Cervical Pain

- Putting pockets of heat or ice in place;
- Being at rest;
- Sitting without bending your neck;
- Sleeping on your stomach;
- Performing stretching.

Sciatica pain

- Putting pockets of heat or ice in place;
- Being at rest alternating with body movements;
- Having good posture;
- Bending your knees to lift a weight;
- Wearing shallow shoes;
- Practicing pilates exercises;
- Practicing yoga;
- Lying down;
- Walking.

Constipation

- Drinking plenty of liquids;
- Practicing physical activity;
- Defecating always at the same time each day;
- Defecating with your feet on a low stool, so that your knees are above the hip.

Inflammation of the skin

- Applying gauze, or thin cloth, soaked in cold water;
- Taking quick baths of fresh water;
- Putting moisturisers on cold skin;
- Keeping the room temperature cool, but not cold;
- Practicing yoga and meditation;
- Gently rubbing the skin;
- Wearing cotton gloves at night;
- Taking a shower instead of a bath;
- Wearing cotton clothing.

H.2 AGGRAVATION FACTORS

Lumbar pain

- Being in a sitting position, with the torso curved;
- Lifting weights;
- Standing;
- Walking;
- Being at complete rest.

Sore throat

- Being in polluted or air-conditioned environments;
- Being in places with many people and little air circulation;
- Drink ice water, soft drinks or eat ice cream;
- Eating irritant substances such as pepper, vinegar, and acidic fruit;
- Smoking;
- Drinking little water;
- Striving for a voice;
- Drinking alcohol.

Earache

- Cleaning the ears with cotton buds or other objects that may cause ear injuries;
- Being in environments polluted with tobacco smoke;
- Using headphones;
- Drinking alcohol or coffee;
- Smoking;
- Intake of water into the ear during bathing, swimming pool or sea;
- Using drops to soften the wax.

Headache

- Drinking alcohol;
- Smoking;
- Being in places with bright light;
- Being in noisy environments;
- Being at high altitudes;
- Eating excess cheese, chocolate, and caffeine;
- Suffering day-to-day setbacks;
- Displaying stress and irritation;
- Climbing stairs;
- Heading down;
- Walking;
- Using intense perfumes;
- Being in front of the TV or computer for a long time.

Muscular pain

- Practicing physical exercise;
- Having family conflicts;
- Performing muscle strain;
- Suffering temperature changes;
- Displaying stress and irritation.

Shortness of breath

- Practicing physical exercise;
- Presenting stress;
- Eating heavy meals;
- Smoking;

- Being in places with smokers;
- Lying down;
- Being in places with allergy-causing materials;
- Being in cold environments.

Painful urination

- Presenting stress;
- Practicing yoga exercises, meditation and pilates;
- Drinking alcoholic, carbonated, and caffeinated beverages and eat foods with caffeine, spicy or sour, chocolates and soya;
- Having sexual relations;
- Smoking;
- Feeling like urinating and not going to urinate;
- Lack of care with personal hygiene.

Vomiting

- Drinking alcohol;
- Eating bitter, fatty, chocolate and tomato stews;
- Drinking carbonated and caffeinated beverages;
- Smoking;
- Eating 2 to 3 hours before going to bed;
- Wearing tight clothes;
- Drinking liquids during meals;
- Carrying out activities that increase the pressure on the stomach, right after meals.

Diarrhoea

- Drinking soft drinks or other liquids with very high amounts of sugar;
- Displaying stress and anxiety;
- Eating food that is difficult to digest;

- Eating wholemeal bread, raw fruit, and vegetable peels;
- Drinking tea and coffee;
- Drinking milk and milk products;
- Eating products of animal origin;
- Smoking.

Itchy

- Presenting stress;
- Using disinfectants;
- Performing hot and prolonged baths with too hot water;
- Using soaps, more concentrated bath products;
- Using fibres and wool in clothing;
- Wearing tight clothes;
- Excessive use of clothes or blankets in bed;
- Being in polluted environments.

Cough

- Smoking;
- Being in low temperature environments;
- Being in draughty environments;
- Being in an environment with infiltrations;
- Being in a polluted environment;
- Drinking very cold drinks.

Chest pain

- Making physical efforts;
- Smoking;
- Presenting stress;

- Presenting anxiety;
- Eating food with fat.

Joint pain

- Making physical efforts;
- Presenting anxiety;
- Sleeping poorly;
- Smoking;
- Sitting for a long time.

Pain in the limbs

- Making physical efforts;
- Smoking;
- Sleeping poorly;
- Overusing computers or electronic games;
- Being in cold environments;
- Walking.

Abdominal ache

- Presenting stress;
- Touching the spot;
- Lying down;
- Drinking coffee, soft drinks, or fried food;
- Presenting anxiety;
- Smoking;
- Drinking alcohol.

Cervical Pain

- Bad sitting position;
- No movements throughout the day;

- Carrying out repetitive movements;
- Presenting stress;
- Sleeping with more than one pillow;
- Reading in bed supported by pillows;
- Using the phone between your head and shoulder;
- Using very heavy bags on one side of the body only.

Sciatica pain

- Lifting weights incorrectly;
- Smoking;
- Sitting or standing for long periods;
- No movements throughout the day;
- Performing sudden movements with the spine;
- Lying down.

Constipation

- Presenting anxiety;
- Ignoring the desire to evacuate;
- Eating food high in sugar or fat.

Inflammation of the skin

- Taking hot baths;
- Presenting stress;
- Scratching the skin;
- Wearing exfoliating gloves during bathing;
- Rubbing wet skin;
- A balanced diet with every meal.

I

QUESTIONNAIRES

In this appendix, the questionnaires carried out to the users of the first and second self-service kiosk prototypes are presented. The questionnaire done to the physicians of the web platform prototype is also provided in this appendix.

I.1 QUESTIONNAIRE OF THE FIRST SELF-SERVICE KIOSK PROTOTYPE

- Overall, I am satisfied with how easy it is to use this system?
- It was simple to use this system?
- I was able to complete the tasks and scenarios quickly using this system?
- I felt comfortable using this system?
- It was easy to learn to use this system?
- I believe I could become productive quickly using this system?
- The system gave error messages that clearly told me how to fix problems?
- Whenever I made a mistake using the system, I could recover easily and quickly?
- The information (such as help, on-screen messages, and other documentation) provided with this system was clear?
- It was easy to find the information I needed?
- The information was effective in helping me complete the tasks and scenarios?
- The organization of information on the system screens was clear?
- The interface of this system was pleasant?
- I liked using the interface of this system?

- This system has all the functions and capabilities I expect it to have?
- Overall, I am satisfied with this system?

I.2 Questionnaires of the Second Self-Service Kiosk Prototype

I.2.1 *Patient Questionnaire*

- Do I believe that the use of the CC was a good way to collect personal information?
- Did the answers' history help me to remember and edit the answers given?
- Did the selection of a body part help me identify my main complaint more quickly?
- The measurement through step-by-step videos, helped me to make the measurement?
- I believe that having assistance is indispensable?
- Overall, am I satisfied with the ease of use of this system?
- I was able to complete the tasks quickly?
- It was easy to learn to use this system?
- The system gave error messages that clearly told me how to fix problems?
- Whenever I made a mistake using the system, I could recover easily and quickly?
- The information (such as help, on-screen messages, and other documentation) provided with this system was clear?
- Overall, I am satisfied with this system?

I.2.2 *Nurse Questionnaire*

- Do I believe that the use of the CC was a good way to collect personal information?
- Did the answers' history help me to remember and edit the answers given?
- Did the selection of a body part help me identify my main complaint more quickly?
- The measurement through step-by-step videos, helped me to make the measurement?
- I believe that having assistance is indispensable?
- Do I believe that the information collected was sufficient?

- Overall, I am satisfied with how easy it is to use this system?
- I was able to complete the tasks quickly?
- It was easy to learn to use this system?
- The system gave error messages that clearly told me how to fix problems?
- Whenever I made a mistake using the system, I could recover easily and quickly?
- The information (such as help, on-screen messages, and other documentation) provided with this system was clear?
- Overall, I am satisfied with this system?

I.3 QUESTIONNAIRE OF THE WEB PLATFORM PROTOTYPE

I.3.1 *Evaluation Effectiveness - First Part*

- Have all health problems been registered by the patient (If the patient only registered A and did not register B)?
- Have all health problems been registered correctly (If the patient registered A and should have registered B)?
- Has all the usual medication been registered by the patient (If the patient only registered A and did not register B)?
- Has all the usual medication been registered correctly (If the patient registered A and should have registered B)?
- Were all measurement values reliable (No major discrepancies between measurements at the kiosk and measurements in the query)?
- Were the answers from the main complaint exploration similar to the answers given in the medical consultation?

I.3.2 *Satisfaction - Second Part*

- Was it easy to research the patients?
- Has the patient's usual medication been clearly presented?
- Did the danger signs present in the biometric data of the patients help me to have an immediate perception of the abnormal values of the patients?

- Did the colours in the answers to the questions of the main complaint exploration help me to have an immediate perception of the positive and negative answers?
- Has the need to scroll become uncomfortable?
- Was the functionality of the “Copy” and “Copy All” buttons useful?
- Did the registers collected help me determine the diagnosis more quickly?
- The presence of a dropdown with several diagnoses allowed me to insert the diagnosis faster?
- Was the information collected from the patient sufficient?
- Overall, I am satisfied with how easy it is to use this system?
- It was easy to learn to use this system?
- The information provided with this system was clear?
- Overall, I am satisfied with this system?

J

FLYER AND POSTER

In this appendix, the flyer given to patients at triage (figure 34) and the physicians' poster (figure 35) are presented.

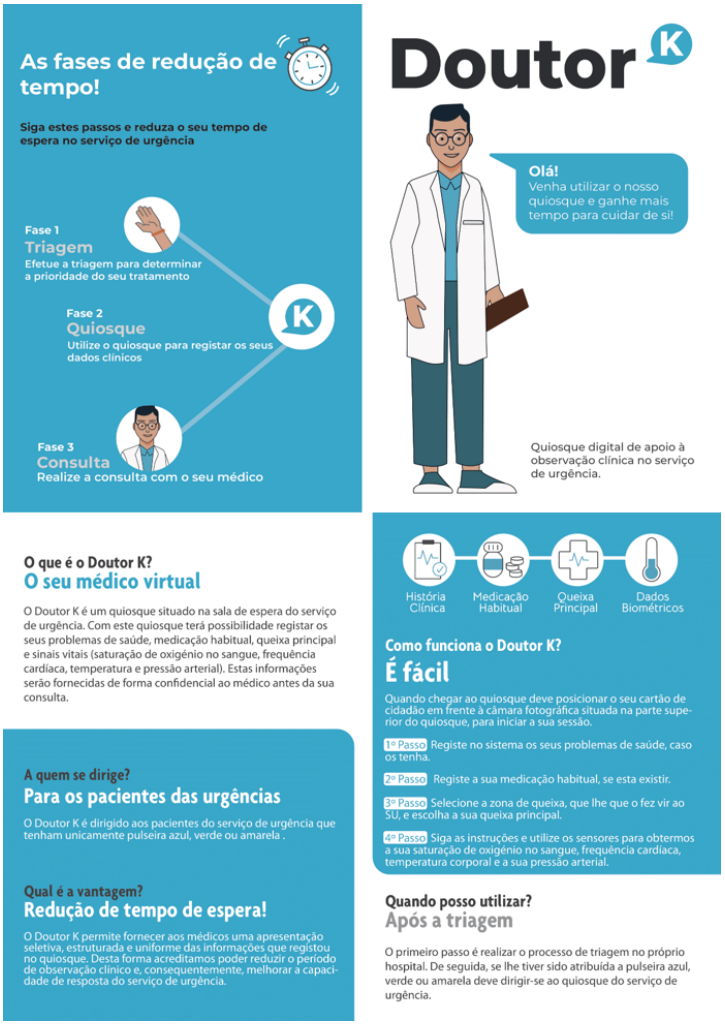

Figure 34: *Patients' flyer*

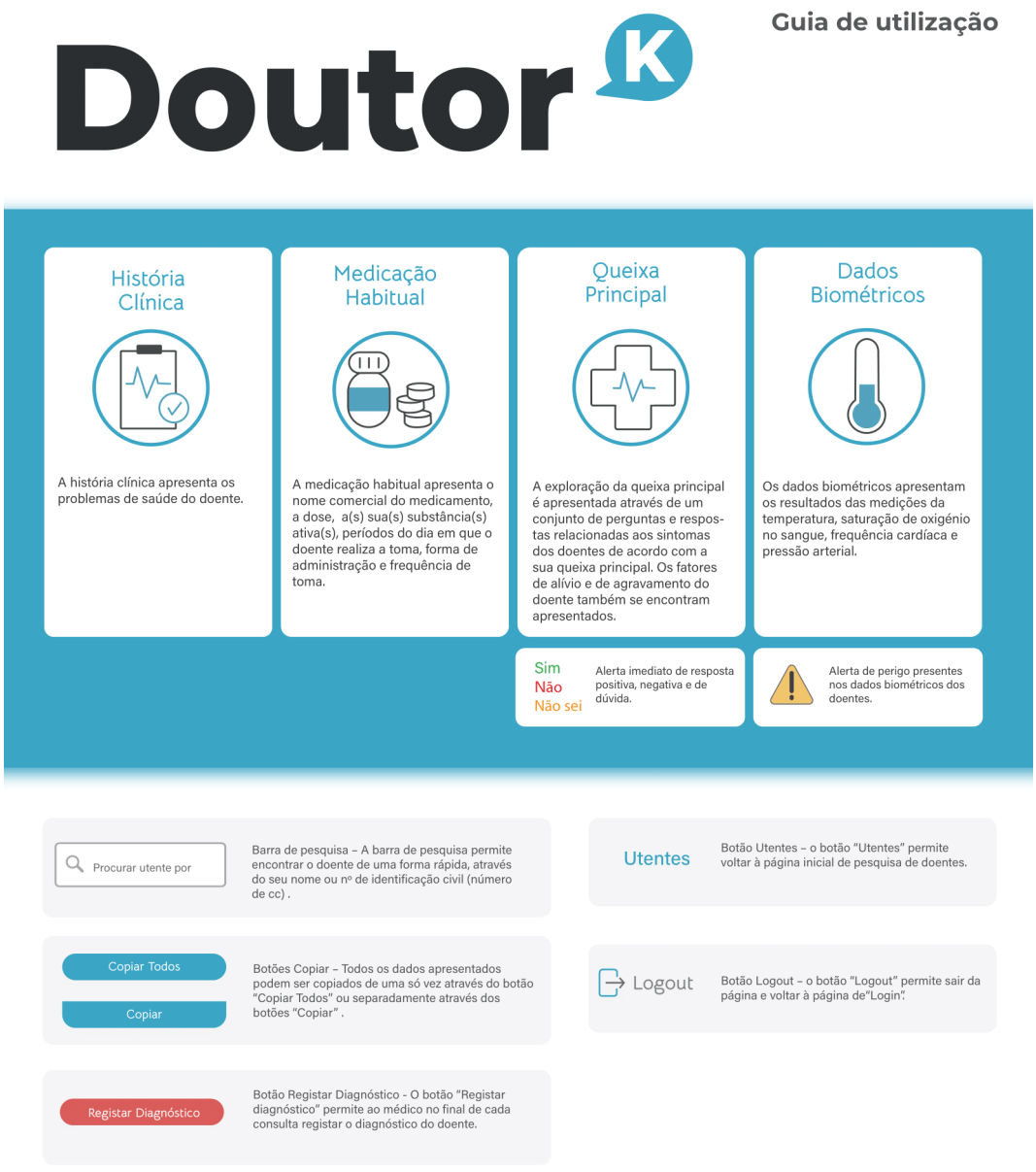

Figure 35: *Physicians' poster*

K

TESTS PROTOCOL

In this appendix, the tests protocol is presented.

K.1 INTRODUCTION

According to the American College of Emergency Physicians, crowding in the ED occurs when the need for emergency services exceeds the resources available for the patients' care in the ED, hospital or both. In general, this phenomenon negatively affects the provision of emergency services, impairing the quality of health care and, consequently, the clinical outcomes of patients. When capacity is high, the time patients wait to see a physician tends to increase, as does the number of patients leaving without medical advice. One of the main reasons for crowding in the ED is the high number of non-urgent or inappropriate patient presentations.

Emerging medical devices open up the possibility of setting up systems that can help collect health information from patients in hospitals or health centres. Examples of such systems are self-service kiosks, that are, independent units that contain computer programs and provide services to patients. In general, these systems are largely portable, interactive and have a simple UI such as a touch screen or keyboard. A study by Grace Ng showed that by placing kiosks in waiting rooms, patients were able to use the time between registration and consultation with the physician to engage in productive tasks that help the medical process. This technological solution aims to improve both the time and the quality of the anamnesis procedure performed by healthcare professionals in the ED by introducing a self-service kiosk placed in the ED waiting room. Information on medical history, medication, main complaint symptoms and vital signs collected by patients through the kiosk will be made available to the physician before each clinical observation. The hypothesis considered is that by providing a selective, structured and uniform presentation of the anamnesis information of each patient, the physician's observation can proceed much faster and more accurately, focusing on the confirmation of the most relevant aspects. The main objective of this solution

is to reduce the period of clinical observation of patients and thus improve the response capacity of the ED with the same resources.

K.2 PROJECT DESCRIPTION

This platform will be provided by the Universidade do Minho, consisting of a set of sensors (thermometer, finger oximeter and pulse BP monitor) from Bewell Connect, a keyboard, a TBee Box, a webcam and a touchscreen monitor.

The patient will access the kiosk via an Android application, where various questions will be asked in accordance with the initial clinical observation procedure carried out by the physicians (anamnesis). Thus, the system integrated with the kiosk should allow the quick registration of this clinical data in an intuitive way, so that the patient is able to use the application independently and without prior training.

It is envisaged that the entire test phase will be carried out within a period of two months.

K.3 TEST PHASE I

The test aims to identify:

- Evaluation of the interface's effectiveness, to record correct and complete patient information. In medical consultations, the physician will carry out the anamnesis process and compare the patient's answers with those recorded in the system. The result of this evaluation will be obtained through a questionnaire to the physician;
- If the registers collected by the kiosk are presented to physicians in a selective, structured and uniform manner. This will be identified through a questionnaire to physicians;
- The impact of the platform's use in the clinical observation process in obtaining the patient's diagnosis. This impact will be determined through a questionnaire to the physicians, where it is intended to understand whether the system has helped in obtaining the patient's diagnosis;
- A set of attributes:
  - Age range;
  - Gender;
  - Educational level;

- Nationality
- Digital competence;
- Health problems;
- Time of a full kiosk session;
- Time per interface;
- Number of clicks in unexpected locations per interface;
- Number of times the patient needed to use the doubt icon on the main complaint exploration interface;
- Values in SPO2, body temperature, HR and BP measurements;
- Using the history for navigation or back button;
- Give-ups in the use of each sensor;
- Patient questionnaire questions;
- Need for assistance for each screen;
- General difficulties, taken from the observation.

How the test will work:
During this phase, there will be only one test group, the intervention group corresponding to the patients who used the kiosk before the medical consultation. Patients in the intervention group will be referred by flyers, offered at triage, and by assistants to the kiosk, where they will be provided with assistance.

Who can participate?
All patients who, after triage in Manchester, have blue, green or yellow bracelets.

Where are trials carried out?
This study will be carried out in the ED of the CHUSJ. The approval of the project was obtained by the ethics committee of the hospital.

How long does the clinical trial last?
In the phase I trial it is intended to obtain 50 user registers. As soon as the desired goals are identified, the platform will be later tested in the phase II trial.

The patient questionnaire will be taken at the end of each session at the kiosk, where a tablet with a questionnaire to fill in will be provided. The physician's questionnaire will be carried out at the end of the test phase to a set of randomly chosen physicians. In the possibility to conduct interviews, these will replace the patient and physician questionnaires,

as interviews provide more detailed and reliable answers.

If some nurses use the kiosk, a specific questionnaire will be carried out for these healthcare professionals to get feedback on their use. This use by these healthcare professionals will have to take place at the beginning or end of this phase so it does not interfere with the registers collected from patients. As with patient and physician questionnaires, if an interview is possible it will replace the questionnaire.

K.4 TEST PHASE II

The test aims to identify:

- The same set of attributes of phase I.
- The types of users of the kiosk. These types of users will be identified using semi-supervised learning;
- The impact of platform use on the clinical observation process. That is if allowed:
  - Reduction of the period of clinical observation;
  - Helped in obtaining the patient's diagnosis.

  This impact will be determined through time comparisons of medical consultations, between control and intervention groups and a questionnaire to physicians.
- If the registers collected by the kiosk are presented to physicians in a selective, structured and uniform manner. This will be identified through a questionnaire to physicians.

The patient questionnaire will be carried out at the end of each session at the kiosk, where a tablet with its respective questionnaire will be provided for completion. The physician's questionnaire will be carried out at the end of the test phase to a set of randomly chosen physicians. This questionnaire will present only the second part, the questionnaire of satisfaction. The possibility of interviews will replace the patient and physician questionnaires, as more detailed and reliable answers will be obtained.

How the trial will work:
During this phase, there will be two groups of tests. The control group, which corresponds to patients who will perform the medical consultation without using the kiosk, and the intervention group, which corresponds to patients who used the kiosk before the consultation. Patients in the intervention group will be referred by flyers, offered at triage, and by assistants to the kiosk, where they will be provided with assistance.

How long will the clinical trial last?
The Phase II trial aims to obtain 100 user registers. As soon as the desired goals are identified, the platform will be tested later in the Phase III or Phase IV trial.

K.5 TEST PHASE III

This test will only be carried out if a considerable number of modifications are made.

The test aims to identify:

- Evaluation of the interface's effectiveness, to record correct and complete patient information. In medical consultations, the physician will carry out the anamnesis process and compare the patient's answers with those recorded in the system. Through the questionnaire to the physician, the result of this evaluation will be obtained;
- If the registers collected by the kiosk are presented to the physicians in a selective, structured and uniform manner. This will be identified through a questionnaire to the physicians;
- Evaluation of the self-adaptive interfaces, through the process of observation, questionnaire and other variables taken from the interaction of the patient with the kiosk.

The trial will operate in the same way as the phase I trial, with the aim of obtaining 50 registers.

K.6 TEST PHASE IV

The Phase IV test seeks to assess:

- The self-adaptive interfaces;
- Whether the registers collected by the kiosk are presented to physicians in a selective, structured and uniform manner (this evaluation will only occur if the interface of the physician's web platform is changed, between phase I and phase IV);
- The period of clinical observation has been reduced.

Determination of evaluations:

- Through the observation process, questionnaires and other variables taken from patient interaction with the kiosk;

- Through a questionnaire to the physicians;
- Performing a comparison of times of use of each interface and complete session of the system in relation to the previous phase;
- Through the times of each medical consultation, it is intended to determine whether a reduction in the period of clinical observation has occurred. Time comparison of the medical consultations between the control group and the intervention group will be carried out.

The trial will operate in the same way as the phase II trial, with the aim of obtaining 50 registers.