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Mobile Application for Reporting Chronic Pain Experiences

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Abstract

"Chronic pain is a condition that affects at least 10% of the world's population". The prevalence of this condition worldwide makes it paramount to study how early chronic pain developments in teens will affect them in adult life. Additionally, the assessments and recordings of pain intensity have to be done continuously and regularly to optimize therapy and improve patients' quality of life. Traditional methods of this assessment require pain-afflicted patients to attend appointments that vary in regularity depending on the severity of this condition.

There are several methods of collecting a patient's pain experiences. These methods, primarily used in paper format, go through simple scales to fully-fledged questionnaires. It is crucial to understand how they work so we can better adapt them to new digital methods.

With the rise of mobile applications in the twenty-first century, the recording of pain experiences has been made much more manageable as patients could now evaluate and manage their pain daily. At the moment, there are hundreds of cross-platform applications for monitoring chronic pain, both for general and specific types of pain.

The application's primary purpose for this work is to collect data from teenagers, with ages comprehended between 15 and 16 years, regarding their pain experiences. These users are participants in ISPUP's (the Public Health Institute of the University of Porto) cohort, named Generation XXI. This application will be used to gather data used in a research context rather than personal use.

The developed Android application used Loopback for its server and Ionic, coupled to Vue, for its client. The final application had a group of eleven users complete a survey during a one-week pilot test. Of these eleven people, three were researchers, and eight were teenagers between 13 and 18. In order to test the impact gamification could have on this application, the teenagers were evenly separated into a control group and a group with access to gamification features. During this test, the viability and usability of the application were tested and compared to on-site methods.

Every objective set for this thesis was fulfilled. The application is expected to, in the short term, create a more flexible and dynamic method of data collection regarding participants' pain experiences as well as improve the quantity and quality of pain data to which researchers will have access. In the long term, it is planned that with the collected data, researchers can assess which initial characteristics are most helpful to predict whether children will develop musculoskeletal pain later in life.

Keywords: Chronic Pain, Generation XXI, Mobile Development, Pain Management, Musculoskeletal Pain

Resumo

"A dor crónica é uma condição que afeta pelo menos 10 % da população mundial". A prevalência dessa condição mundialmente torna fundamental o estudo de como a evolução precoce da dor crónica em adolescentes os afetará na vida adulta. Além disso, as avaliações e registos da intensidade da dor devem ser feitos contínua e regularmente para otimizar a terapia e melhorar a qualidade de vida do paciente. Os métodos tradicionais dessa avaliação exigem que os pacientes com dor compareçam a consultas que variam em regularidade, dependendo da gravidade da condição.

Existem vários métodos de recolha das experiências de dor de um paciente. Estes métodos, que são usados principalmente num formato em papel, vão desde escalas simples até questionários completos. É importante entender como estes funcionam para que possamos melhor adaptá-los aos novos métodos digitais.

Com a maior utilização de aplicações móveis no século XXI, o registo das experiências de dor tornou-se muito mais gerenciável, pois os pacientes agora podem avaliar e controlar sua dor diariamente. De momento, existem centenas de aplicações *cross-platform* para monitorar a dor crónica, tanto para tipos gerais como para tipos específicos de dor.

O objetivo principal da aplicação desenvolvida para este trabalho é recolher dados sobre as experiências de dor de adolescentes com idades compreendidas entre os 15 e 16 anos. Estes utilizadores são participantes na coorte do ISPUP (Instituto de Saúde Pública da Universidade do Porto), denominada Geração XXI. Esta aplicação será usada para recolher dados que serão usados num contexto de pesquisa ao invés de uso pessoal.

A aplicação desenvolvida para Android utilizou Loopback para o servidor e Ionic, juntamente com Vue, para o cliente. A aplicação final teve um grupo de onze utilizadores a completarem um inquérito durante um teste piloto de uma semana. Dessas onze pessoas, três eram investigadores e oito eram adolescentes com idades entre os 13 e 18 anos. Para testar o impacto que a gamificação poderia ter nesta aplicação, os adolescentes foram separados uniformemente num grupo de controle e num grupo com acesso às funcionalidades de gamificação. Foi durante este teste que foram avalidas a viabilidade e usabilidade da aplicação, quando comparada com os métodos tradicionais.

Todos os objetivos definidos para esta tese foram cumpridos. Espera-se que a aplicação crie, a curto prazo, um método mais flexível e dinâmico de recolha de dados sobre as experiências de dor dos participantes, bem como melhore a quantidade e a qualidade dos dados sobre a dor aos quais os investigadores terão acesso. A longo prazo, planeia-se que, com os dados recolhidos, os investigadores possam avaliar quais características iniciais são mais úteis para prever se as crianças desenvolverão dores musculoesqueléticas mais tarde na vida.

Keywords: Dor crónica, Geração XXI, Desenvolvimento de aplicações móvis, Gestão da dor, Dor musculoesquelética

Acknowledgements

"Sucking at something is the first step towards being sorta good at something."

Jake the Dog

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Abbreviations

API	**A**pplication **P**rogramming **I**nterface
CSV	**C**omma-**S**eparated **V**alues
FPS-R	**F**aces **P**ain **S**cale - **R**evised
HCP	**H**ealth**C**are **P**rofessionals
HTTP	**H**yper**T**ext **T**ransfer **P**rotocol
INESC	**IN**stituto de **E**ngenharia de **S**istemas e **C**omputadores
ISPUP	**I**nstituto de **S**aúde **P**ública da **U**niversidade do **P**orto
JSON	**J**ava**S**cript **O**bject **N**otation
JWT	**J**SON **W**eb **T**oken
MSK	**M**usculo**s**keletal
NRS	**N**umerical **R**ating **S**cale
REST	**RE**presentational **S**tate **T**ransfer
SVG	**S**calable **V**ector **G**raphics
VAS	**V**isual **A**nalog **S**cale

Chapter 1

Introduction

Chronic pain is a type of affliction that, by 2014, affected at least 10 percent of the world's population[21]. It is also a growing concern during childhood and adolescence, with reported rates approaching those among adults[9]. There are several different types of pain. One of the most common types is musculoskeletal (MSK) pain. MSK conditions are not just conditions of older age as they are prevalent across the life-course. Between one in three and one in five people (including children) live with a musculoskeletal pain condition[32].

Traditional therapy consists of regular assessments that patients understand and yield excellent specificity and sensitivity. However, these evaluations are generally low-frequency face-to-face consultations.

Throughout the last decade, numerous mobile applications with the intent of aiding pain-afflicted patients better manage their pain experiences have been created, allowing these assessments to reach a broader number of patients quickly. Although many of these applications may have improved their users' quality of life, they are yet empirically proven. They rarely have the involvement of healthcare professionals (HCP) when building the app. A 2011 study concluded that, out of 111 pain management applications, 86 percent reported no HCP involvement, either directly as the app's creator or indirectly as a source of information or evaluation of app content[3].

1.1 Context

This work is aligned with a study financed by the Foundation for Research in Rheumatology (FOREUM) in cooperation with the University of Porto's Public Health Institute (ISPUP), Faculty of Medicine, and the Institute for Systems and Computer Engineering, Technology and Science (INESCTEC).

The study is named "Uncovering musculoskeletal pain susceptibility profiles since childhood by bringing together population and clinical cohorts". It bridges population-based and clinical cohorts to investigate early markers of pain trajectories. The project examines how children and their caregivers describe the child's pain experience and assesses which early features are the most useful to predict whether children are going to develop later MSK pain. One of the objectives of

this study is developing an interactive graphical tool with the intent of quantifying the explicit long-term memory of pain, which falls into the primary purpose of this dissertation — the development of a mobile application for reporting chronic pain[1].

The application is intended to be used by cohort participants, such as the Generation XXI cohort — the first Portuguese birth cohort — with participants, at the time of writing this thesis, aged between 15 and 16 years, with generally no prior diagnosis of any pain. Chapter 2.4 will better detail what this cohort is and who its participants are.

1.2 Motivation

The Generation XXI cohort does not have any off-site digital methods of gathering data regarding participant's pain experiences. As mentioned above, the current method of gathering pain experiences relies on in-person meetings, where participants are surveyed on the memory of their past experiences. Combined with the fact that these meetings do not occur frequently, these experiences are not reported as they happen. With this emerges a need to turn the data collection process more dynamic and less error-prone while, at the same time, creating a method of quantifying and qualifying pain in the long term.

It is also important to stress that, given the face-to-face nature of these meetings, they are not suitable amid the global pandemic we are currently living in.

Moreover, the reports of this non-diagnosed MSK pain experiences can then be compared with the experiences of patients with idiopathic arthritis — a diagnosed type of MSK pain. The similarities of these experiences can then be analyzed, which leads to faster research outcomes that may help future patients get diagnosed sooner, and, with that, they begin their treatment sooner.

1.3 Objectives

This dissertation aims to digitize the traditional method for collecting the cohort participant's pain experiences. This goal can be sectioned into three smaller ones:

- **Development of a cross-platform mobile application**: where a user can continuously register its pain experiences by completing a set of dynamic surveys, with a database model and web services to persist data inherent to its use.

- **Assessment of the application's viability and usability**: by testing the use of the application in an off-site method, with the participation of end-users and domain specialists.

In addition to the objectives listed above, outside of the scope of this thesis, this work will, in the long term, enable cohorts with innovative methods for pain experiences follow-ups. By digitizing the current method that is being applied in follow-ups, the cohort can have a more dynamic pain data collection process and increase both in quantity and quality of the collected pain experiences.

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[1]*FOREUM*, https://www.foreum.org/population_clinical_cohorts.cfm

1.4   Document Structure

This document has a total of 7 chapters. Aside from this chapter, which covered the introduction, chapter 2 encompasses the *Background*, which is a description of the medical concepts and topics that are the basis for this dissertation. Chapter 3 describes the *Related Work*, an analysis of pain applications and their functionalities. Chapter 4, the *Problem*, contains a description of the problem posed for this dissertation, as well as all the defined requirements. Chapter 5 goes over the *Development*, a description of the development process of the application created for this dissertation. Chapter 6, the *Test, Results, and Discussion* presents and analyses the study conducted to evaluate the application's usability. Finally, chapter 6 contains the *Conclusions and Future Work*, a summary of the contributions made by this dissertation, as well the work that has yet to be made.

Chapter 2

Background

This chapter introduces the medical background on which this dissertation is built. It includes the description of chronic pain and MSK pain, different pain assessment methods, and the Generation XXI cohort's characterization.

2.1 Chronic Pain

Chronic pain is a continuous type of pain that usually lasts longer than six months. It varies not only in duration but also in its intensity[21]. Chronic pain affects people of all ages, from children to the elderly, and is a widespread reason for medical consultations.

This type of pain can be caused by an injury or illness and extends itself even after what caused it has healed[5]. However, chronic pain can also occur without any specific or underlying disease that can be found. It is called *non-specific* since it is not clear what is causing the pain[40], making it difficult to diagnose.

In 2016, 10 percent of the world's population was afflicted by chronic pain. In Portugal, the first epidemiological study about chronic pain, which took place in 2007, revealed that 31 percent of the adult population suffered from chronic pain. The location of pain that was most registered was the lumbar region, a type of musculoskeletal pain[11], making it difficult to diagnose. Additionally, a study evaluating the prevalence of pediatric chronic pain revealed that, in Portugal, around 31.4 percent of children between 11 and 19 years reported having some chronic pain, with 46.3 percent of these children reporting having had lumbar pain in the past[15].

2.2 Musculoskeletal Pain

Pain can affect many different locations of an individual's body. Regarding this dissertation, the most relevant location of pain is musculoskeletal. It affects muscles, bones, joints, and associated tissues such as tendon ligaments. MSK pain is one of the most common types of pain. According to the World's Health Organization, MSK conditions are the leading contributor to disability worldwide[32].

2.3   Evaluation of Pain

The assessment of chronic pain is a crucial step in its better management. These evaluations are generally self-reported and can range from simple scales to fully-fledged questionnaires. Through these, patients are most commonly asked to provide the location and intensity of their pain and its duration and frequency. Pain evaluations are not only crucial in a clinical setting, as they provide a way for HCP to track the evolution of a patient's well-being, but also offer a method for these patients to have a better understatement of their pain.

This section reports on some of the most used scales and questionnaires regarding collecting patient's pain experiences.

2.3.1   Scales

In a pain management context, a scale is used to collect a single aspect in a patient's pain report. The scales described in this subsection, except for the Body Map follow the Portuguese Directorate-General of Health orientation regarding pediatric pain assessments towards children between 6 and 18 years old[10].

Numerical Rating Scale

The NRS is a 10-point Likert-scale, as depicted in Figure 2.1. Patients that make use of this scale are asked to select the number that best indicates the amount of pain they are experiencing at the given time[18].

The use of this scale is beneficial since it is simple and easy to comprehend. However, assigning a single number to a pain experience might not always be the best representation of an individual's experience. Additionally, a patient with a pain level of *10*, in case this pain worsens, has no way to indicate this using this scale.
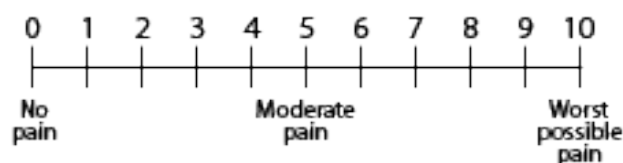
Figure 2.1: Numeric Pain Rating Scale

Visual Analogue Scale

The VAS, in Figure 2.2, is, generally, a horizontal line, 10 cm in length, bounded at the left-most side with a text that indicates low or no pain and, at the right-most side, a text that indicates a very high amount of pain. The individual using this scale indicates the point which they feel represents

their pain experience at the moment. The VAS score is then determined by measuring the distance in millimeters from the left-most side of the line to the end of the individual's position.

This scale is handy not only for its simplicity but also for its adaptability to a broad range of settings. Nevertheless, its lack of defined intervals (as the ones of the NRS) can make the pain assessment subjective[34].

Figure 2.2: Visual Analogue Scale

Wong-Baker Faces

The Wong-Baker Faces scale represents six faces, all representing an emotion from happy to crying, as represented in Figure 2.3. The participant using this scale chooses, based on the faces and their descriptions, the face that best represents their pain at the current moment[14].

This scale is mainly presented to younger children for its more straightforward and more engaging style. However, since these scales rate how much pain a person feels and not how their face looks externally, it might confuse children, who may interpret the expressions as emotions, such as being happy or sad.
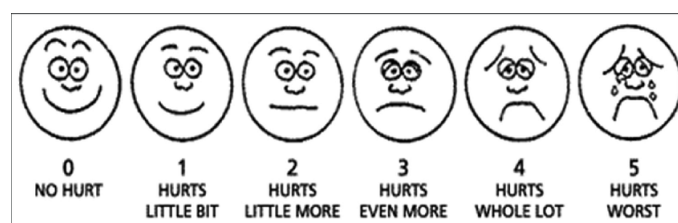
Figure 2.3: Wong-Baker Faces Scale

Faces Pain Scale —- Revised

The FPS-R is very similar to the Wong-Baker Faces as it also presents six faces, all representing different emotions from happy to sad. Figure 2.4 illustrates this scale. The method of completion for this assessment follows the one needed to complete the Wong-Baker Faces scale.

This method is also generally applied to young children and diverges from the Wong-Baker scale for its lesser focus on the face's emotion. The left-most face does not have a noticeable smile, and the right-most scale is not represented crying. It makes this scale slightly less subject to confusion[19].

Figure 2.4: Faces Pain Scale – Revised

Body Map

This method is solely used to assess a patient's pain locations and not its intensity as the other previous assessments. This evaluation, applied in a paper format, consists of outline drawings of the human body, front and back, on which the individual indicates where they are experiencing or have experienced pain. An example of a body map can be seen in Figure 2.5.

The body map allows for a more interactive way of selecting an individual's pain locations than other methods involving the individual in question to select a location from a list of previously defined locations. It can also accurately assess the distribution and spread of body pain[4]. Nevertheless, there are still some issues to overcome in adapting a body map to a mobile application. Small body parts such as individual fingers or toes are very hard to select on a small screen.
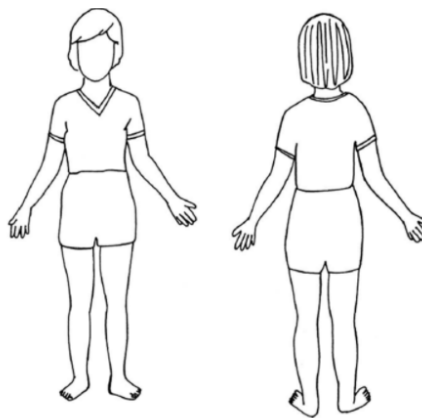
Figure 2.5: Body Map Example

2.3.2   Questionnaires

Pain management questionnaires are used to collect several components of pain, from its intensity and location to its impact on a patient's well-being. However, there is not one single questionnaire that is viewed as ideal for evaluating pain. The reason why this occurs is related to the fact that these surveys need to be adapted to different age groups, cultures, and languages. Moreover, different questionnaires often approach different components of a patient's pain.

This section will list some of the questionnaires being used nowadays and what information they gather.

McGill Pain Questionnaire

The McGill Pain Questionnaire presents patients with three questions:

- What Does Your Pain Feel Like?

- How Does Your Pain Change with Time?

- How Strong is Your Pain?

Each one of these questions represents a section in the questionnaire. A patient can answer these questions by selecting from an extensive list of pain descriptors — organized into 20 different dimensions — the ones they feel best answer the question. These words are associated with a certain number of points (for more details, see Annex F.1). By adding the points of the words which a patient chose, a score ranging from 0 to 78 can be obtained by the end of the questionnaire. With this questionnaire, the higher the pain score, the greater the pain the patient feels[29].

Brief Pain Inventory — Short Form

The Brief Pain Inventory is sectioned into nine questions that evaluate the severity of a patient's pain and its impact on their daily functioning. The patient is asked to rate their worst, least, average, and current pain intensity, list current treatments and their perceived effectiveness and rate the degree that pain interferes with general activity. The evaluations generally make use of the Body Map and the Numerical Rating Scale[1].

Pediatric Pain Questionnaire

The Pediatric Pain Questionnaire is intended to be applied to younger children for its structure and approach. However, the information collected on this questionnaire is essentially the same as in the ones detailed above. This survey utilizes the Body Map to assess the pain locations of the patient, an adapted version of the Wong-Baker Faces scale in order to rate the patient's current and worst pain and the word selection method used in the McGill Pain Questionnaire in order to determine the patient's description of their pain [2].

Adolescent Pediatric Pain Tool — Portuguese Version

The Adolescent Pediatric Pain Tool is adapted from the McGill Pain Questionnaire and is intended to be used by children and adolescents from 8 to 18 years of age. Similar to the McGill questionnaire, it is also split into three sections. In the first one, the patient's pain locations can be indicated

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[1]*Brief Pain Inventory - Short Form*, https://www.physio-pedia.com/BriefPainInventory
[2]*Pediatric Pain Questionnaire*, https://www.seattlechildrens.org/pediatric_pain_questionnaire

through the use of a Body Map. The second one is a version of the Visual Analogue Scale which is used to determine the pain intensity a patient is feeling at the moment. Finally, the third section presents a list of pain descriptors. From a total of 67 descriptors, organized into four sections — sensory, evaluative, emotional, and temporal —, the patient selects the ones that best represent their pain[13].

2.4 Generation XXI

Generation XXI is the first Portuguese birth cohort. It intends to understand the characteristics of pregnancy and childhood that were related to the development and health of the child in the subsequent life phases[3].

Participants

Every participant was recruited between April 2005 and August 2006 in Porto's five public maternity units. This recruitment period gathered 8495 caregivers and 8647 infants as participants for this cohort [17].

Participant characterization

The participants in this cohort are all, at this time, 15 or 16 years old, coming from various demographic, religious, and economic backgrounds. Each participant has at least one caregiver associated with them, and both have identifiers composed of their family's identifier and their unique one.

Follow-ups

The children and caregivers participating in this study were submitted to follow-ups at 4, 7, and 10 years old. During these follow-ups, a series of tests and questionnaires regarding many different aspects of their health were applied. The follow-ups questionnaires applied at seven years of age included questions about their memory of past pain experiences. Their caregivers were questioned about their perception of their child's pain.

2.5 Summary

From this chapter, we can assess several viable and validated methods of gathering a patient's pain experiences, most of which are used in the application developed for this thesis. Moreover, even though these methods are usually applied to pain-afflicted patients, the methods of collecting the pain experiences are broad enough that they can be used in people that have not reported or shown any previous sign of pain in the past.

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[3]*Geração 21*, https://www.geracao21.com/pt/projeto/

Although the survey that was applied to the users of the application was created by the researchers at ISPUP, it is essential to understand how they work. By understanding the data collected and how it is collected, the development process of the methods of pain experience collection can be made much more straightforward.

Chapter 3

Related Work

This chapter analyses the purposes and functionalities of different applications that pain-afflicted patients — adults, children, and adolescents — can use to monitor and cope with their pain. This chapter will also present a brief analysis of computerized body maps' implementation methods in different mobile applications. Finally, by the end of this chapter, a report on a few mobile development frameworks will be presented.

3.1 Pain Management Applications

As mentioned in Chapter 2, a considerable portion of the world's population is afflicted by chronic pain. In some cases, people use mobile applications to either manage or learn more about their condition. Listed below are the most relevant applications to the above-mentioned problem and their techniques to gather information about pain experiences.

Affleck et al.(1996) [1] conducted a study on 50 women with fibromyalgia syndrome — a type of musculoskeletal pain that affects muscles and soft tissue. They were asked to record, several times a day for 30 days, their sleep quality, pain intensity, and attention to pain using a palm-top computer. Since fibromyalgia is a disease that affects sleep, their conclusions on the participants' sleep quality are not as relevant for the context of this dissertation.

However, Affleck discovered by assessing attention to pain as a daily process that participants in more pain appeared to pay more attention to it, meaning they decided to report that more times a day in the provided application.

Ghinea et al.(2008) [16] gathered 45 participants with a diagnosed type of back pain and, for five months, they were prompted to report their pain location, type (numbness, pain, pins and needles, and ache), and intensity using a three-dimensional body map. Ghinea's study aimed to test and validate the created three-dimensional body in a real-world scenario. This study proved to have good acceptability and usability in both clinicians contacted before the study began and participants who reported feeling better control over their pain. There were, however, some suggestions that the body map should have had some finer divisions and allowed patients to report multiple types of pain in the exact location.

Jamison et al.(2002) [23] conducted a study that aimed to validate the assessment of pain intensity using a VAS on healthy volunteers. The 24 participants were invited for a session where they were asked to complete various VAS both on paper and electronically. Overall, electronic VAS scores were positively correlated with paper VAS scores, and assessments using electronic VAS did not differ from such assessments on paper.

Intending to determine the effect of the usage of a cross-platform mobile application that allows patients with chronic pain to evaluate, monitor, and communicate their health status with HCP, Jamison et al.(2017) [22], recruited 105 patients. Of these participants, 52 of them would have a 2-way messaging app with healthcare professionals. The participants were asked to, during three months to fill in daily assessments with questions regarding their pain intensity and location, frequency and duration, and depression and anxiousness. The participants were also encouraged by using gamification techniques and push notifications to become committed to the app daily.

By the end of the study, patients were happy with the application, although the 2-way messaging functionality only moderately improved compliance with daily assessments. According to patient satisfaction ratings, the functionalities responsible for the participants' continuous engagement were goal setting and motivational push notifications.

A 2019 study to analyze pain management efficiency using a mobile application versus combined physiotherapy plus online education gathered 101 patients. The participants all suffered from non-specific lower back pain for six weeks to a year, separating them into a control group with physiotherapy and online classes and an intervention group, which were asked to use the Kaia app. This app does not focus on gathering information about pain but on providing education and personalized exercises for each different type of pain. Every six weeks, the participants participated in a follow-up that questioned their recollection of past pain experiences.

The study concluded that the therapy program provided by the application performed better than the program provided in the control group, supported by the fact that reported pain levels in the application were significantly lower as compared to the ones in the control group [39].

3.2   Pain Management Applications for Children and Adolescents

Considering the user scope for this dissertation, it is also important to analyze some applications used to manage pain in children. One of the biggest problems that needs to be analyzed in these applications with daily assessments that require some effort and attention from the participants is their compliance rates.

Connelly et al.(2010,2012) [7, 8], in a study with children with ages between 8 and 17 years and their caregivers, prompted the participants to make an assessment of pain characteristics, activity limitations, intensity of positive and negative emotions, and emotion management three times a day for 28 days. These children all had juvenile idiopathic arthritis, a type of MSK pain, a chronic inflammatory disease in which arthritis is present in one or more joints. The goal of this study was to assess how emotion can be linked with pain in young children. This e-diary was completed with compliance rates ranging from 41 to 100 percent.

Lewandowski et al.(2009) [27], in a study involving 93 children and adolescents from ages ranging from 8 to 16 years, with diagnosed chronic pain, gathered information on the participant's pain intensity, pain location, activity restriction, and depression. Over one week, participants were asked to assess the mentioned domains daily. 65 out of the 93 participants reported these experiences on paper, while the remaining 28 reported them on an electronic device.

At the end of the study, Lewandowski observed greater compliance with the electronic format, with a mean of 6.89 days of data completed, in contrast to the paper format, with a mean of 4.97 days completed.

3.3 Computerized Pain Body Maps

As mentioned in Section 2.3.1 the traditional body map can be challenging to adapt to a mobile screen. However, this challenge has already been approached by other health-related mobile applications.

This section will present three different applications that have adopted this method of evaluating pain to a mobile device and some of the problems that had to be overcome. Some of the depicted applications could also fall into Section 3.1, but in this section, there will be a focus on the body map functionality they offer.

The *Pain Diary App* from *SECUSO Research Group* allows their users to record their pain in a daily manner. The users of this app, whenever questioned in regards to the location of their pain, are presented the body map in Figure 3.1. This body map is sectioned into 44 selectable regions, 22 for the front of the map and 22 for the back.

On the one hand, this approach easily allows users to understand which region of the body map they are selecting. On the other hand, the fact that these regions are not labeled in any way and the fact that the front and back versions of the body map are precisely the same can prove to be confusing when users do not know which exact region to select[1].

The *PainScale — Free Chronic Pain Tracker Diary* from *Boston Scientific, Inc* is another pain diary application where users can track their pain, treatments, medications, activity, mood, and sleep. This application features two types of body maps presented in Figure 3.2. Figure 3.2a presents a body map composed of 18 selectable regions in the front portion and 20 different regions in the back. Figure 3.2b displays a more detailed version of the latter body map, with several other selectable regions. It is available for users who wish to indicate their pain locations with more precision.

Although this application, in the less detailed version of the body map, does not have as many selectable regions as the one in the first application described in this section, it is improved by the labeling of these different regions and the noticeable difference between the front and rear portions of the body map[2].

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[1]*Pain Diary (Privacy Friendly)*, https://play.google.com/apps/secuso/
[2]*PainScale — Free Chronic Pain Tracker Diary*, https://www.painscale.com/painscaleBodyMap
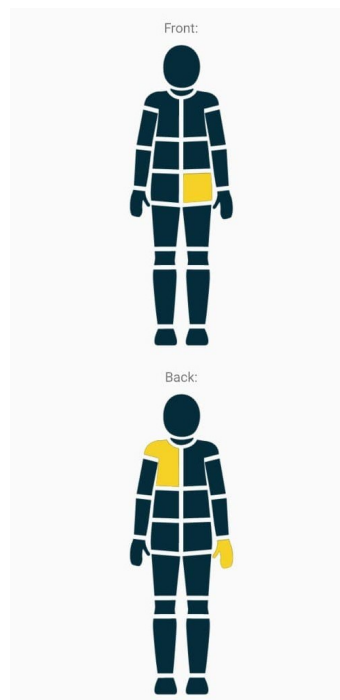
Figure 3.1: Pain Diary App's Body Map

Stinson et al.(2013) [38] conducted the development and testing of an iPhone pain assessment application for adolescents with cancer called Pain Squad. This study made use of a user-centered approach to the design and development of the application. This approach allowed it to create a better approach on how to gather the pain locations of the participants through the use of a body map, as shown in Figure 3.3, showing before (left) and after (right) body parts were combined as recommended by adolescents. Although this study does not report on how this body map was sectioned, it is vital to observe that the participants were compliant with a body map structured very similarly to those presented above.
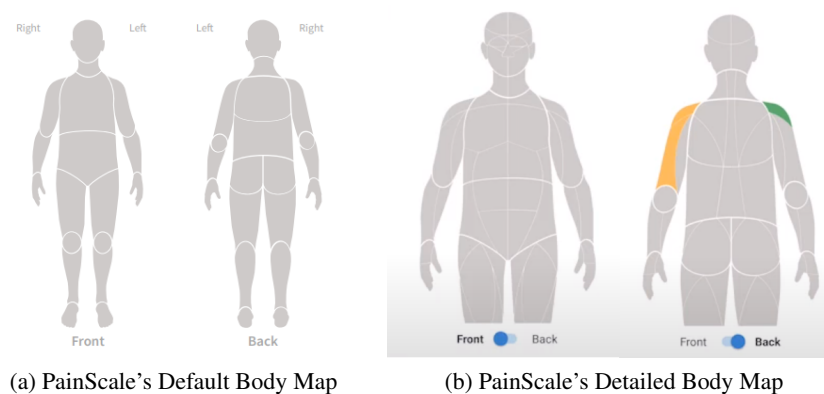
(a) PainScale's Default Body Map   (b) PainScale's Detailed Body Map

Figure 3.2: PainScale's Two Types of Body Maps.

Figure 3.3: Pain Squad's Body Map Iteration

Finally, Nour Shaballout et al.(2019) [36], in a systematic review of the milestones in the transition of body maps from paper to digital, concluded that computer-based methods allow an analysis of pain patterns in greater detail. Furthermore, the fact that computerised body maps guide their users through the pain location selection process and conform them to a particular selection type improves the quality of the obtained data in the long term.

3.4 Summary

In this chapter, it can be seen that the assessment of pain experiences through a digital method is a topic that has been thoroughly explored throughout the years, both for adults and children. Moreover, in some of the presented studies, it should also be noted that when comparing the digital methods of collecting pain experiences to the on-site methods, the digital ones had higher compliance rates.

Regarding digital body maps, it can be observed that they mostly follow the same look and usage method, with some more detailed than others when it comes to the body regions to select.

Chapter 4

Problem

This chapter will describe the problem and the requirements defined before the application's development to solve it.

4.1 Problem

The Generation XXI cohort does not have any off-site digital methods of gathering data regarding participant's pain experiences. These recordings are gathered through face-to-face meetings, which do not occur frequently enough. As mentioned in Section 2.3, a patient should record their pain experiences as frequently as possible to guarantee better management of this affliction.

As evidenced in the Related Work, there are already several cross-platform mobile applications that fulfill the role of a pain management application quite well. However, the application built in the context of this dissertation needs to gather information on the participant's pain experiences, which will be used in a research context rather than for personal use. Therefore, alongside the mobile application, a user management platform where researchers can create surveys, interact with the collected data, and manage its users, would also be needed, although this falls out of the scope of this work.

4.2 Proposed Solution

The solution will encompass the development of both a cross-platform mobile application, available for Android and iOS operating systems. The current solution was created throughout several meetings with the project's stakeholders, including the head researcher, Dra. Raquel Lucas.

4.2.1 Mobile Application

The users of this application will be cohort participants and their respective caregivers. The participant's age ranges from 15 to 16 years. This application aims to collect the pain experiences and perceptions of the pain of the participants through a series of **surveys**. In a first approach, a **survey** will take place throughout a month. During this month, participants will be asked to answer

one questionnaire once every week, in a total of 4 questionnaires. From this point forward, these questionnaires will be called **moments** to fall in line with the application's architecture presented in Section 4.3.3.

Each of the moments will contain a series of **questions** regarding different aspects of chronic pain and the participant's experiences on them. These questions can come accompanied by different types of pain evaluations such as a scale or body map such as those mentioned in Section 2.3, to comprehend and complete them quickly. The described solution was built with the intent of being broad enough to accommodate a survey structure different from the one depicted above and be applied to other cohorts.

Considering the application users' age and the fact that the completion of the surveys is entirely voluntary, it was decided to assess if applying some game-design elements to the application would benefit the quantity and quality of the answers obtained in the surveys. This process is known as gamification, and it has been proved to help maintain user retention and motivate users to interact with the application [26, 28]. In mobile healthcare applications, it has been noticed that gamification tends to persuade users to show more interest in their healthcare and well-being [26, 25, 33].

In order to employ this technique in the application, the following features have been devised. At the time of creating their account, each participant will have the chance to create a custom avatar. This avatar can be further customized with the purchase of items in an in-app shop using tokens gained from completing surveys, quizzes, or unlocking achievements. These quizzes are short questionnaires that aim to introduce and teach users new concepts regarding chronic pain. The achievements would be unlocked upon completing specific vital points, such as completing one evaluation moment.

Using a different account, the participant's caregivers would also participate in this application by completing questionnaires regarding their perception of their children's pain and general questionnaires about their own experiences of pain. These accounts will not have access to any gamification features. Moreover, caregivers would see their child's overall activity on the application, such as the last time they completed a questionnaire, given the child's prior consent. They would not, however, be able to see their child's answer to the surveys.

4.3   Requirements Analysis

After the broad definition of the problem was structured, the requirement elicitation process began, following its best practises [37]. The requirements were gathered by discussing with the clients, through interviews and brainstorming sessions, and discovering what their expectations for the application were. Following this step, the requirements were organized by prioritizing and arranging them in order of importance. Ambiguous and conflicting requirements were then adapted or removed through further negotiation and discussion with the clients until a final list of requirements was completed. The creation of these requirements was also instrumental as it facilitated

the interaction with the clients by exposing in a more structured method how the application was going to be structured and what functionalities it would have.

This section will go through the complete list of requirements that were defined for this project. Some of these requirements are not present in the developed application shown in Chapter 6, but since they were created as a part of the overall solution, they will be depicted as well.

4.3.1 Actors

The actors of the application are structured as shown in Figure 4.1. Going into more depth, the **User** is a generalization of the two actors — Authenticated User and Visitor. An Authenticated User is a generalization of the three remaining actors — Participant, Caregiver, and Researcher. The **Participant** and **Caregiver** are Authenticated Users who can interact with the application's features. A **Researcher** is an Authenticated User that can only access the user management platform. Table 4.1 goes into more detail on how these actors interact with the application. Tables 4.2, 4.3, 4.4, 4.5, 4.6 and 4.7 each describe the user stories of the User, Visitor, Authenticated User, Participant, Caregiver and Researcher respectively.

Table 4.1: System Actors Description

Identifier	Description
User	Actor that can access and view the Login page. It is subdivided into Authenticated Actor and Visitor.
Visitor	User that can log into the application.
Authenticated User	User that has an account and has already logged into the application. It is subdivided into Participant, Caregiver, and Researcher.
Participant	Authenticated User who has access to pain management surveys, profile page, and an Avatar and its customization.
Caregiver	Authenticated User who has access to pain management and perception of their children's pain questionnaires, a profile page, and its child's app activity, in case the child decides to share them.
Researcher	System administrator. Can manage accounts, access participant submitted data, and access general information about the user's usage of the application.

4.3.2 User Stories

The created user stories' structure is based on the widely used format: "As a <role> I can <capability>, so that <receive benefit>" [6]. Moreover, the user stories are associated with a priority, where *High* means that the feature depicted is essential in the pilot test that was conducted,
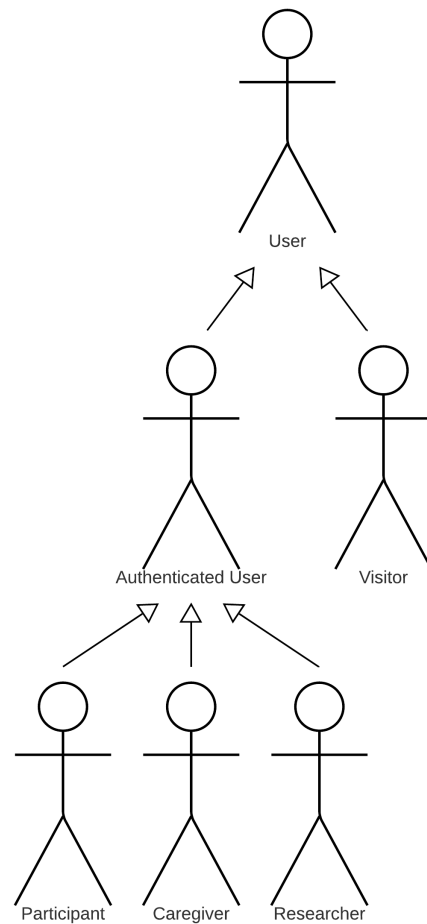
Figure 4.1: System's Actors

Medium means that, although not in this thesis' scope, they will be implemented in the future and *Low* depicts a feature that is not necessary to have in the final application, it would just be an extra functionality. Since during the requirement elicitation process, no features were deemed as unnecessary, there are no user stories with a *Low* priority in this project.

User's User Stories

Table 4.2: User's User Stories

Identifier	Name	Priority	Description
US00	Login page	High	As a User, I want to view the Login page so that I can insert my credentials and log into the application

Visitor's User Stories

Table 4.3: Visitor's User Stories

Identifier	Name	Priority	Description
US10	Sign In	High	As a Visitor, I want to sign in so that I can access my account

Authenticated User's User Stories

Table 4.4: Authenticated User's User Stories

Identifier	Name	Priority	Description
US20	Log Out	High	As an Authenticated User, I want to log out from my account so that I can keep my account secure when I'm not using it

Participant's User Stories

Table 4.5: Participant's User Stories

Identifier	Name	Priority	Description
US30	Main Page	High	As a Participant, I want to access the main page so that I am able to access new surveys or quizzes
US31	Surveys	High	As a Participant, I want to answer questionnaires so that I am able to better understand my pain
US32	Submit survey	High	As a Participant, I want to submit the data about my pain so that I can provide it to the application
US33	Notifications	Medium	As a Participant, I want to receive a push notification so that I am able to remember to fill my questionnaires
US34	Settings	Medium	As a Participant, I want to change the app's settings so that I am able to adapt it to my personal preferences
US35	Tutorial	Medium	As a Participant, I want to access an on-boarding and walk-through of the application so that I am able to better understand how to use it

Table 4.5 – continued from previous page

Identifier	Name	Priority	Description
US36	Create Avatar	High	As a Participant, I want to create an avatar so that I can personalize my application
US37	Edit Avatar	High	As a Participant, I want to edit my Avatar so that I can better adapt it to my preferences.
US38	Buy items	High	As a Participant, I want to buy items from the in-game shop so that I can have more options for customizing my avatar's look
US39	Complete quizzes	Medium	As a Participant, I want to complete different quizzes so that I can collect in-app tokens and learn more about chronic pain as a whole
US310	Unlock Achievements	Medium	As a Participant, I want to unlock achievements so that I can collect in-app tokens
US311	Share activity	Medium	As a Participant, I want to allow or disallow my caregiver from seeing my activity on the application so that I can decide on whether I want my caregiver to have access to my app activity or not.

Caregiver's User Stories

Table 4.6: Caregiver's User Stories

Identifier	Name	Priority	Description
US40	Main Page	Medium	As a Caregiver, I want to access the main page so that I'm able to see my child's activity on the application and answer surveys on their pain experience
US41	Questionnaires	Medium	As a Caregiver, I want to answer questionnaires on my perception of my child's pain so that I am able to portray my observations of their pain
US42	Submit questionnaire	Medium	As a Caregiver, I want to submit the data about my pain so that I can provide it to the application
US43	Notifications	Medium	As a Caregiver, I want to receive a push notification so that I am able to remember to check my child's activity on the application
US44	Settings	Medium	As a Caregiver, I want to change the app's settings so that I am able to adapt it to my personal preferences

Table 4.6 – continued from previous page

Identifier	Name	Priority	Description
US45	Tutorial	Medium	As a Caregiver, I want to access an on-boarding and walk-through of the application so that I am able to better understand how to use it
US46	See child's app activity	Medium	As a Caregiver, I want to see my child's activity on the application so that I'm able to know how their participation in the project is going

Researcher's User Stories

Table 4.7: Researcher's User Stories

Identifier	Name	Priority	Description
US50	Researcher Panel	Medium	As a Researcher, I want an admin panel so that I can have admin tools easily accessible, such as a list of accounts and data submitted from the accounts
US51	Add Participant	Medium	As a Researcher, I want to add new participants to the system so that I am able to expand the number of users in the application
US52	Remove account	Medium	As a Researcher, I want to disable access of accounts from the system so that I am able to manage the applications accounts
US53	See data	Medium	As a Researcher, I want to see data submitted by the users so that I am able to analyse them for future research
US54	Add Researcher	Medium	As a Researcher, I want to create other Researcher accounts so that I can have more admins in case the user base increases
US55	Export data	Medium	As a Researcher, I want to export the participants data as CSV.

4.3.3   Domain Requirements

This section will provide an in-depth analysis of the current solution's domain model. For a better analysis of each of the domain model's classes, this structure will be divided into four parts. In

order to have a global understanding of the developed architecture, its connections, and relations, Annex A displays the entire domain model.

4.3.3.1   Users

The *User*, *Participant* and *Caregiver* classes represent the actors of the mobile application. *Participant* and *Caregiver* are generalizations of the *User* class. The association class *Kinship* indicates whether the *Caregiver* is the father, mother or other legal guardian of the *Participant*.

The *Log* class is responsible for saving a user's interaction with the mobile application. These *Logs* can then be used for the researchers to know how frequently users are interacting with the application.

For further explanation, the *controlGroup* attribute in the *User* class is used for the test described in Chapter 6 as a method of distinguishing users who have access to the gamification features from those who have not. The *cohortToken* attribute is a code that will be used to connect a participant to a caregiver.

Figure 4.2 is the representation of the classes mentioned above in the domain model.
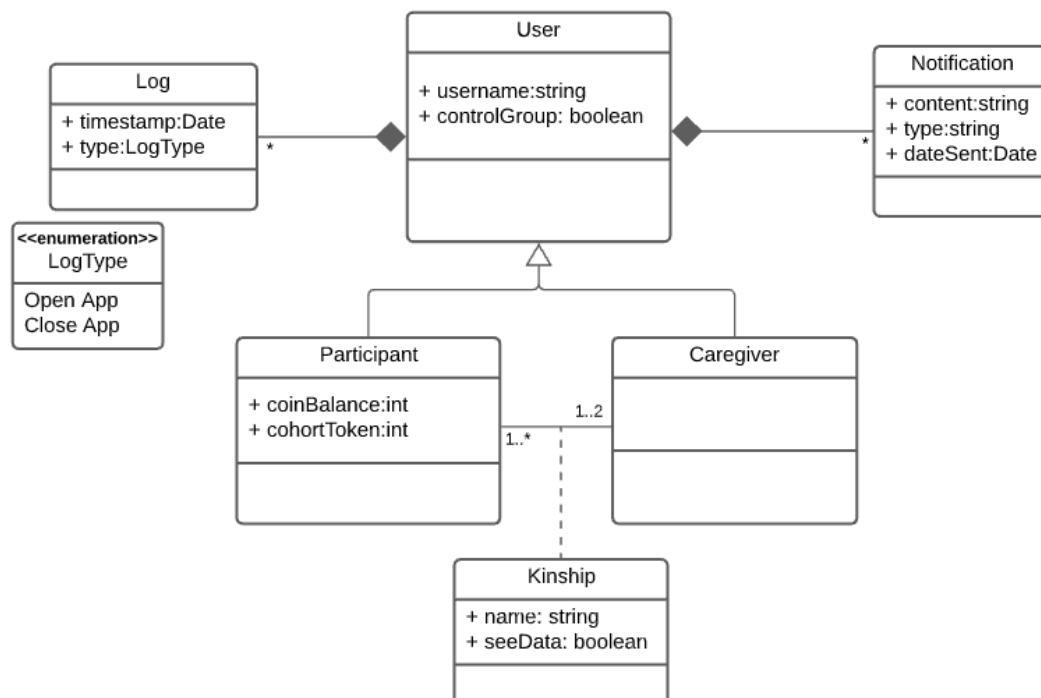

Figure 4.2: Classes Representing the Application's Actors

4.3.3.2 Surveys

The *Survey*, *Moment*, *Section*, *SectionElement* and *Answer* classes represent the whole architecture behind the surveys the users would need to fill. As detailed in Section 4.2, a *Survey* is composed of various *Moments* (4 for the solution depicted above). In turn, a *Moment* is split into various *Sections*, which contain distinct *SectionElements*. The *SectionElements* are the questions the user would then *Answer*.

The classes *SurveyLog*, *MomentLog* and *SectionLog* are association classes which model the date at which a user started a given *Survey* and for the date at which a user completed a *Moment* and a *Section*, respectively.

The purpose of the *Cohort* class is to adapt the architecture to accommodate a future usage of this app on other cohorts.

For further explanation, the *sectionIndexList* attribute in the *Moment* section is used to store which sections a user will navigate through. This attribute is useful in case a question has an answer that, if selected, jumps to a section that is not immediately adjacent to it. In the *SectionElement* class, the *options* attribute stores every answer possible that a question has. More on this attribute is detailed in Section 5.4.

In regards to the business rules, it is important to notice that an *Answer* can only be relative to one *SectionElement* which itself can only be related to one *Survey*. This means that one *SectionElement* can only be associated with one answer.

Figure 4.3 is the representation of the classes mentioned above in the domain model. In this figure, the *Participant* and *User* classes are not connected in order to simplify the model's representation. Refer to Figure 4.2 to view these classes as they are truly represented in the domain model.

4.3.3.3 Quizzes

The *Quiz*, *QuizElement*, *QuizAnswer* and *QuizLog* classes represent the whole architecture behind the quizzes the users could fill and interact with. The *Quiz*, *QuizElement* and *QuizAnswer* work in a very similar way to the *Moment*, *SectionElement*, and *Answer* classes, respectively. The only difference is that they are applied to the quizzes instead of the surveys. The *QuizLog* class stores the date at which a user starts a certain *Quiz*.

In regards to the business rules, it is important to notice that an *QuizAnswer* can only be relative to one *QuizElement* which itself can only be related to one *Quiz*. This means that one *QuizElement* can only be associated with one answer.

Figure 4.4 is the representation of the classes mentioned above in the domain model.

4.3.3.4 Avatar, Shop and Achievements

The *Avatar* class models the general information on the participant's choices for their avatar customization. The *ShopItems* class contains all the items available in the application (awarded by activities detailed in Section 4.2). The association class *Equipped* is responsible for storing the
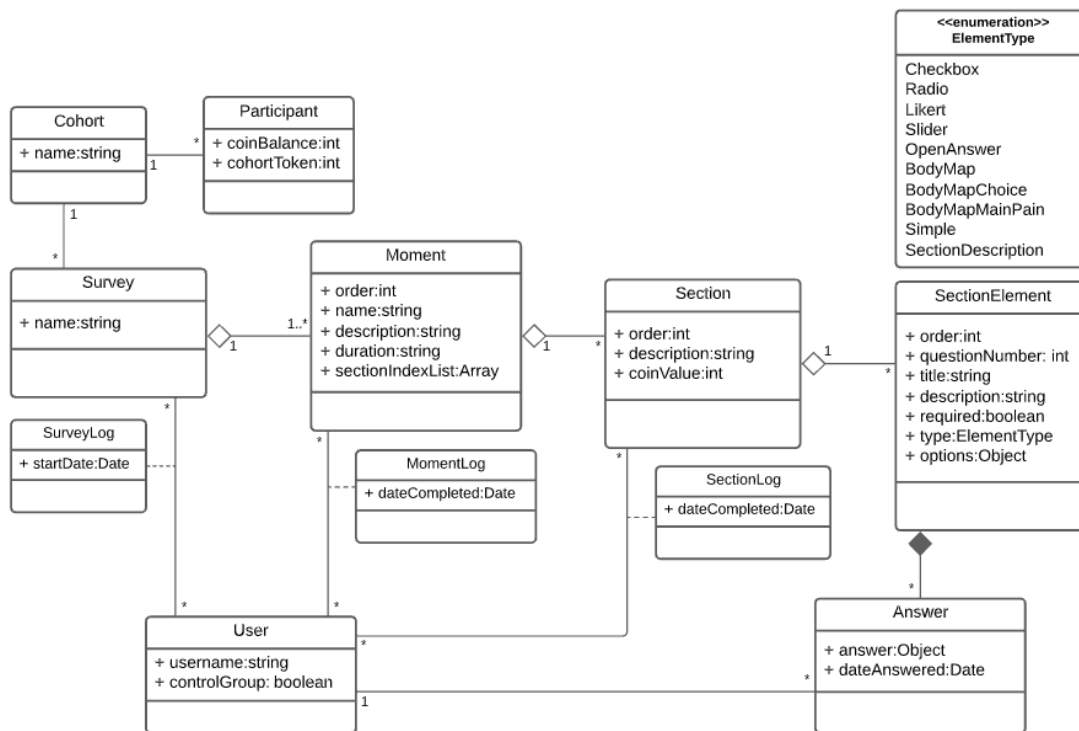
Figure 4.3: Classes Representing the Application's Survey Architecture

items that a user has bought and whether they are equipped or not. The *Achievement* class stores all the achievements that are available to be unlocked. The *level* attribute in this class can range from zero to three, where zero means the achievement has not been unlocked yet and one through three are the variations of this achievement, each one increasing in difficulty and rewarding the user with more coins than the last level.

Figure 4.5 is the representation of the classes mentioned above in the domain model.

4.3.4 Mobile Application's Mock-ups

Login Page

Figure 4.6 represents the Login page of the application where a *Participant* or a *Caregiver* can log in into their account after their credentials have been previously shared with them by the cohort's researchers. As seen below, a user only needs a username and a password for its authentication in the application.

Main Page

Figure 4.7 represents the Main page of the application for the *Participant*. On this page, the *Participant* can see its avatar, a section where they can continue or start a new moment, and, in case there are any quizzes available, a banner indicating the name, number of coins awarded, and
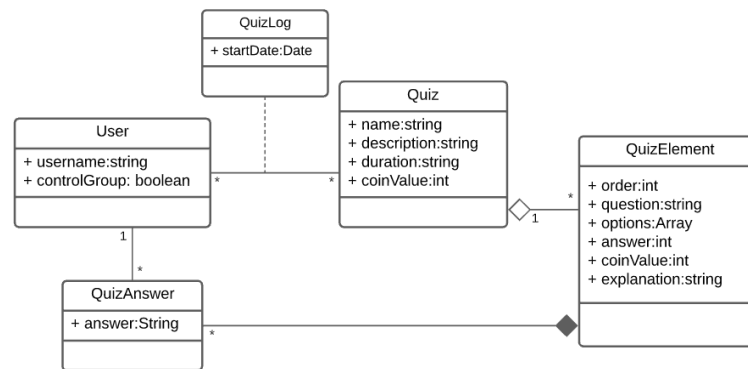
Figure 4.4: Classes Representing the Application's Quiz Architecture

time to complete the available quiz. Additionally, at the end of the page, there is also a banner that is always present in the application. By clicking on "Yes", the user is taken to a short survey that asks them a few questions about the pain they are feeling at the current moment.

Shop

Figure 4.8 represents the Shop page. Here, the *Participant* can see buy new items for his avatar with the coins they have earned through the use of the application.

Profile Page

Figure 4.9 represents the Profile page of a Participant. Here, the Participant can edit its avatar, see the achievements they have unlocked, and alter their account settings.

Pain Report Page

Figure 4.10 represents two pages, which, in turn, represent a moment. Each page consists of a section of that exact moment. It is important to stress that these questions are only placeholders and differ from survey to survey and moment to moment.

Quiz Page

Figure 4.11 represents the Quiz page. The *User* can land on this page by clicking the banner on the Main Page. Here, they can answer a few simple questions, which awards them with extra coins if they answer correctly.

Caregiver's Main and Profile Page

Figure 4.12 represents the two pages the *Caregiver* would have access to. Figure 4.12a displays the caregiver's main page, where they can see the participants associated with them and their
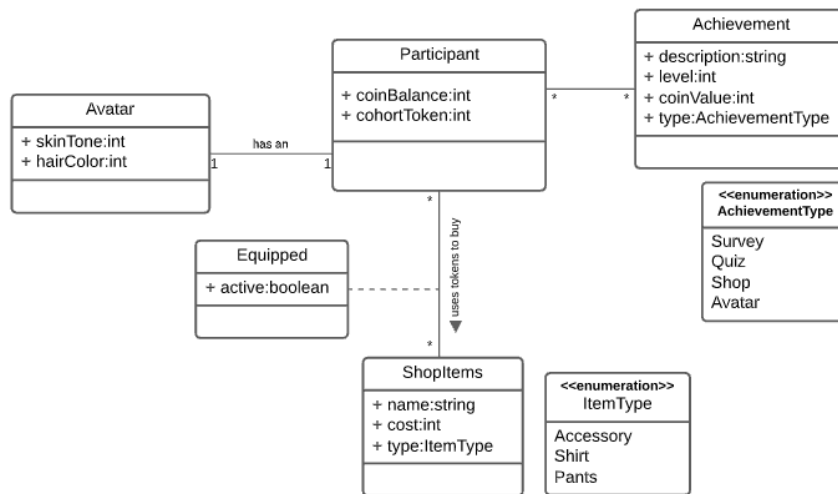
Figure 4.5: Classes Representing the Application's Gamification Architecture

activity on the application. Similar to the participants, they would also have a question that is always present in the application. By clicking on "Yes", the user is taken to a short survey that asks them a few questions about the pain they are feeling at the current moment. Figure 4.12b is the caregiver's profile page. Here, all the connections a caregiver has with participants can be managed. It is on this page that the caregivers would change their profile settings as well.

4.4   Summary

In this chapter, the problem and its proposed solution were presented. Currently, there are sections of the proposed solution that are not part of the scope for this thesis but need to be implemented for the project proposed by FOREUM.
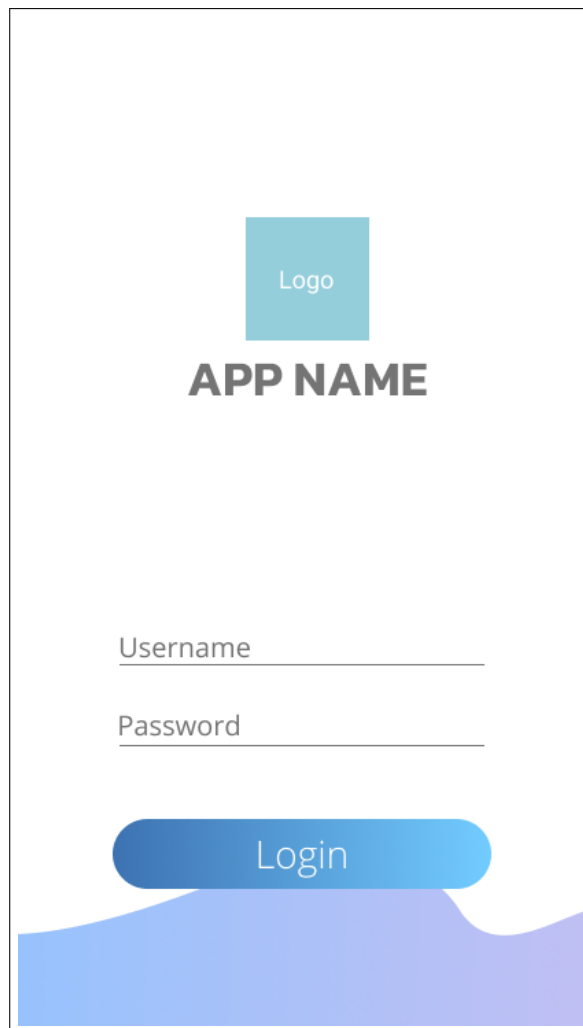
Figure 4.6: Login Page Mock-up
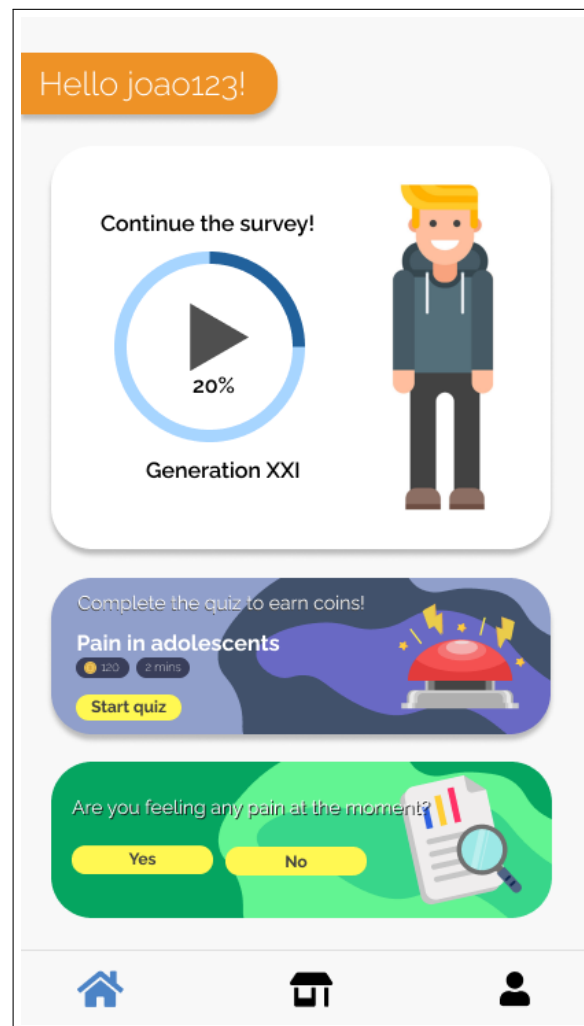
Figure 4.7: Main Page Mock-up
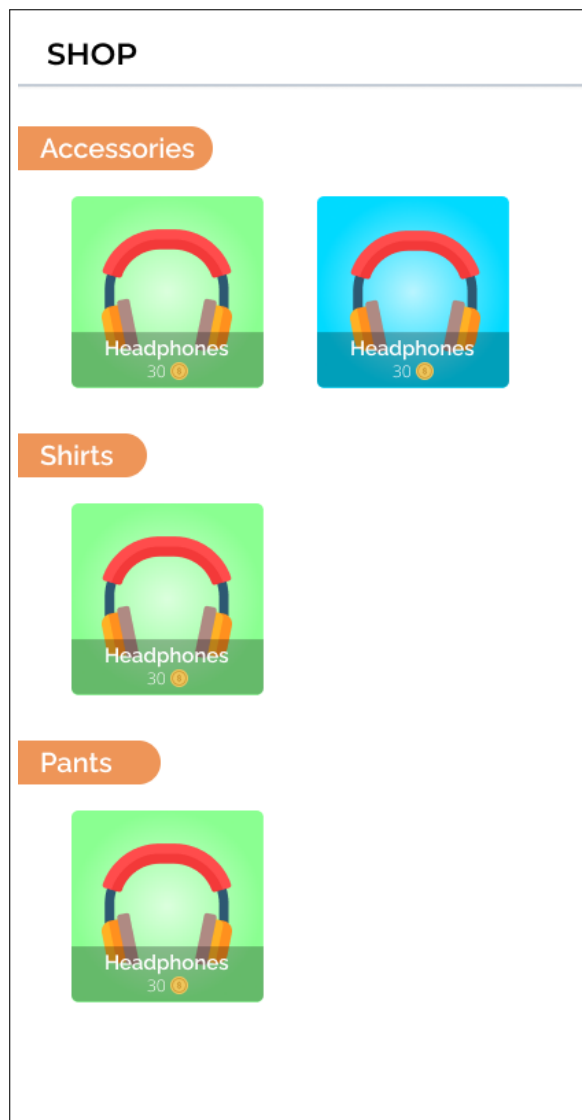
Figure 4.8: Shop Page Mock-up
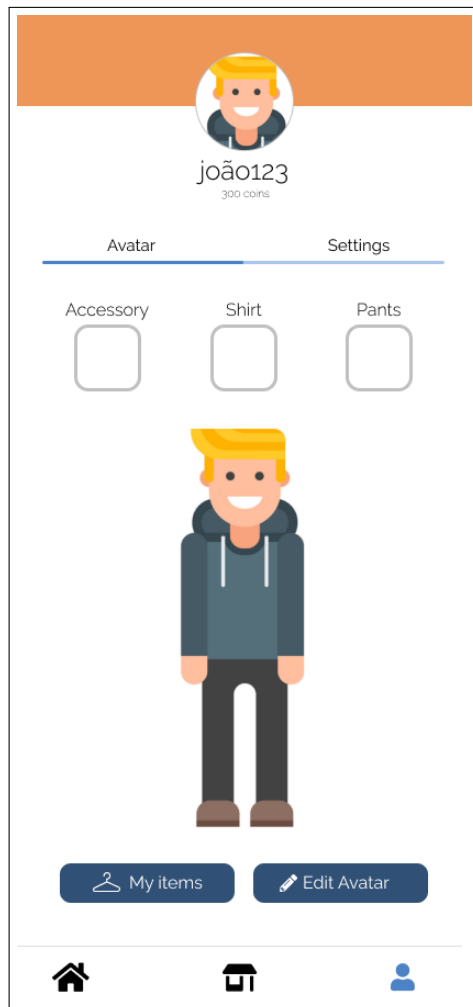
(a) Profile Page Mock-up — Avatar
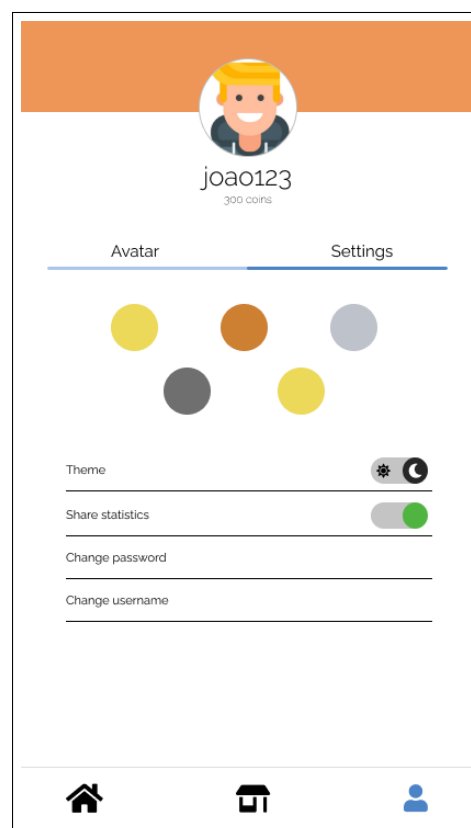
(b) Profile Page Mock-up — Settings and Achievements

Figure 4.9: Profile Page Mock-ups
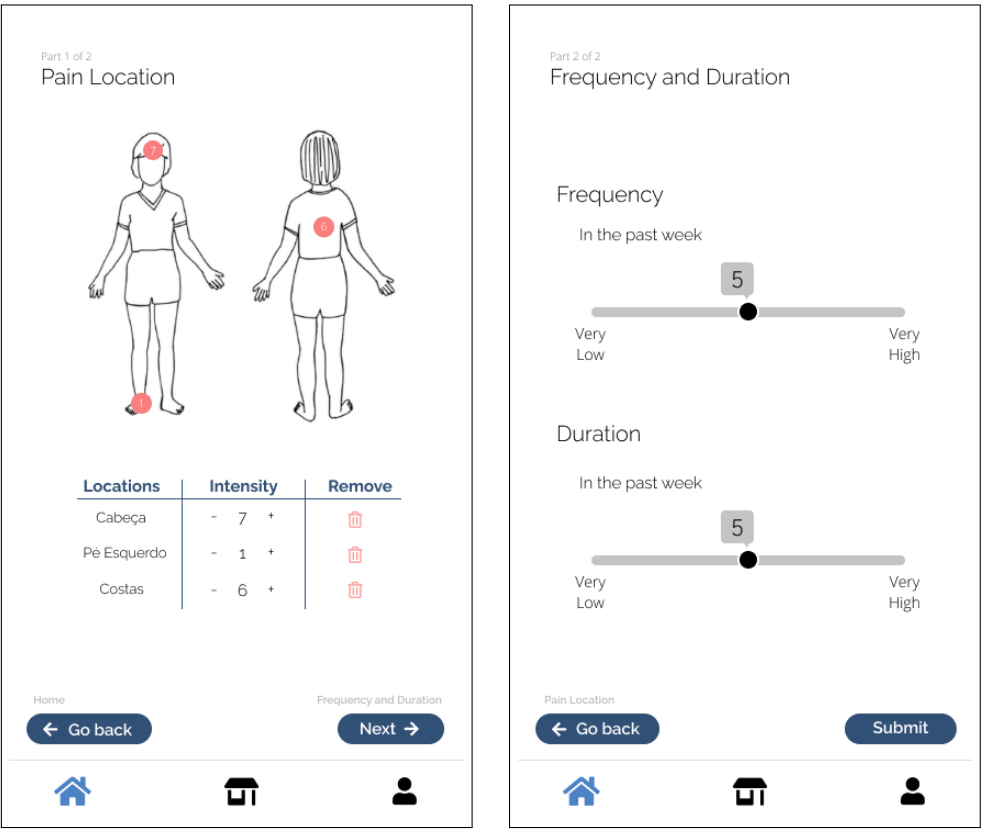
Figure 4.10: Moment Page Mock-ups
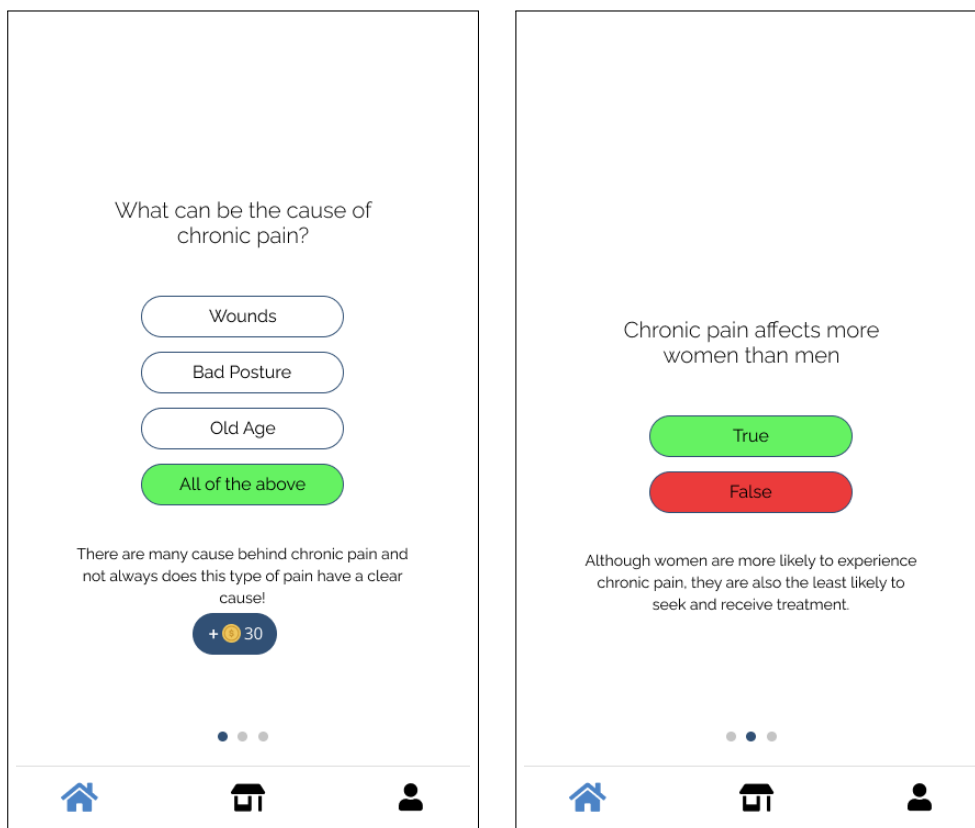
Figure 4.11: Quiz Page Mock-ups
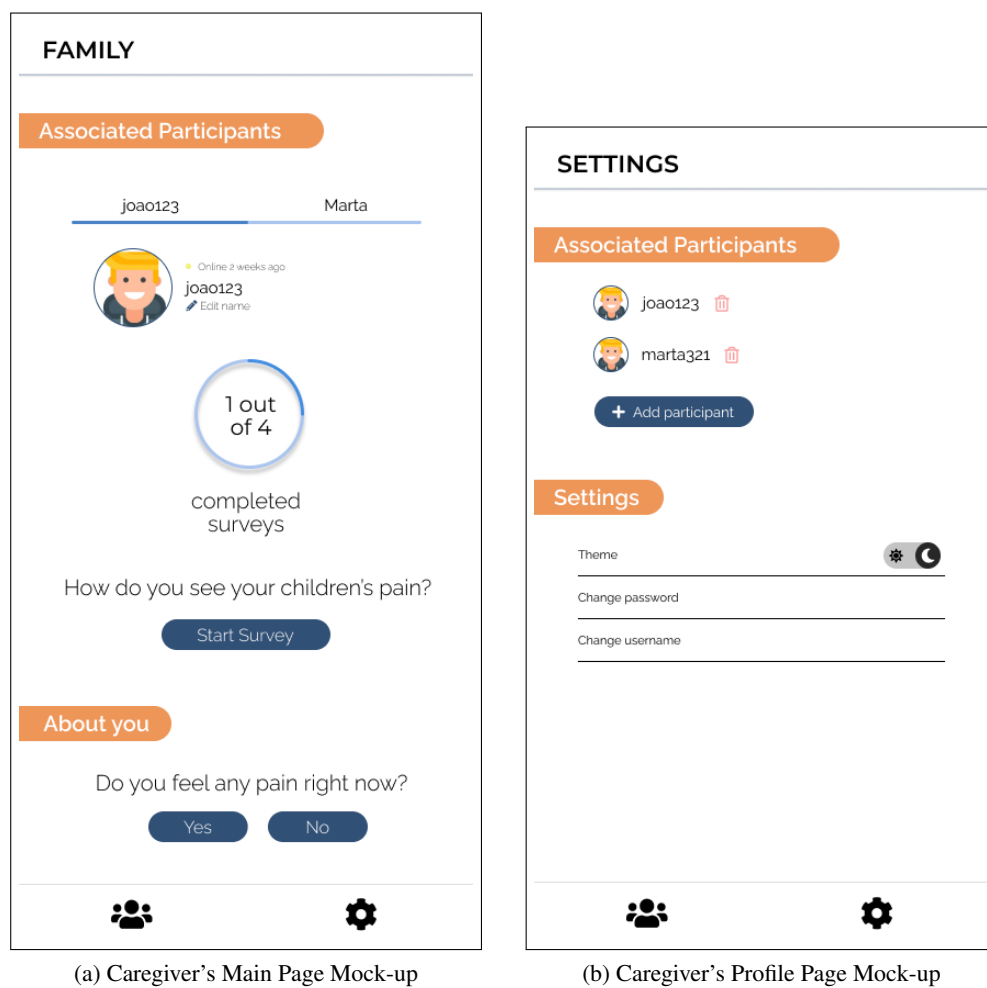
(a) Caregiver's Main Page Mock-up   (b) Caregiver's Profile Page Mock-up

Figure 4.12: Profile Page Mock-ups

Chapter 5

Development

This chapter will focus on the steps taken during the development of the application, going into depth regarding the server's and client's structure, analysing the method of parsing the survey the users of the application would need to complete and describing the development methodology that was used.

5.1 Application Architecture

The final application has two main structures — the server and the client. In Figure 5.1, a global view of the application's architecture is presented.

The server is, with the usage of a PostgreSQL database, responsible for the storage of all the necessary user data. The creation of this database is made possible with Loopback, the framework which is also used for handling all the logic and creation of the application's REST API. The user authentication is also handled in the application's server and is managed by Keycloak [1]. Section 5.2 provides a more in-depth analysis of these structures.

The client is responsible for holding and displaying the application's interface to the end-user. It is in this structure that the calls a user makes to the API are handled. These calls are handled by a Promise-based client — Axios. Section 5.3 provides a more in-depth analysis of these structures.

The developed application was built with Docker. Figure 5.2 represents how the different Docker containers are structured. In this figure, each box represents a container, with its name and port presented in the lower section and what it contains in the top section.

5.2 Server Application Structure

This section goes through the technologies and all the structures used in the application's server — the back-end framework, the REST API and the authentication service.

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[1] *Keycloak*, https://www.keycloak.org
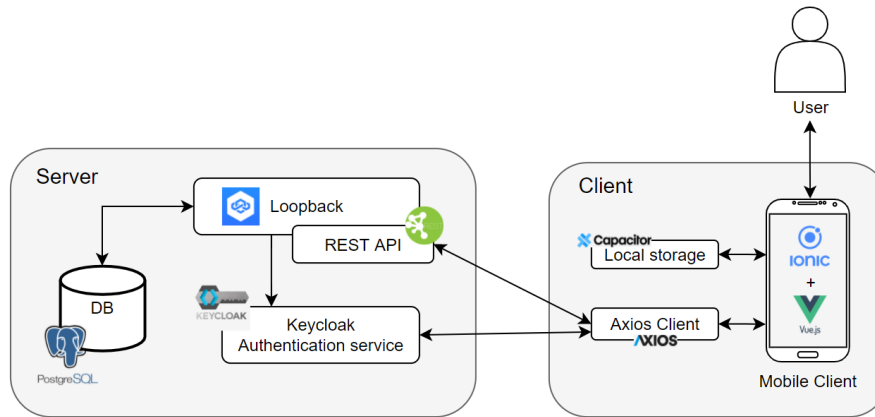
Figure 5.1: Application's Architecture
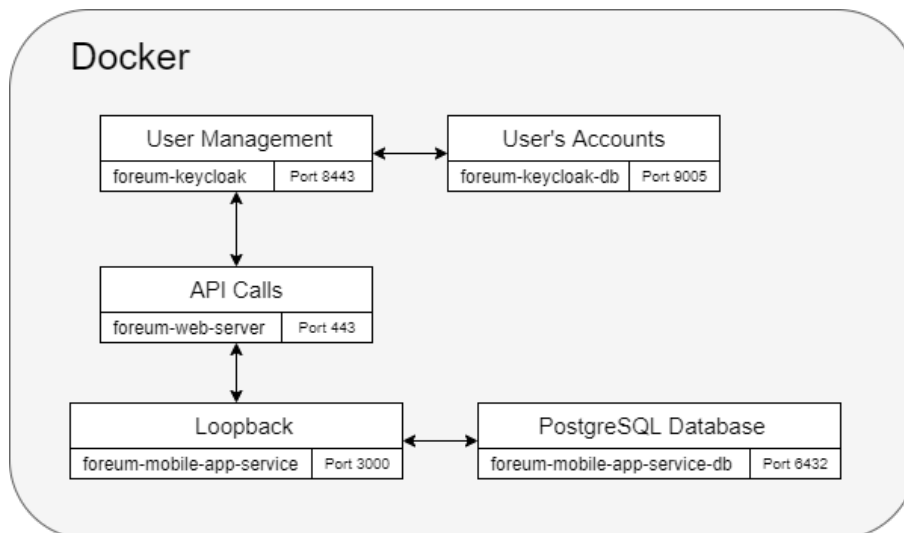
Figure 5.2: Docker Container's Structure

5.2.1 Technologies Used

The developed application made use of Loopback 4 [2], the most recent version of this open-source framework built upon Node.js [3], for the creation of the models and architecture necessary for the application's REST API. This framework was selected to meet the needs of the developers at INESC TEC, who have already been using it on projects prior to this one, which could cut some time on future analysis and development on the already existing code. Additionally, Loopback accelerates the implementation process by creating fully customizable API routes. This framework is responsible for the creation of the models and connection to a PostgreSQL [4] database which was used for the storage of all the data necessary for the application's correct functioning.

5.2.2 Server Structure

The following sections will describe the Loopback elements used to develop the server application and, by extension, its structure.

Models

Models follow a structure that is very similar to what is needed to create a PostgreSQL table. These are structures that represent the classes of the domain model evidenced in Section 4.3.3. The attributes represented in each of the domain model's classes are properties of Loopback's models. Additionally, each model contains an identifier, which is used as the primary key in the PostgreSQL database, and identifiers to other connected models used as the database's foreign keys.

Moreover, so that classes that are connected using *many to many* relationships could be represented in the framework, additional individual models were created. These models are responsible for handling the connection between the two classes, having only three properties: their unique identifier and two other identifiers pointing to the necessary model. If the two classes had an association class attached, the attributes of these association classes were added to the newly created model and the three properties mentioned above.

Each one of Loopback's models represents a table in the PostgreSQL database. Annex C illustrates the final entity relationship diagram

Repositories

Repositories are responsible for the connections between Loopback's models. They are mainly used in the REST API as they serve to collect the data necessary for a specific method call while navigating through the model's previously set relations.

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[2]*Loopback*, https://loopback.io/

[3]*Node.js*, https://nodejs.org/en/

[4]*PostgreSQL*, https://www.postgresql.org/

Figure 5.3: REST API Controller

```
1  export class SurveyRepository extends DefaultCrudRepository<
2    Survey,
3    typeof Survey.prototype.id,
4    SurveyRelations
5  > {
6
7    public readonly moments: HasManyRepositoryFactory<Moment, typeof Survey.prototype.id>;
8    public readonly cohort: BelongsToAccessor<Cohort, typeof Survey.prototype.id>;
9
10   constructor(
11     @inject('datasources.Foreum') dataSource: ForeumDataSource, @repository.getter('MomentRepository') protected
            momentRepositoryGetter: Getter<MomentRepository>, @repository.getter('CohortRepository') protected
            cohortRepositoryGetter: Getter<CohortRepository>,
12   ) {
13     super(Survey, dataSource);
14     this.cohort = this.createBelongsToAccessorFor('cohort', cohortRepositoryGetter,);
15     this.registerInclusionResolver('cohort', this.cohort.inclusionResolver);
16     this.moments = this.createHasManyRepositoryFactoryFor('moments', momentRepositoryGetter,);
17     this.registerInclusionResolver('moments', this.moments.inclusionResolver);
18   }
19 }
```

Listing 5.1: Survey repository

Using the example above, which is the repository for the Survey model, it can be observed that the *moments* and *cohort* variables, in line 7 and 8, respectively, are associated with a type of relation — the *hasMany* and *belongsTo* relations. In Section 4.3.3.2, it can be seen that the relations of the *Survey* class are then being translated through these repositories. Therefore, each of these variables can be used to fetch the cohort or moments that are associated with a certain survey.

Controllers

In this project, these structures hold all the application's REST API calls, although they can also be used to implement methods for the application's internal use (which do not need to be exposed as API routes). They are sectioned in a way that each controller only handles the calls over a specific model. A better illustration of this is reflected in Figure 5.3, which shows a single controller — the Answer controller — with its respective routes.

More information regarding the REST API is presented in Section 5.2.3.
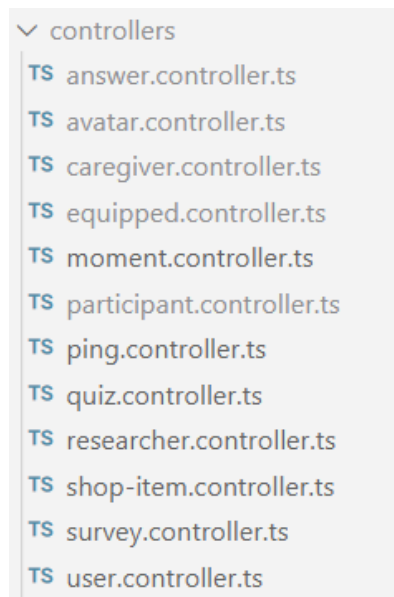
Figure 5.4: All Implemented Controllers

Interceptors

The interceptor can be applied to all or just a single API route. They are responsible for validating any data the client sends to the server before they reach the latter. They are used to prevent the user from sending data that may harm the server's integrity and to perform all sorts of logic validation.

5.2.3 REST API

The server uses a REST API to manage all the requests a client makes to the server. This section will briefly describe the structure this API follows and analyse some of the routes used.

The developed API [5] can handle the client's requests for most of the functionalities listed in Section 4.3.2. More specifically, the application handles the requests in the controllers displayed in Figure 5.4.

The *User*, *Participant*, and *Caregiver* controllers are responsible for fetching the client's information, such as identifiers and permissions, or for altering data such as passwords. The *Survey*, *Moment*, and *Quiz* controllers handle all the requests for fetching the data related to the surveys. The *Avatar*, *Shop Item*, and *Equipped* controllers are responsible for all the API calls related to the gamification. Finally, the *Answer* controller sees to the handling of the answers the users provide in the application. This means that it saves the answers to the database and takes care of its fetching in case the user wishes to see it again. In addition to the already mentioned controllers, a *Researcher* one was also created. This controller is responsible, at the moment, for the creation of users in the application — participants, caregivers, or even other researchers.

---

[5]https://sepia.inesctec.pt/mobile-app-service/explorer/
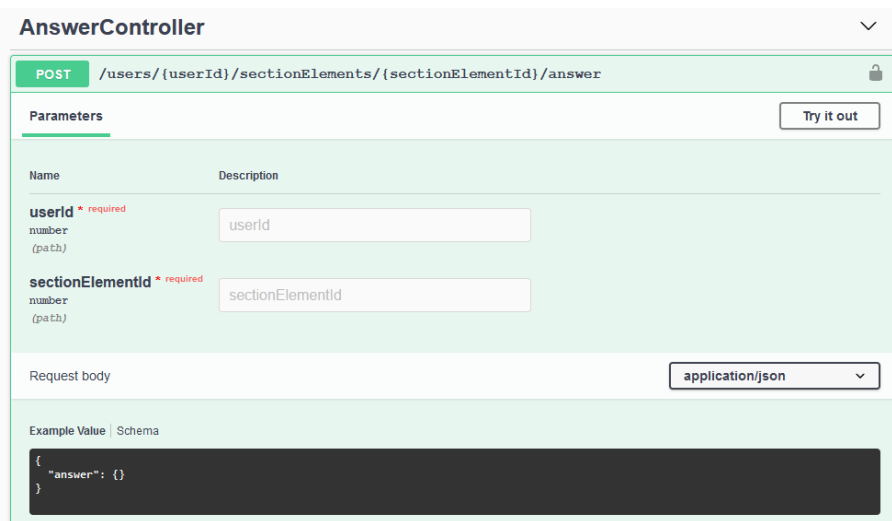
Figure 5.5: Single API Route

Route Structure

In order to exemplify how the routes themselves are structured, Figure 5.5 displays the route responsible for saving a user's answer in the database.

As presented in Figure 5.5, the route follows this structure: "/collection/collectionId". All of the other routes follow the same convention in order to fall into REST API's naming conventions [6]. In addition to that, all the routes begin with "/users/userId". The reason for this is related to the application's authentication management and is better detailed in Section 5.2.4. Finally, the routes function as typical REST API routes. The client sends the request with the necessary identifiers and a request body, if necessary. This data is validated in the interceptors, and the response is created and sent back to the client application.

A complete list of the developed REST API routes can be found in Annex B.

Acceptance Testing

All of the developed routes have an associated acceptance test. These tests validate all the possible responses a route can return. Listing 5.2 displays the test that corresponds to the route presented in Figure 5.5. As shown in that listing, lines 2 through 10 test the "Success" route, while lines 12 through 19 test the "Error" response route.

```
1  describe("describe POST /users/{userId}/sectionElements/{sectionElementId}/answer", () => {
2      it('SUCCESS', async () => {
3          const authToken = await authenticateUser('testparticipant', 'testparticipant');
4          const res = await client
5              .post('/users/${appUser.id}/sectionElements/${appSectionElement.id}/answer')
6              .set('Authorization', 'Bearer ${authToken}')
7              .send({answer: "testAnswer"})
8              .expect(200);
9          expect(res.body).to.containDeep(answer);
```

---

[6]*REST API Naming Conventions and Best Practices*, Restful API, https://restfulapi.net/resource-naming/

```
10      });
11
12      it('FAILS - 403 FORBIDDEN', async () => {
13        const authToken = await authenticateUser('testparticipant2', 'testparticipant2');
14          const res = await client
15          .post('/users/${appUser.id}/sectionElements/${appSectionElement.id}/answer')
16          .set('Authorization', `Bearer ${authToken}`)
17          .send({answer: "testAnswer"})
18          .expect(403);
19      });
20
21      after(async () => {
22        await answerRepository.deleteAll();
23      });
24    });
```

Listing 5.2: Acceptance test of an API route

5.2.4 Authentication Management

The application's authentication is managed by Keycloak, an open-source identity and access management solution. This platform is responsible for the storage of the user's access data and managing their permissions.

When a user logs in to the application, their credentials are validated by Keycloak. If no errors occur, their access token, which comes in the form of a JWT token, is created, containing, among other information, the user's roles. These roles are responsible for sorting the user's permissions and access rights. For this application, three roles were created — *participant*, *caregiver*, and *researcher* — to manage the access a user has to specific routes.

When a user makes an API call, their access token is analyzed and validated in the server. If no errors are found in this token, the server will then verify if the user who made the request has access to the route in question. This is accomplished by verifying the user's role. Since before each route is specified what roles have access to it, the server can compare this information with the current user's role. If the user indeed has access, the request can continue with no other issues. However, if that is not the case, the server will respond with an authorization error.

5.3 Client Application Structure

This section goes through the technologies and all the structures used in the application's client — the front-end framework, and the service used for the handling of API calls.

5.3.1 Mobile Development Frameworks

This section will report on some of the features of existing mobile development frameworks. Since the application developed in the context of this dissertation will need to be available for both Android and iOS, thus we will only consider cross-platform frameworks.

5.3.1.1 Ionic

The Ionic framework presents the following features[7]:

- **Web Standards-based**: The framework is built on web technologies, such as HTML (Hypertext Markup Language), CSS (Cascading Style Sheets), and JavaScript.

- **Access to device-native functionalities**: It offers the API (Application Programming Interface), which is needed for using native device functions with JavaScript code.

- **Framework compatibility**: Ionic can be integrated with other frameworks, such as React.js, Angular, and Vue.js.

- **Single Codebase**: Ionic maintains a single codebase for the development of the iOS and Android applications.

- **Easy Testing**: The Ionic framework allows the developer to test the application on every operating system.

When compared to other frameworks, Ionic still poses some issues concerning its performance in case the application built is graphics-heavy. Since the framework renders its graphic elements through a webview, it will perform worse than frameworks compiled directly into native code. Additionally, this webview can make the application heavier and take up more space than other cross-platform frameworks[30, 2].

5.3.1.2 React Native

The React Native framework presents the following features[8]:

- **Reusable Code**: The same code is used for deployment on iOS as well as on Android.

- **Hot Reload**: The hot reload feature enables the developer to immediately see the result of the latest change that they have made to the code.

- **Strong performance in mobile environments**: React Native's architecture is well-tuned to mobile devices. It uses the GPU (Graphics Processing Unit), while native platforms are more CPU (Central Processing Unit) intensive. Additionally, the code written in React Native is compiled into native code, which enables it for both operating systems and functions in the same way on both platforms.

- **Modular architecture**: The framework's modular architecture turns code maintenance much more manageable in case the developed application needs to be worked upon after the completion of this dissertation.

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[7]*Ionic Framework*, https://ionicframework.com/
[8]*React Native Framework*, https://reactnative.dev/

Future development with the React Native framework will introduce some problems since this framework still lacks support for some native app functionalities, such as push notifications, which will be needed for this application. It is important to note, however, that this problem can be solved, although not ideally, with the usage of existing plugins[20, 35, 31].

5.3.1.3   Flutter

The Flutter framework presents the following features[9]:

- **Single Codebase**: Flutter maintains a single codebase for the development of the iOS and Android applications.

- **Hot Reload**: The hot reload feature enables the developer to immediately see the result of the latest change that they have made to the code.

- **Similar to Native App Performance**: Flutter does not rely on any intermediate code representations or interpretation. Flutter applications are built directly into the native code.

- **Widgets**: The Flutter framework offers widgets, which are capable of developing customizable specific designs.

However, it is important to notice that Flutter is not as mature as the two other frameworks mentioned above, meaning that it can change rapidly at times. This means that the code might be difficult to maintain in the long run. Moreover, this lack of maturity is also reflected in the features available in Flutter. Many Flutter functions are in alpha and beta testing and may not always work properly[35, 24, 12].

These three frameworks were selected in disfavor of other cross-platform applications with similar functionalities given their more considerable popularity in the mobile development frameworks area. In addition to the fact that all the three applications are open-source and with large and active communities, this guarantees that there will be continued support and development of these frameworks in the years to come.

5.3.2   Technologies Used

The client application was developed using Ionic. This framework was selected over the others mentioned in Section 5.3.1, since it gives access to all the functionalities needed for the development of the application as well as access to well-structured documentation. Additionally, compared to Flutter, Ionic might prove to be better given the maturity of the framework itself and the fact that it is built on more mature web technologies. Even given that applications built with Ionic can perform worse and be slightly larger than applications built with the other platforms, these issues were not noticeable in the final application.

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[9]*Flutter Framework*, https://flutter.dev/

Home
  ➥ **Avatar**
Login
Moment
  ➥ **Section**
      ➥ **SectionElement**
      ➥ **CheckBox**
      ➥ **Radio**
      ➥ **BodyMaps**
          ➥ **BodyMap**
      ➥ **Slider**
      ➥ **Likert**
      ➥ **BodyMapChoice**
          ➥ **BodyMap**
      ➥ **BodyMapMainPain**
          ➥ **BodyMap**
      ➥ **OpenAnswer**

Profile
  ➥ **ShopItem**
      ➥ **ItemImage**
  ➥ **Avatar**
  ➥ **ItemImage**
Shop
  ➥ **ShopItem**
      ➥ **ItemImage**
Surveys
  ➥ **Survey**
      ➥ **Moment**
Tabs

Figure 5.6: View and Component Structure

In order to be able to package and deploy the application to the necessary mobile platforms, Ionic was used in conjunction with Capacitor [10]. With this runtime, it is also possible to access several native functionalities without running into platform-specific details.

Alongside Ionic, the application interface was created with Vue [11], a JavaScript-based framework.

5.3.3 Client Structure

Following Vue's conventions, the application's interface is structured into Views — which represent the pages of the application — and Components — which represent smaller, usually repeatable elements of the Views. These pages and components can be seen in more detail in Chapter 6. Figure 5.6 represents the structure of the views and components and how they are nested in each other. The green elements represent the created views while the orange ones represent the components. Each arrow signifies that the element that follows it is a child of the above view or component.

The communication between the client and the server was achieved using Axios, a Promise-based HTTP service. This service is responsible for sending the necessary API calls to the server, through the use of two modules — *auth* and *client*. The *auth* module handles the data sent to all the routes related to a user's authentication, while the *client* module handles the data sent to the server.

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[10]*Capacitor*, https://capacitorjs.com/
[11]*Vue.js*, https://vuejs.org/

Figure 5.7: Rendered Check Boxes

In order to access and store data in the device's local storage, another service was created, which made use of Capacitor's local storage functionalities. This service allowed any data to be saved, edited, or removed from the device's local storage.

5.4 Question Parsing

The main requirement of the application was for users to have the ability to fill in and submit a survey. This survey and its rendering were one of the main focuses during the development of the client application. Since the questions in these surveys could come in several types, creating a parser that could correctly display this information on a user's screen was essential.

As evidenced in Section 4.3.3.2, a section element, or question, contains an "options" attribute, — a list of JSON objects — which contains all the possible answer options a question might have, and an identifier to the Element Type class. This class contains all the different types of questions, which are then used by the client application to decide what element to render.

Listed below are all the possible types of questions the application currently handles and renders and how each of these types uses the "options" attribute.

5.4.1 Check Boxes and Radio Boxes

In order to render the check boxes and radio boxes, the "options" attribute contains another "options" object, which itself contains a list of strings with the necessary answer options as shown in Figure 5.7 and Figure 5.8.

Figure 5.8: Rendered Radio Boxes
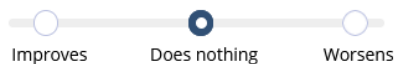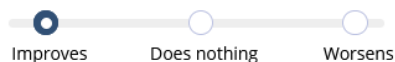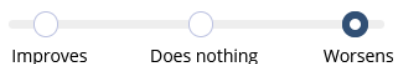
Figure 5.9: Rendered Likert Scale

5.4.2 Likert Scales

Likert scales receive two objects in the "options" attribute: "label" and "scale". The "label" object contains a list of strings with the text that is represented in bold in Figure 5.9. The "scale" object contained a list of strings with the text presented under the clickable scale answer options.

5.4.3 Sliders

Sliders receive five objects in the "options" attribute: "start", "end", "max", "min" and "step". They represent, respectively, the left and right hand-side of the slider presented in Figure 5.10, the maximum and minimum value the slider can go through and the steps at which the slider can be moved.

5.4.4 Open Answers

Open answers receive one object — "characterLimit" —, which contains an integer that limits the maximum amount of characters a user can insert in their response. Figure 5.11 displays an example of this type of question being rendered.

Figure 5.10: Rendered Slider

Figure 5.11: Rendered Open Answer

5.4.5 Body Maps

Body Maps receive an empty object since its contents are immutable from question to question. In addition to this type, two additional derived ones: "BodyMapChoice" and "BodyMapMain-Pain", had to be created since their styling and/or layout were vastly different from the default "BodyMap" type.

The "BodyMapChoice" consists of two radio buttons where its contents are the images of the two available body maps in the application. This question exists to make the application as inclusive as possible by giving the user the choice of selecting their preferred body map. It was intentionally left out the identification of these body maps as "male" or "female".

The "BodyMapMainPain" type is a question similar to the default body map one. However, in this question, instead of being able to select every area of the body map, a user can only select one of the areas. Moreover, the available selectable areas are only the user selected in the question before this one. This means that this question cannot precede the default body map question.

Finally, the blue and red areas that are displayed in Figure 5.12 have been drawn onto the body map images. The location and shape of these areas were based on a diagram created by the domain specialists, which depicted the necessary information for creating the areas. Each one of these areas is an SVG image which was manually adapted to fit the aforementioned shapes.

5.4.6 Simple Elements and Section Descriptions

These elements are a type of question that does not contain any possible answer, meaning the "options" attribute is empty. Although these two are similar, their existence is purposely sectioned in this way, since the styling of these elements differs from one another. Their final look can be seen in Figures 5.13 and 5.14.

5.4.7 Additional Options

Aside from the question types, there are certain options that can be applied to any of these elements. This section will enumerate and describe each of these options.

Conditional Elements

When a specific answer needs additional data, a conditional element object can be added to the "options" attribute. This object contains a label, a question type and a target index. The label and

3. Select every area where you've felt pain in the last 3 months:
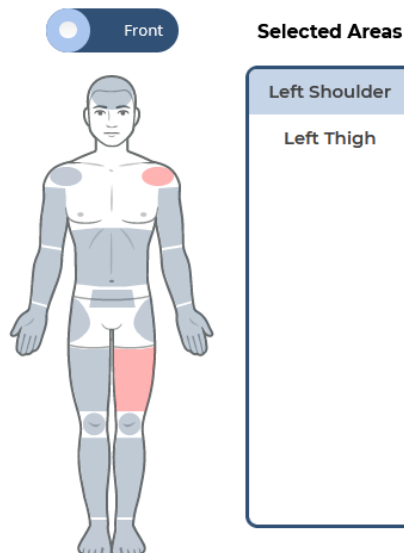
Figure 5.12: Rendered Body Map

5. The following questions are about the pain in your *__Left Thigh__* you've previously selected.

Figure 5.13: Rendered Simple Element

Part 9 out of 17

We'd like to know how you have been in the last week. That's why we've thought about a few questions that we'd like you to answer. Read each question attentively. Think about how things have been going in the past week. Select the answer that better matches your experience.

Figure 5.14: Rendered Section Description
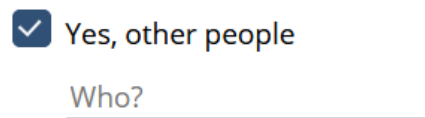
Figure 5.15: Conditional Element

question type are used to render the new element, like the one shown in Figure 5.15. The target index is the position in the options list of the element that, when clicked, creates this new element.

Conditional Blocks

When a user selects a certain answer, sometimes it would make sense to disable other possible answers, since the data collected from that answer would not be coherent. Figure 5.16 shows an example of this in action. When a user selects "No", the other options should be disabled, as they would not be coherent with what the user just selected. The conditional blocks object contains a blocked options index and a target index. The first one is a list of indexes that point to elements of the "options" object that need to be blocked when a user clicks on the element with the given target index.

Conditional Jump
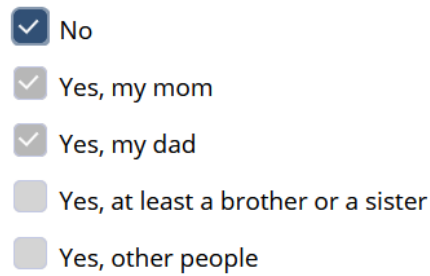
Some questions, depending on a user's answer will require the survey to jump a certain number of sections. With a conditional block object, an element receives a target section and a target index. The target section is the new section the survey will have to navigate to and the target index is the option which, when selected and submitted, will activate this jump.

Conditional Options

There can be questions that are only shown if a user selects a certain answer on a prior question. In these cases, the conditional options object is used on the element that will only be created if a certain answer is selected. This object contains a target section element and a target index which is used to fetch the needed question and check if the option at the target index has been selected.

5.5   Development Methodology

The development of the application for this dissertation followed an Agile methodology. In ten to fifteen minutes daily meetings with the dissertation's co-supervisor, I reviewed what had been done the day prior and planned what was to be done each day. In addition to that, when the development of the mobile application interface began, I started undergoing weekly sprints. At the end of these sprints, there was a meeting with the dissertation's supervisors and the application's domain specialists to present and get feedback on the progress made in the past sprint.

Figure 5.16: Disabled Elements

Both the server and client applications were developed on a development branch in INESC TEC's Gitlab, leaving the master branch for a future, full release.

5.6 Summary

This chapter reports on the development process conducted during this thesis. It is believed that the developed architecture, with all the technologies being used, can be easily worked upon to further improve the application. The server models and handles most of the necessary logic specified in Chapter 4. The client side of the application, does not fit the necessary solution needed for the FOREUM project yet. However, it already contains the interface and interactions necessary to conduct a pilot-test that could evaluate its viability when compared to on-site pain experience collection methods, which will be reported on Chapter 6.

Chapter 6

Test, Results and Discussion

In order to evaluate the application's usability and viability in an off-site approach, a pilot test of the system was conceptualized. This chapter will present the final look of the application for this test, describe how it was structured and conducted, and analyse the obtained results.

6.1 Test Structure

The conducted test was made available for a total of 11 people. Out of these, three were domain specialists and researchers at ISPUP. The remaining eight were teenagers, five men, and three women aged between 13 and 18 years old. The application was only released in Google's Play Store, meaning that all the participants had an Android device. This decision was made since Apple's App Store, aside from having more extended wait periods when it comes to the testing and acceptance of the application into this store, also requires a well-defined privacy policy and user agreement, which were not available at the time of the beginning of the pilot-test.

In order to assess the impact of the gamification features built into the application, the teenagers were divided into two groups. The first group, the control group, only had access to the application's basic features — the survey and the ability to change some profile settings. The second one had access to the previously mentioned features and the avatar, and the shop. Participants in this group could change their avatar's hair and skin tone and buy and equip different items from the shop. In order to buy these items, the participants could earn coins by completing the survey's different sections.

This pilot test ran throughout a week and had participants use the application freely during this time frame. The participants were asked to fill in the available survey, a 26-part questionnaire created by the ISPUP's researchers. By the end of this test, the participants were asked to answer a survey asking them about their experience while using the application.

This survey was composed of two main sections. The first section contained the System Usability Scale [41], which is a reliable and validated tool for determining the usability of a certain system. In addition to this scale, two more questions about the gamification features were added,

which were only presented to participants who had access to these features. Annex D presents the survey in its entirety.

When collecting the answers from the final survey, it was necessary to know what group a participant who answered this survey belonged to. In order to do that, each participant's username was created following a "userXXX" format, where the X's represent a 3-digit number. If this number was lower than 500, it was decided that this particular user would be part of the control group. If the number were higher or equal to 500 and lower or equal to 999, the user would be part of the gamification group.

Finally, to ensure the participant's privacy, they were only contacted by ISPUP with their randomly generated credentials and a guide explaining what the purpose of the test was and what features the application had. This meant that there were two separate guides, one for the participants in the control group and another one for the participants in the group with access to the gamification features. Annex E contains the gamification group's guide in its entirety. The control group's guide is not present in this thesis since it has essentially the same contents as the other guide.

6.2   Final Application

This section will display a few figures which represent the application's final interface. This section will only display the interface for the users with access to the gamification features, as it represents the whole range of advanced functionalities.

The users were given access to the application, with randomly generated credentials, through the Login page, in Figure 6.1a. From there, they would land on the Home page, in Figure 6.1b, from where they could start or continue the survey that was available throughout this test or access their avatar's customization page. However, the users could also answer the survey by navigating to the Surveys page in Figure 6.2a.

When starting the survey, the user would enter the first section or be redirected to the last section they answered if they had already started answering it. The sections were pages similar to the one in Figure 6.2b.

Finally, the users could customize their avatar or change their profile settings in the Profile page, in Figure 6.3a and 6.3b, respectively. In order to customize their avatar's accessories, shirts, or pants, the users would first have to buy them on the Store page, in Figure 6.4. All the icons used in this application were created from scratch in order to fit their exact needs.

<center>(a) Login Screen   (b) Home Screen</center>
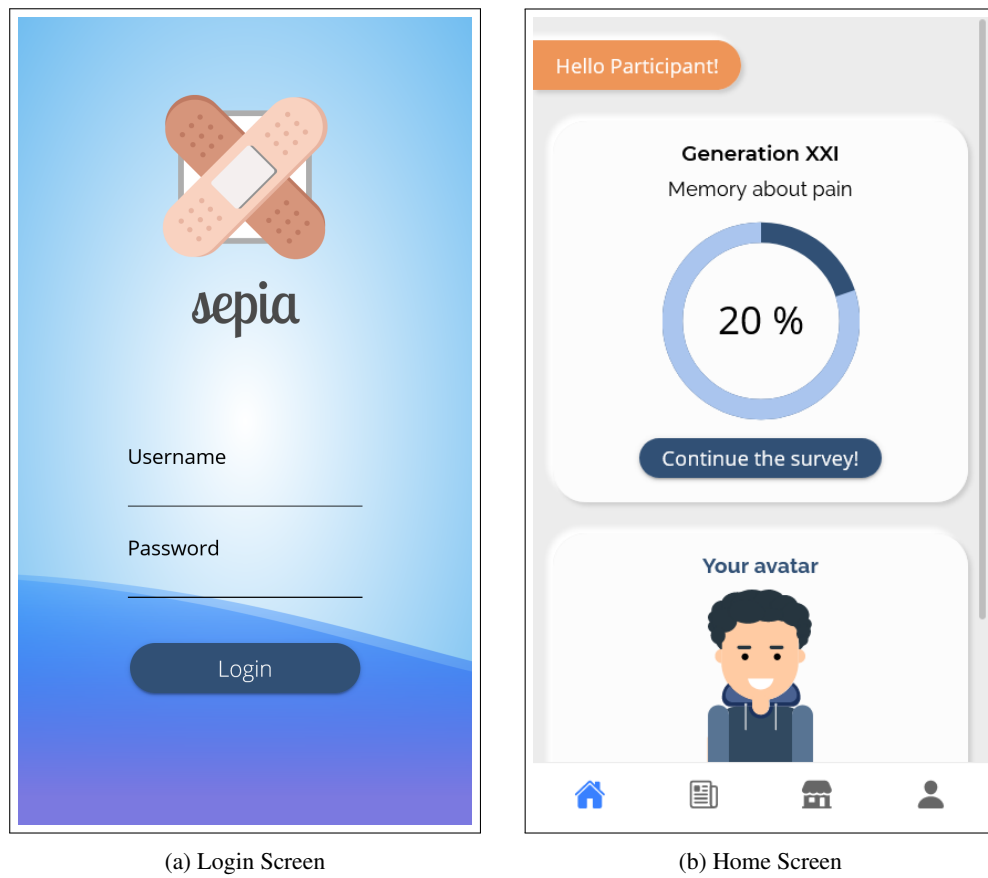
<center>Figure 6.1: Login and Home Screen</center>
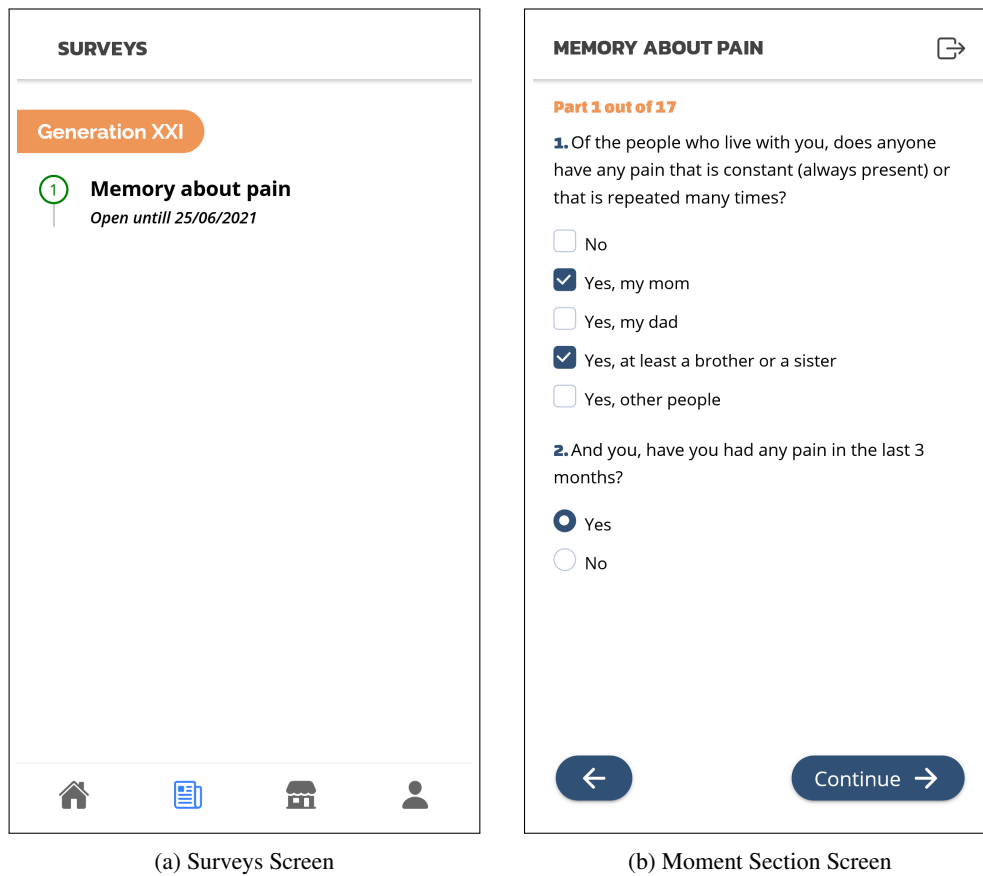
(a) Surveys Screen (b) Moment Section Screen

Figure 6.2: Survey and Moment Section Screen
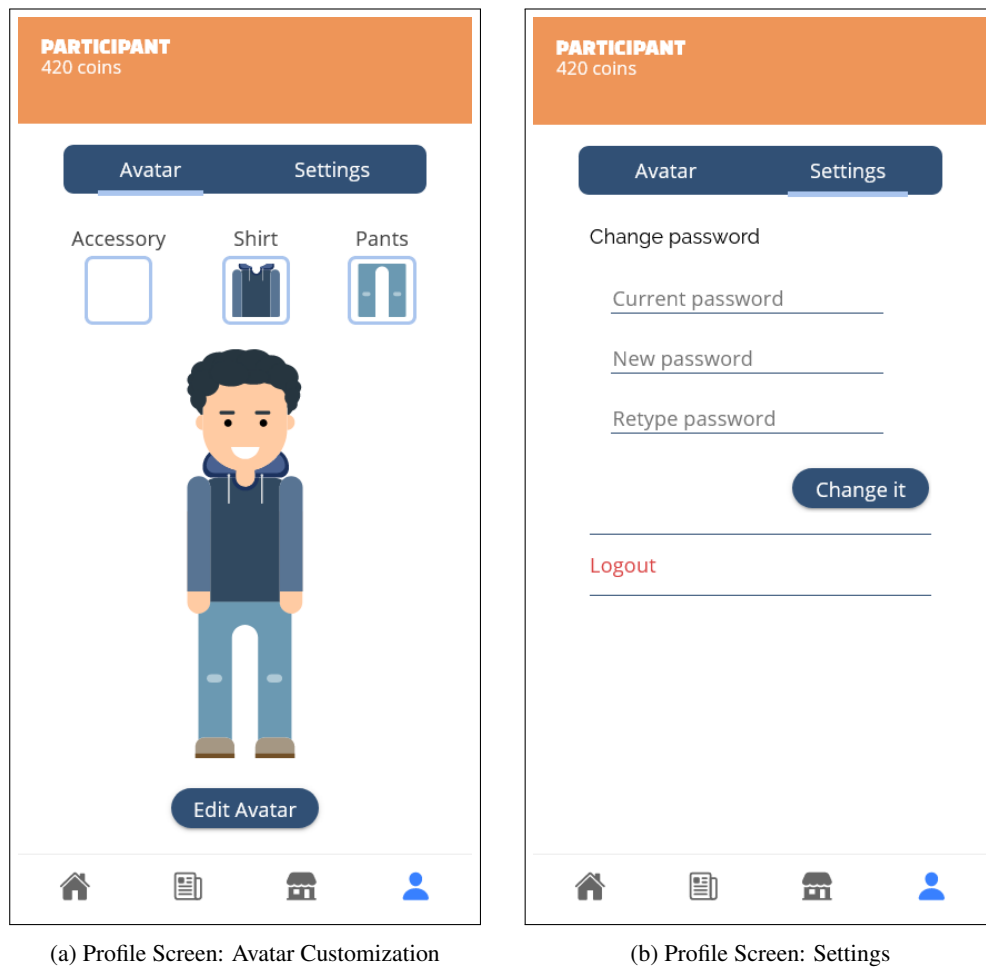
(a) Profile Screen: Avatar Customization   (b) Profile Screen: Settings

Figure 6.3: Profile Screen
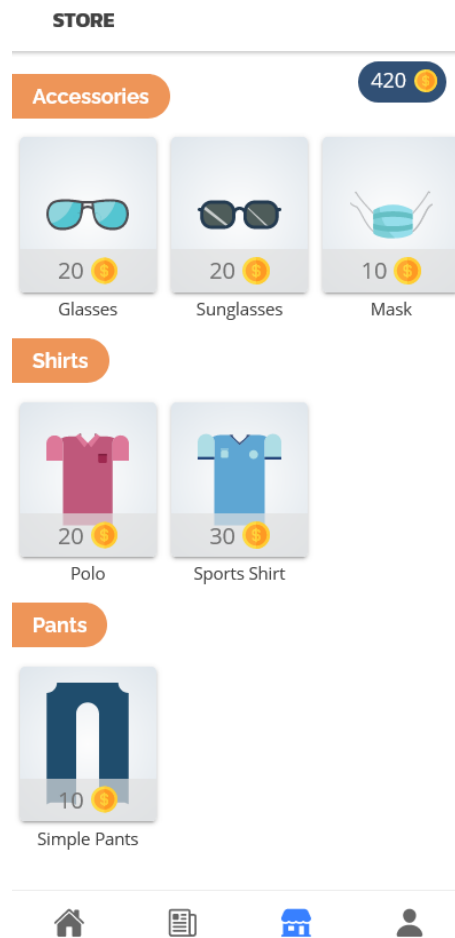
Figure 6.4: Store Screen

6.3 Results and Discussion

Regarding the teenager's interaction with the application, it was seen that, out of the eight that were contacted, two of them, both members of the control group, did not interact with the application at any moment. Why they have not used the application is not known at the moment of the writing of this dissertation. All the remaining participants successfully finished the survey that was available in the application.

From the four participants who had access to the gamification features, one did not buy items from the shop but customized their avatar's hair and skin tone. All the remaining participants of this group edited their avatar's physical look, bought items from the shop, and equipped them on their avatar.

Regarding the System Usability Scale form, only five of the teenagers filled it during the pilot test, meaning that one participant, who was a member of the control group, despite having interacted with the application, did not manage to provide their answer to this form. The researchers
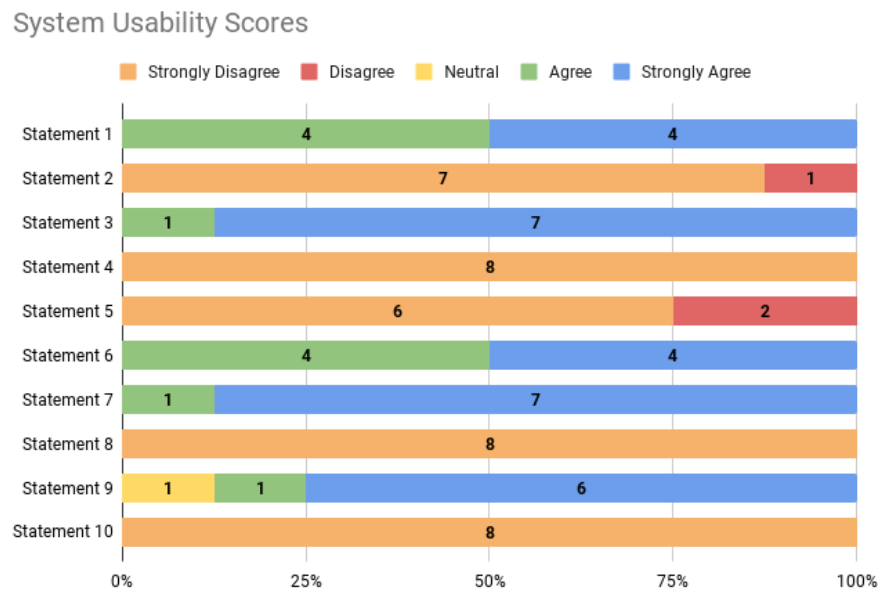
Figure 6.5: System Usability Scale Results

at ISPUP were also asked to fill in this exact form so that it is possible to understand their overall appreciation of the developed application. Figure 6.5 displays the scores of the System Usability Scale from eight users (three researchers at ISPUP and five teenagers), where the *Statements* are the following:

1. I think that I would like to use this system frequently.

2. I found the system unnecessarily complex.

3. I thought the system was easy to use.

4. I think that I would need the support of a technical person to be able to use this system.

5. I found the various functions in this system were well integrated.

6. I thought there was too much inconsistency in this system.

7. I would imagine that most people would learn to use this system very quickly.

8. I found the system very cumbersome to use.

9. I felt very confident using the system.

10. I needed to learn a lot of things before I could get going with this system.

The application achieved a system usability score of 94.7, which indicates well-above-average usability. Although this version of the application is not a final one, both teenagers and researchers
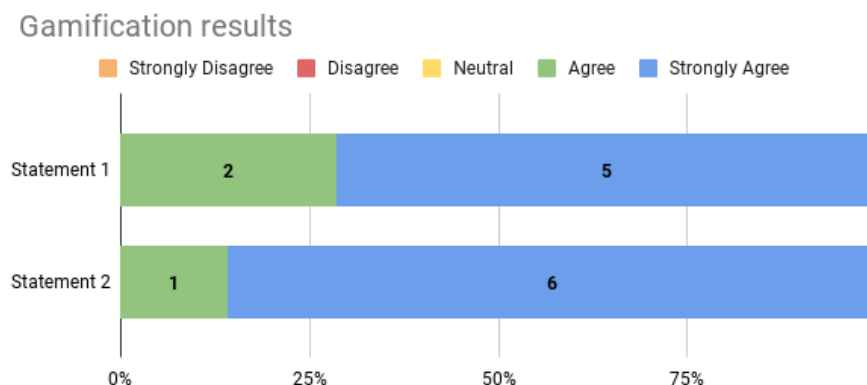
Figure 6.6: Gamification Questions Results

provided very positive feedback. This unusually high score can be partly explained by the small number of users participating in this pilot test. Nevertheless, the obtained results still validate the work done throughout this dissertation and incentivize the continuation of the development of this application.

Regarding the gamification features, the application also received positive feedback. Figure 6.6 displays the answers obtained to the following statements:

1. I quickly understood how to customize my avatar

2. I think the store and the avatar were simple to use and customize

With this data, we can conclude that the users who had access to the shop and avatar could easily understand and interact with these components.

The participants were also asked to report how much time they believed they took to complete the survey. This was used to understand if there was any discrepancy between the time the users had perceived they had taken and the time they had taken in reality to complete the survey. However, no user responded with a time that did not correspond with the real-time they had taken.

When trying to determine if the gamification features had any improvement on the users' interactions with the application, it can be concluded that there is no sufficient evidence that can support this. It is known that users who had access to gamification features spent more time using the application than users in the control group since that, in addition to the time they took completing the survey, they also explored the shop and avatar components for a few minutes. However, these actions all took place on the same day, meaning no user came back to the application.

In order to thoroughly test the viability of the gamification features in this application, a much longer test had to be conducted, with more moments the users could answer, throughout this test. However, this pilot test indicated that the users showed interest in the gamification features, even with their limited functionalities. This gives hope that, in the future, with a more robust and complete application, the gamification features can help maintain the user's attention on the app.

Ultimately, with the results obtained, it can be concluded that the usage of the surveys is, in fact, viable. The users who actively participated in the pilot test managed to complete the survey without any significant issues, and their answers were successfully recorded for future analysis by the ISPUP researchers.

6.4 Summary

In this chapter, the final product of this dissertation was shown and what conclusions could be taken from its use. The conducted pilot test produced, mostly, the results that were expected at the beginning of this thesis.

Chapter 7

Conclusions and Future Work

The model of the solution created in this dissertation's context encompasses, to the best of our knowledge, all the functionalities needed for the project proposed to the Foundation for Research in Rheumatology. However, the developed application is only a subset of the full scope of this project. The usage of pain evaluation methods that are standards in the chronic pain area leads us to believe that the data obtained from the surveys will be optimal for future research.

Moreover, this solution also attempts to be flexible enough to be easily applied to other cohort studies made in the future.

As for future work, we still intend to improve the current application throughout various meetings with Dra. Raquel Lucas, the project's Principal Investigator, and other ISPUP researchers involved in this project. Regarding the application developed for this thesis, aside from the feedback left from researchers and participants during the test, some work is still left to be done. The current project's solution mentioned an application for caregivers, quizzes, push notifications, achievements, and a platform where researchers could manage the application and its users. Although not implemented in the final version of the application developed for this thesis, these features have already been modeled and primarily implemented in the application's server. In order to reach the goal of using this application as a completely viable substitute for the on-site methods that are being used to the current day, the features mentioned above are essential.

Regarding the objectives of this thesis, it can be concluded that they were all met. The application was created and successfully launched onto Google's Play Store so that users could test it and evaluate its usability. Since the application presented a great usability score and all the answers the users provided in the survey were saved and stored without issues — meaning the researchers at ISPUP could easily access this data and analyse it —, the viability of this application was also validated.

This thesis's main contribution is the digitization of the Generation XXI cohort's pain experiences participant data. Moreover, using the data collected from this application, it might be possible to identify children at higher risk of MSK pain in the absence of an identifiable disease.

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Appendix A

Domain Model
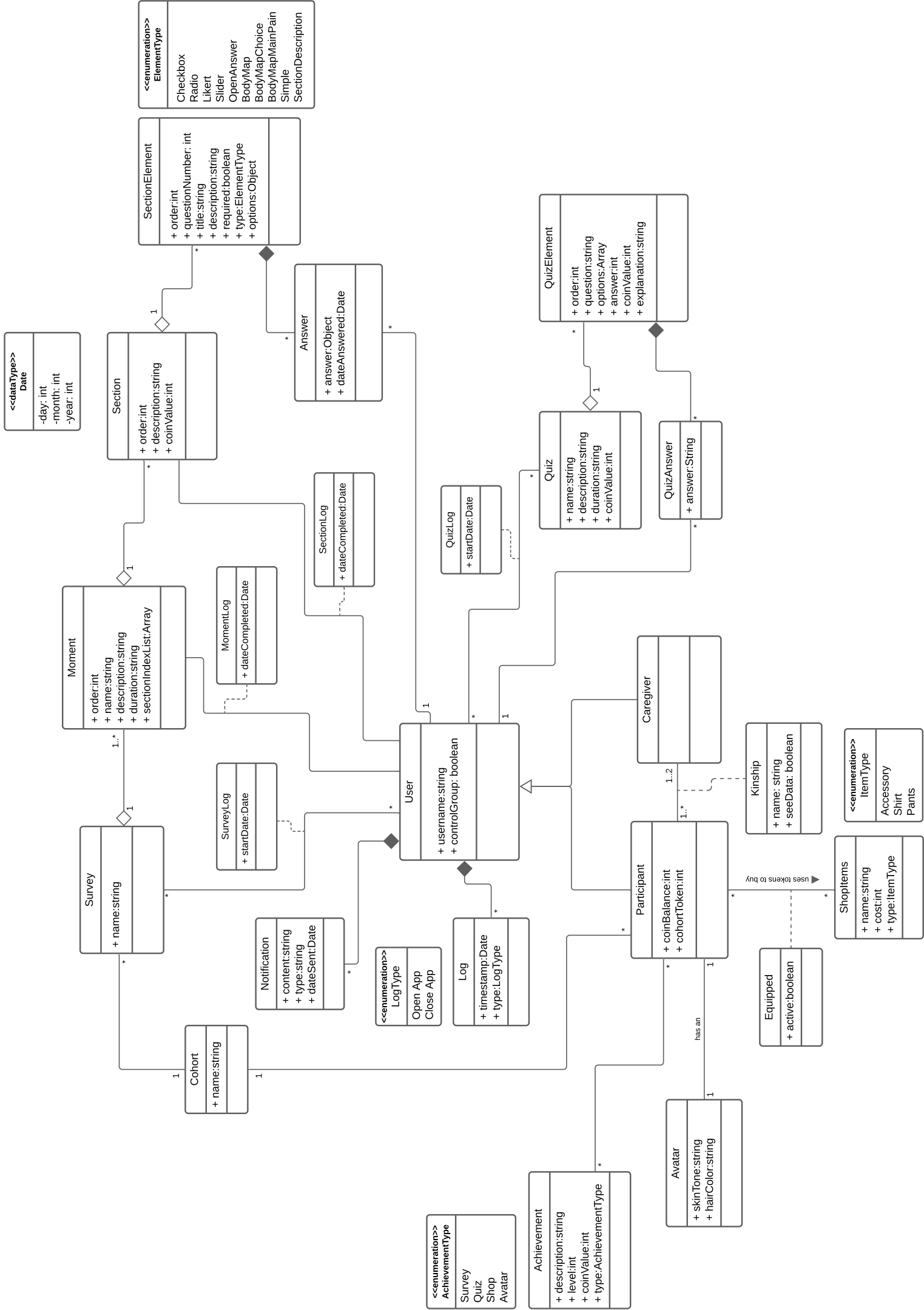
Appendix B

All REST API Routes

SurveyController

| GET | /elementTypes/{elementTypeId} | 🔓 |

| GET | /users/{userId}/surveys/{surveyId} | 🔓 |

| GET | /users/{userId}/surveys | 🔓 |

ResearcherController

| POST | /users/{userId}/caregiver | 🔓 |

| GET | /users/{userId}/caregivers | 🔓 |

| POST | /users/{userId}/cohort | 🔓 |

| POST | /users/{userId}/kinshipRelation | 🔓 |

| DELETE | /users/{userId}/kinshipRelation | 🔓 |

| POST | /users/{userId}/participant | 🔓 |

| GET | /users/{userId}/participants | 🔓 |

| POST | /users/{userId}/researcher | 🔓 |

| GET | /users/{userId}/researchers | 🔓 |

CaregiverController

| GET | /users/{userId}/caregivers/{caregiverId} | 🔓 |

UserController ⌄

| PATCH | /users/{userId}/changePass | 🔓 |

| PATCH | /users/{userId} | 🔓 |

| GET | /users/{userId} | 🔓 |

| GET | /whoAmI | 🔓 |

MomentController ⌄

| PATCH | /users/{userId}/moments/{momentId}/sectionList | 🔓 |

| PATCH | /users/{userId}/moments/{momentId}/startDate | 🔓 |

| GET | /users/{userId}/surveys/{surveyId}/moments/{momentId} | 🔓 |

| GET | /users/{userId}/surveys/{surveyId}/moments | 🔓 |

EquippedController ⌄

| GET | /users/{userId}/participants/{participantId}/avatar/equipped | 🔓 |

| PATCH | /users/{userId}/participants/{participantId}/shopItems/{shopItemId}/equipped | 🔓 |

AvatarController ⌄

| PATCH | /users/{userId}/participants/{participantId}/avatar | 🔓 |

| GET | /users/{userId}/participants/{participantId}/avatar | 🔓 |

PoliciesController ⌄

| GET | /users/{userId}/participants/{participantId}/policies/accepted | 🔓 |

| GET | /users/{userId}/participants/{participantId}/policies/required | 🔓 |

| GET | /users/{userId}/participants/{participantId}/policies/types | 🔓 |

| POST | /users/{userId}/participants/{participantId}/policies | 🔓 |

| GET | /users/{userId}/participants/{participantId}/policies | 🔓 |

ShopItemController ⌄

| GET | /users/{userId}/participants/{participantId}/shopItems/bought | 🔓 |

| POST | /users/{userId}/participants/{participantId}/shopItems/{shopItemId} | 🔓 |

| GET | /users/{userId}/participants/{participantId}/shopItems | 🔓 |

ParticipantController ⌄

| PATCH | /users/{userId}/participants/{participantId} | 🔓 |

| GET | /users/{userId}/participants/{participantId} | 🔓 |

PingController ⌄

| GET | /users/{userId}/ping | 🔓 |

QuizzController ⌄

POST	/users/{userId}/quizElements/{quizElementId}/answer	🔓
GET	/users/{userId}/quizElements/{quizElementId}/answer	🔒
GET	/users/{userId}/quizzes/{quizId}	🔒
GET	/users/{userId}/quizzes	🔒

AnswerController ⌄

POST	/users/{userId}/sectionElements/{sectionElementId}/answer	🔒
GET	/users/{userId}/sectionElements/{sectionElementId}/answer	🔒
POST	/users/{userId}/sectionElements/{sectionElementId}/sectionLog	🔒
GET	/users/{userId}/sectionLogs	🔒

Appendix C

Entity Relationship Diagram

Entity-Relationship Diagram

elementtype
- id
- name
- createdat
- updatedat

sectionelement
- id
- order
- questionnumber
- title
- description
- required
- options
- createdat
- updatedat
- sectionid
- elementtypeid

answer
- id
- answer
- dateanswered
- createdat
- updatedat
- userid
- sectionelementid

quizelement
- id
- order
- question
- options
- answer
- coinvalue
- explanation
- createdat
- updatedat
- quizid

quiz
- id
- name
- description
- coinvalue
- startdate
- duration
- createdat
- updatedat

quizlog
- id
- createdat
- updatedat
- userid
- quizid

quizanswer
- id
- answer
- createdat
- updatedat
- userid
- quizelementid

section
- id
- order
- name
- description
- coinvalue
- createdat
- updatedat
- momentid

sectionlog
- id
- datecompleted
- createdat
- updatedat
- userid
- sectionid

moment
- id
- order
- name
- description
- startdate
- duration
- sectionindexlist
- type
- createdat
- updatedat
- surveyid

momentlog
- id
- datecompleted
- createdat
- updatedat
- userid
- momentid

researcher
- id
- fullname
- perms
- createdat
- updatedat
- userid

user
- id
- username
- controlgroup
- createdat
- updatedat

caregiver
- id
- createdat
- updatedat
- userid

kinship
- id
- name
- seedata
- createdat
- updatedat
- participantid
- caregiverid

survey
- id
- name
- createdat
- updatedat
- cohortid

surveylog
- id
- controlgroup
- startdate
- createdat
- updatedat
- userid
- surveyid

cohort
- id
- name
- createdat
- updatedat

shopitem
- id
- name
- cost
- type
- createdat
- updatedat

equipped
- id
- active
- createdat
- updatedat
- participantid
- shopitemid

participant
- id
- coinbalance
- cohorttoken
- createdat
- updatedat
- cohortid
- userid

logs
- id
- route
- params
- body
- query
- path
- method
- ip
- protocol
- userid
- createdat
- updatedat

notification
- id
- content
- datesent
- sent
- createdat
- updatedat
- userid

unlock
- id
- createdat
- updatedat
- participantid
- achievementid

policiesversions
- id
- type
- date
- createdat
- updatedat

policiesaccepted
- id
- createdat
- updatedat
- userid
- policiesversionsid

avatar
- id
- skintone
- haircolor
- hairstyle
- createdat
- updatedat
- participantid

achievement
- id
- description
- level
- coinvalue
- createdat
- updatedat
- achievementtypeid

achievementtype
- id
- name
- createdat
- updatedat

Appendix D

SEPIA Usability Evaluation Form

SEPIA - Usability Evaluation

Form description

What is your username in the app? *

Example: user000

Short-answer text

Is the number in your username lower than or greater than 500? *

○ Lower

○ Greater

How long do you think it took you to complete the survey? *

If you've been doing it for a few days, only answer with the time you spent actively answering the questions

○ 0 to 10 minutes

○ 10 to 20 minutes

○ 20 to 30 minutes

○ More than 30 minutes

I'd use this application frequently *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think the application was unnecessarily complex *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think the application was easy to use *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think I would need help so that I could use this application *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think that the several features of the application were well integrated *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think the application was inconsistent *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think most people would learn how to use this application very quickly *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think it's complicated to use the application *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I felt confident while using the application *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I had to learn a lot before I could use this application *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Shop and Avatar's Usability

Description (optional)

I quickly understood how to customize my avatar *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think the store and the avatar were simple to use and customize *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Additional Notes

Description (optional)

Is there something else you'd like to say about the app?

What have you liked more or less, some features you'd have like having access to...

Long-answer text

Appendix E

SEPIA User Guide

SEPIA - User Guide

Hello! Thank you for accepting to participate in this usability assessment that we have prepared! During the next 7 days you will have access to an application designed for you to fill in a short survey. In order to complete this survey you will need to have an Internet connection. After these seven days or as soon as you finish the questionnaire, we ask you to answer some questions about your experience with the application, available at: https://forms.gle/WrYR566jLPNrToMVA

The following steps illustrate what you will need to do:

1. **Install the application.** Follow this link to download the application: https://play.google.com/store/apps/details?id=pt.inesctec.sepia
2. **Log into the application.** With the credentials sent to you, you will be able to access your account. As soon as possible, you should change your password on the Profile page which is mentioned later in this document. It is important that you keep these credentials!
3. **Complete the survey and explore the application!** The main purpose of this assessment is for you to complete the survey. However, the application will have some more features that you will be able to explore.

Important! As you complete the survey, your progress will be saved. So if you want to stop doing it and come back later, you can start in the section where you left off.

The list below illustrates the pages you will have access to while using the application.

- **Login:** Where you can log in to the application.
- **Main page:** Here you can see your progress in the survey and you can also see your avatar in the app.

- **Surveys:** A listing of all the surveys you have to fill out. For this test you will only have one survey available. Clicking on it will immediately start it.
- **Shop:** As you progress through the survey, you'll earn coins. You can use these coins to buy items in the store and in this way customize your avatar.
- **Profile:** On this page you can customize your avatar with items purchased from the store, see the coins you've collected and change your account password.

Thank you for your participation!

Appendix F

Pain Evaluation Questionnaires

F.1 McGill Pain Questionnaire

The McGill Pain Questionnaire

Overview: The McGill Pain Questionnaire can be used to evaluate a person experiencing significant pain. It can be used to monitor the pain over time and to determine the effectiveness of any intervention. It was developed at by Dr. Melzack at McGill University in Montreal Canada and has been translated into several languages.

Sections:

(1) What Does Your Pain Feel Like?

(2) How Does Your Pain Change with Time?

(3) How Strong is Your Pain?

What Does Your Pain Feel Like?

Statement: Some of the following words below describe your <u>present</u> pain. Circle <u>ONLY</u> those words that best describe it. Leave out any category that is not suitable. Use only a single word in each appropriate category - the one that applies best.

Group	Descriptor	Points
1 (temporal)	flickering	1
	quivering	2
	pulsing	3
	throbbing	4
	beating	5
	pounding	6
2 (spatial)	jumping	1
	flashing	2
	shooting	3
3 (punctate pressure)	pricking	1
	boring	2
	drilling	3
	stabbing	4
	lancinating	5
4 (incisive pressure)	sharp	1
	cutting	2
	lacerating	3

5 (constrictive pressure)	pinching	1
	pressing	2
	gnawing	3
	cramping	4
	crushing	5
6 (traction pressure)	tugging	1
	pulling	2
	wrenching	3
7 (thermal)	hot	1
	boring	2
	scalding	3
	searing	4
8 (brightness)	tingling	1
	itchy	2
	smarting	3
	stinging	4
9 (dullness)	dull	1
	sore	2
	hurting	3
	aching	4
	heavy	5
10 (sensory miscellaneous)	tender	1
	taut	2
	rasping	3
	splitting	4
11 (tension)	tiring	1
	exhausting	2
12 (autonomic)	sickening	1

	suffocating	2
13 (fear)	fearful	1
	frightful	2
	terrifying	3
14 (pinishment)	punishing	1
	gruelling	2
	cruel	3
	vicious	4
	killing	5
15 (affective-evaluative-sensory: miscellaneous)	wretched	1
	blinding	2
16 (evaluative)	annoying	1
	troublesome	2
	miserable	3
	intense	4
	unbearable	5
17 (sensory: miscellaneous)	spreading	1
	radiating	2
	penetrating	3
	piercing	4
18 (sensory: miscellaneous)	tight	1
	numb	2
	drawing	3
	squeezing	4
	tearing	5
19 (sensory)	cool	1
	cold	2
	freezing	3

20 (affective-evaluative: miscellaneous)	nagging	1
	nauseating	2
	agonizing	3
	dreadful	4
	torturing	5

pain score = SUM(points for applicable descriptors)

How Does Your Pain Change with Time?

Question	Response	Points
Which word or words would you use to describe the pattern of your pain?	continuous steady constant	1
	rhythmic periodic intermittent	2
	brief momentary transient	3

Do the following items increase or decrease your pain?

(1) liquor

(2) stimulants such as coffee

(3) eating

(4) heat

(5) cold

(6) damp

(7) weather changes

(8) massage or use of a vibrator

(9) pressure

(10) no movement

(11) movement

(12) sleep or rest

(13) lying down

(14) distraction (TV reading etc.)

(15) urination or defecation

(16) tension

(17) bright lights

(18) loud noises

(19) going to work

(20) intercourse

(21) mild exercise

(22) fatigue

How Strong is Your Pain?

Statement: People agree that the following 5 words (mild discomforting distressing horrible excruciating) represent pain of increasing intensity. To answer each question below write the number of the most appropriate word in the space beside the question.

Question	Response	Points
Which word describes your pain right now?	mild	1
	discomforting	2
	distressing	3
	horrible	4
	excruciating	5
Which word describes it at its worst?	mild	1
	discomforting	2
	distressing	3
	horrible	4
	excruciating	5
Which word describes it when it is least?	mild	1
	discomforting	2
	distressing	3
	horrible	4
	excruciating	5