FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Outdoor Park Exploration using Augmented Reality and Mobile Computing

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Mestrado Integrado em Engenharia Informática e Computação

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Abstract

The increasing number of tourists in Portugal and the continuously growing market of mobile devices is resulting in new ways to guide tourists and create more memorable experiences for visitors. Augmented Reality has proved before, that it can be a great asset to create more immersive and interactive experiences, both for entertainment as for education.

When an application using Augmented Reality uses location-based systems in a gamifying way, it can create pleasant and entertaining outdoor experiences without losing its pedagogical ability, making it a promising fit to a nature park.

This dissertation consists of the design, implementation and evaluation of a mobile application with the purpose of disseminating scientific knowledge about the fauna and flora of the nature park "Parque Biológico de Gaia", located in Porto district, Portugal in a complementary and pleasant manner, thus not removing the focus from the park.

To accomplish this, the application makes use of location-based systems and Augmented Reality interactive experiences. Gaming elements are also introduced in the design of the application to try and improve the engagement and involvement in the various activities of the application and its contents.

User tests were performed during and at the end of the development of the prototype. The results allow us to conclude that mobile applications, for an outdoor park, using location-based systems with augmented reality and gaming elements can improve the visitors' experience while at the same time disseminate scientific knowledge.

Resumo

O crescente influxo de turistas em Portugal e o aumento no crescimento do mercado de dispositivos móveis tem levado à criação de novas maneiras de ajudar os turistas e tornar as suas experiências mais memoráveis. A Realidade Aumentada tem provado consecutivamente que consegue contribuir na criação de experiências interativas e imersivas, tanto para entretenimento, como para educação.

Quando uma aplicação de Realidade Aumentada com elementos de gamificação é feita em conjunto com sistemas de localização, ela pode criar experiências ao ar livre agradáveis e divertidas sem perder as suas capacidades pedagógicas, tornando-se assim uma adição promissora a um parque natural.

Esta dissertação foca-se no design, implementação e avaliação de uma aplicação móvel que tem o propósito de disseminar conhecimento científico sobre a fauna e flora do "Parque Biológico de Gaia", localizado no distrito do Porto, Portugal. De modo a não desviar o foco da visita ao parque, a aplicação foi criada com a intenção de ser um complemento agradável, que visa enriquecer a visita e não distrair o visitante do propósito da mesma.

Para atingir este objetivo, a aplicação faz uso de sistemas de localização e experiências interativas de Realidade Aumentada. Para tentar melhorar o interesse e envolvimento nas várias atividades e conteúdos que a aplicação proporciona, são também introduzidos elementos de gamificação no design da aplicação.

Durante e após o término do desenvolvimento do protótipo, testes de usabilidade foram feitos à aplicação. Estes permitiram concluir que aplicações móveis, desenhadas para um parque ao ar livre, que usam sistemas de localização com realidade aumentada e elementos de gamificação, podem melhorar a experiência dos seus visitantes enquanto, ao mesmo tempo disseminam conhecimento científico.

Acknowledgements

I would like to thank everyone who directly and indirectly supported me through this long journey that led me to the concretization of this dissertation.

To my father and mother who always supported and helped me through my whole life. To my brother, to whom I wish every success in the challenges that lie ahead.

To my supervisors, Rui Nóbrega and António Coelho, who were always supportive and available to guide me throughout this dissertation, as to the student Liliana Santos who I wish great success.

To my family, friends and colleagues who were always present with their patience, help and support, making me overcome many hardships.

Nuno Silva

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Abbreviations

AR	Augmented Reality
GPS	Global Positioning System
OS	Operating System
VR	Virtual Reality
FPS	First Person Shooter
UI	User Interface
POI	Point of Interest
GUI	Graphical User Interface

Chapter 1

Introduction

The increasing influx of tourists in Portugal has made the tourist sector, the biggest economic activity of the country [Est17]. Being the diversity of experiences one of the main objectives of those visitors, we can take advantage of new technologies and the growing use of smartphones [Ken12] to give an answer for that search.

Games can be a solution for that search, as they enable the creation of pleasant experiences, while still maintaining other priorities as its focus. This makes games an adaptable solution for various problems and situations that require a personalized approach, as is the case of the uniqueness of different tourism locations.

The versatility of games and their "potential to integrate pleasure, learning, reflecting" [Gee06] is known. Also, the introduction, advancement and popularization of new technologies, have, in recent years, been opening new doors to innovative ways of integrating games in daily tasks.

Augmented Reality offers ways to create interaction and bringing information, between the physical and the digital world [Car11]. The widespread use of mobile devices, like smartphones, that have capabilities to locate the position and orientation of the device [Avo12], led to the appearance of applications that, directly and indirectly, influence positively the health, education and entertainment of its users.

The increasing use of computational devices is taking the attention away from the outside world, starting at very young ages[1]. Capturing the attention away from the screen is a big challenge, thus tourist attractions like museums and nature parks have to find new ways to disseminate their intended message to the visitor while still maintaining the focus on their mission.

[1] The iPad really IS child's play: More than half of toddlers can use Apple's tablet when they are just ONE, researchers say. https://www.dailymail.co.uk/sciencetech/article-3149025/The-iPad-really-child-s-play-half-toddlers-use-Apple-s-tablet-just-ONE-researchers-say.html (last access 2019)

Applying Augmented Reality elements, with location-based systems, in a gamified way, provides a bridge between the digital world and the physical world, giving pedagogical content, while still maintaining the epic experience a tourism visit should have.

1.1. Motivation

This dissertation topic is mainly motivated by the need to achieve the mission of giving the visitors of nature parks information about its natural heritage. This needs to be accomplished in a way that doesn't remove the pleasantness of the park's visit and acts as a support to the visit so the focus isn't deviated from these large parks.

"Parque Biológico de Gaia" is a nature park located in the Porto district, with an extensive area (35 hectares) populated with hundreds of species of animals and plants living in a wild state. The park opened to the Public in March 1983 with the objective of informing the visitors about the natural heritage of the region, in all its components: fauna, flora, weather, rural architecture of the region, and its contrast between the nature aspects of the park and the urban spaces that are growing around the region.

The search for new experiences by tourists and the need for a system that can serve as an information support about what the park has to offer led to this dissertation. The main goal is to create a functional mobile application that aims to be a supportive way to inform and educate the visitors of "Parque Biológico de Gaia" about its region biodiversity, while still maintaining a pleasant and fun experience. To do this the application needs a way to interact with the park environment, on which Augmented Reality and location-based systems allow to expand that type of interaction. The entertainment and fun aspects of the application can be accomplished with the use of serious games, which have the advantage of being tools to disseminate knowledge.

1.2. Problem Statement

Following the main goal of this project, the following problem was defined:

> *Can a location-based mobile application integrating augmented reality and gamification elements improve the visitors' experience while at the same time disseminate scientific knowledge?*

This problem creates the need to research related work about tourism and applications made for tourists in an outdoor environment, what exists about games in relation to education and its effects on knowledge intake. Furthermore, how can AR be implemented in an application aimed for an outdoor experience and how to do all this while maintaining a pleasant user experience.

1.3. Objectives

Considering the established problem statement, a list of objectives for the dissertation's work are proposed:

- Research about designing applications oriented for tourists, how gamification can be used in education, how design these games, in order to improve the user engagement, research type of games and examples of those games that can fit the context of this project and augmented reality, namely using augmented reality as an informative support;
- Design and implementation of a location-based mobile application that can act as a support for the visitors of the park and serve as an informative tool in order to disseminate the natural heritage of the "Parque Biológico de Gaia" natural park;
- Integrate augmented reality interactive experiences with gamification elements into the prototype;
- Test and evaluate the prototype through user studies.

During the design and implementation of the prototype user tests are done, thus maintaining and user-centred development process.

The final user test, done inside the park with the finalized prototype, is performed to analyse and evaluate the application, thus allowing to reach to an answer to the question stated in the problem statement (section **1.2**).

1.4. Contributions

This dissertation contributes with the implementation of a prototype, designed for the nature park "Parque Biológico de Gaia". This location-based mobile application uses augmented reality and gamification elements that tries to improve the visitors' experience while at the same time disseminate the park's natural heritage.

Additionally, the development of the prototype was preceded by a research on subjects related to various themes that helped the creation of this prototype, namely:

- Designing Tourism-Oriented Mobile Applications.
- Gamification in Education.
- Pervasive Games.
- Game Design and User Engagement.
- Informative Augmented Reality Applications.

It also contributes with this dissertation document which presents the design and implementation details of the application. It also details two different Augmented Reality interactive experiences that use scientific knowledge as their content.

At the end of this document, an evaluation and analyse of the user experience is done. These results can be used to guide future work related to the creation of a location-based mobile

application for an outdoor nature park that aims to be a pleasant supportive and informative tool for its visitors.

1.5. Document Structure

This document is structured in six chapters, starting with chapter one, where the introduction of the theme is presented. Chapter two follows with the state-of-the-art review, where related and relevant work for the theme in hand is analysed, to serve as a basis and guide for the development of the project.

The third chapter describes the proposed solution, defining its requirements and then going in detail about the design of the prototype explaining how the application works.

The next and fourth chapter describes the implementation of the application in a more detailed manner, focusing on the technical aspect of the application, its structure, tools, methods used and the reason they were used in the implementation.

Chapter five covers the performed tests, each one divided into a section. Each of the sections is related to one of the tests done through the development of the prototype, with the respective protocol results and analysis.

Finally, chapter six concludes the dissertation, giving an answer to the defined problem and discusses future work.

Chapter 2

State of the Art Review

This chapter provides an overview of the studies and work related to Mobile Applications, Gamification in Education, Pervasive Games and Augmented Reality applications. It describes relevant works and applications that can be used as a guide for the development of the project that this document describes.

The chapter starts by analysing the principles to develop a tourism-oriented application, followed by an analysis on the effects of games, in the topic of effectiveness in the dissemination of knowledge, and an analysis of pervasive games and its ability to relate the user experience in the game with the real world. After game design and user engagement practices are described for a better understanding on how to improve user experience. Lastly examples of Augmented Reality applications that have the purpose of serving as visual information tools are also presented.

2.1. Designing Tourism-Oriented Mobile Applications

The target audience should be the focal point when crafting a good application. In the case of tourists, according to Brown [Bro03], their main problem is the unfamiliarity with the visiting spot which can be addressed by focusing on resolving three main questions:

- What to do?
- How to do these different activities?
- Where are these activities?

Apart from these questions, it is also noted that "tourism is very much a social activity" [Bro03], in a constrained time.

Guidebooks and maps are referred by Brown [Bro03], as the two most typical tourist publications. These should always be represented in a tourism-oriented application in a literal or metaphorical way. The guidebook purpose is to provide the answer to the first two questions, by providing information about the location, activities, attractions and other types of useful and relevant information for an outsider.

The map is used to help the visitor navigate the unfamiliar location, making it the response for the third question, by being a visual aid for the visitor, as referred by Brown, "map use is often less about explicit route planning and more about wandering a city in a 'roughly correct' manner" [Bro03].

It shouldn't be forgotten that some of the pleasure in tourism comes with the exploration aspect of the experience, that's why games like *Geocaching* are so popular. Therefore, maps and the guiding information of the application should be enough to avoid making the visitor feel lost and not too detailed to encourage exploration. The promising results of the work done by Santos et al. [San17] show that these types of location-based applications have the possibility to improve the tourist experience.

Additionally, the application should promote the ability to share moments with friends and families, by making the activity in a way to encourage social activities or with options to share experiences like social media does.

For AR tourism-oriented applications, Han [Han17] states the importance of four product features:

- **Content** – The information should be updated and personalized according to the user profile and, if applicable, with routes to the destination and options for reviews and ratings.
- **Presentation** – The interface should be simple, authentic and the GPS-based AR overlay should be as accurate as possible.
- **Functionality** – There should be options to save information on the device, navigate using AR and users should be able to have the capability to use multiple languages and filter information.
- **Interaction** – The interaction must be smooth and fast with the ability to have it adjusted to the device's hardware.

Han [Han17] also states that for the AR experience succeed, it needs to be goal and action oriented by being a clever alternative to access information.

2.2. Gamification in Education

Motivation is defined by the Oxford dictionary as "a reason or reasons for acting or behaving in a particular way". According to Sosyal [Sos13], motivation is a process that helps us reach our aim and that has a big role when learning new topics.

In a study made by Legault [Leg06], it is concluded that the lack of motivation is detrimental to the learning process. It is also referred that amotivation, the lack of motivation, is associated with boredom and poor concentration. In the same study, it is pointed out that motivation has positive effects in terms of greater cognitive flexibility, conceptual understanding, active information processing and better academic performance.

Serious games can help with the motivation issue, in fact, according to Shute, "well-designed games can serve as one excellent type of learning environment" [Shu12] and "serious games can

extend the value of training films and books by allowing the player to not only learn, but also to demonstrate and apply what he or she has learned" [Mic06].

According to Laamarti, "the idea of playing a game dates to the ancient past and is considered an integral part of all societies" [Laa14]. Through history, directly and indirectly, games had been a cornerstone in society. They are a result of the curiosity and competition that is sunk in human nature.

From Children playing physical games like Hide and Seek, which in ancient times could be used to develop skills as avoiding predators, to military officers playing games like Chess and Go, which develops strategy thinking, the variety of games in existence and their usefulness shouldn't be ignored or overlooked. These benefits were the reason that led to the current growth of the serious games market with a prediction to grow even further from the valued $2,731 million in 2016 to $9,167 million by 2023[2].

Laamarti [Laa14], analysed the trends in the serious games field and concluded that not only it is growing rapidly in the Industry, but is also increasing its popularity at a similar rate in the Research Field.

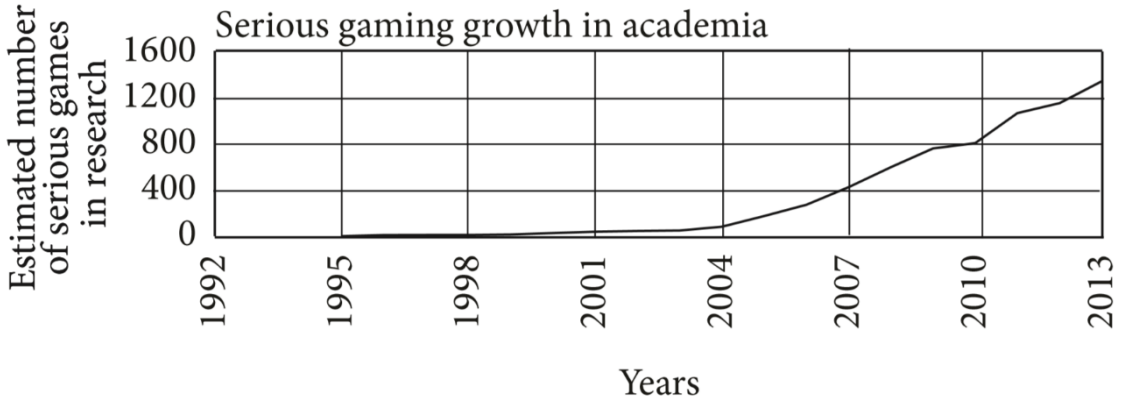
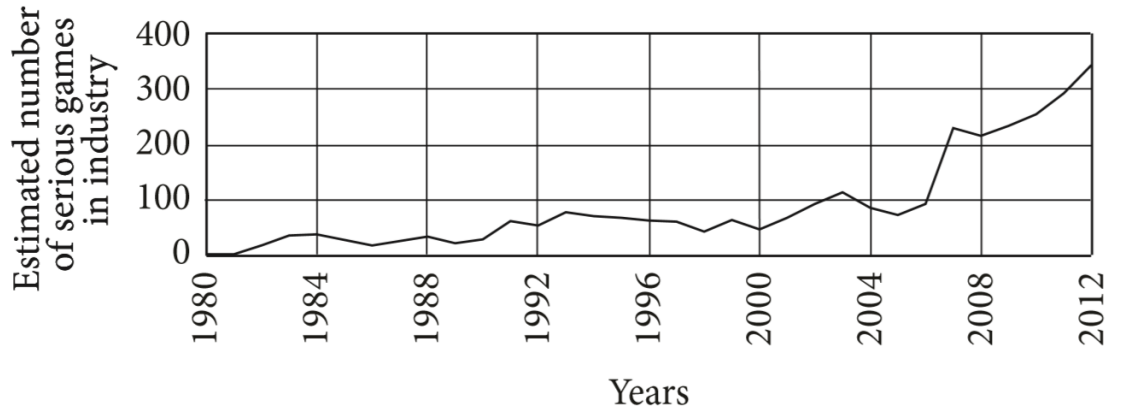


Figure 2.1: Serious games growth in the research field based on surveyed papers in ACM digital library and IEEE Xplore [Laa14]



[2] Serious Games Market Expected to Reach $9,167 Million, Globally, by 2023. https://www.alliedmarketresearch.com/press-release/serious-games-market.html (last access 2019)

Figure 2.2: Serious games growth in the industry [Laa14]

This growth is a result of advances in technology and the many applications serious games have in the education field.

Serious games are games used for simulation, training and education. They are focused in the educational aspect of the experience, instead of the tradicional games which has entertainmet as its center of attention. This types of games can be categorized differently and according to Susi [Sus07], can they be categorized as Military Games, Government Games, Educational Games, Corporate Games and Healthcare Games.

Military games – Through human history, ironically being an organization with war as its main theme, the military has always been involved, directly and indirectly, as a main contributor to the advance of civilization, through research in technologies and methods that can give an advantage in the battlefield.

It's not surprising that the military has one of the longest histories of using games like *Chess* as a training method to improve performance in the battlefield. *Chess* is one of the most well known and older strategy games used by the military, it dates to the 7th century and even its creation is based on earlier wargames that go back thousands of years [Mic06].

Figure 2.3: Chess board [Wik08]

In more recent times, with the development of technology and increase in the capabilities of computers, simulations take a big role in the field of military games. Perhaps the most known examples are flight simulators which are now considered a necessary step in pilot training [Mic06]. These types of simulators offer a realistic environment with cockpits and conditions simulating the real world, thus preparing the trainee to real situations.

Figure 2.4: Copilot menu in the simulation [XPl19]

America's Army is another example of a military serious game. This game is one of the most successful military recruiting tools the United States Army and serving as a basic training simulation, showing what the new recruits should expect, appealing the ones who are more likely to succeed in the Army, which translates to saves in recruitment of new soldiers [Mic06].

Figure 2.5: World simulation in *America's Army* [Stea19]

Government Games – These types of games aim to train and teach within the government domain, from a small scale such as municipal and city level to a higher scale, country and continent level. Simulation and management type of games are common in this category which aim to simulate crisis and environments, preparing the player to correctly prepare and respond to scenarios, such as outbreaks, health care policies issues, traffic control, city budgeting, city land planning and many more.

One good example of a game that fits this category and that further the argument that games can be a good education tool is *Cities: Skylines*. This game was not designed to be a serious game and it is simplified in some aspects of city planning but, according to Haahtela, "the game does a good job in simulating the traffic and transportation system of a city and this makes it possible to simulate accessibility efficiently" [Haa15], which consequently serve as a tool to simulate traffic in real time and be a good visual teaching tool.

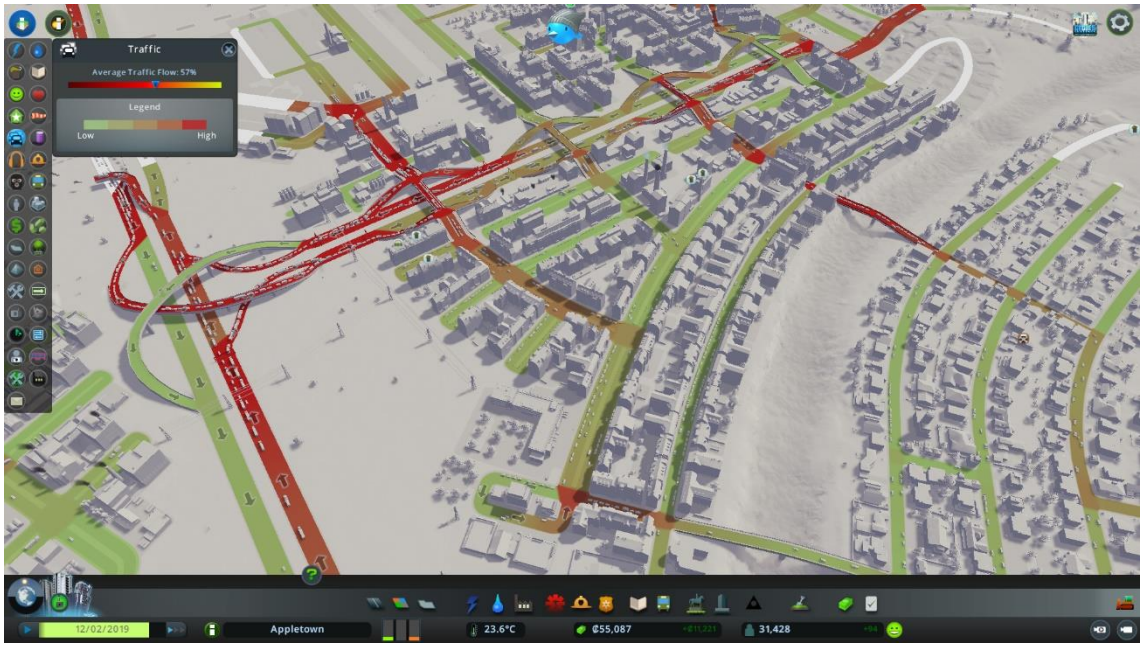


Figure 2.6: In-game screenshot with traffic information of the game scenario "Fix the Traffic" in *Cities: Skylines*

Educational Games – The popularity of video games is unquestionable, it is the most popular and profitable form of entertainment at the current time of writing, being it valued in May 2018 at $116 billion[3]. With percentages as high as 91% of kids playing video games reported[4], video games are a captivating interaction media on which educators can use to improve the learning process.

[3] Investing in the Soaring Popularity of Gaming. https://www.reuters.com/sponsored/article/popularity-of-gaming (last access 2019)

[4] 91 percent of kids play video games, says study. https://www.digitaltrends.com/computing/91-percent-of-kids-play-video-games-says-study/ (last access 2019)

In a study made by Hendrix [Hen13], it is concluded that using games in the educational field is effective in improving students' problem-solving skills and increases the students' learning motivation.

An example of an educational game is *Dragon Box Elements*, which is a game designed for nine-year-olds and older, that teaches the fundamentals of geometry without the player even noticing they are learning and at the same time, giving players the confidence in subjects like mathematics[5].

The designing process is very important in this type of games. According to Ibrahim [Ibr09], designing an educational game is not an easy task, as it requires the many considerations from many perspectives and that it should include game design and content experts to ensure that the resulting game is fun, engaging and focused on the learning aspect. That's why the age focus that went into the design of *Dragon Box Elements* is important, because the game must be simple and appealing with vivid colours to attract the younger audience and the gameplay revolves around puzzles that require knowledge about geometry.

Figure 2.7: In-game screenshot of *Dragon Box Elements* [Dra19]

Corporate Games – According to Michael [Mic06], in the 1990s, corporate tranning evolved to e-learning, significantly reducing the costs to the company, but the effectiveness wasn't very different from the training videos it replaced. He also says that it wasn't very engaging, and it promoted memorization which didn't translate to learning and understanding of the knowledge provided. Michael [Mic06] says that to improve engagement and interest of the trainee, corporations have turned to serious games, which is effective in training faster and at a lower cost than traditional methods, because it evolved the individual is an active part of the

[5] DragonBox Elements. https://dragonbox.com/products/elements (last access 2019)

learning process, instead of just being passively consuming information and ignoring it right away.

An example of a corporate game is *Our Worlds of Makrini*™. It is a role-playing serious game that takes place in a company located in space, filled with aliens from different planets called *Makrini*. It is aimed to teach the learner introductory diversity awareness and inclusion and does that by making the player take the role of one of its employers, who is assigned various tasks that improve the imaginary company's business and tasks related to issues of cultural diversity.

Figure 2.8: Characters diversity in *Our Worlds of Makrini*™ [PIX10]

Healthcare Games – Although the healthcare industry already uses games and simulators to train and prepare healthcare professionals as other mentioned industries, according to Michael [Mic06], modern medicine has begun to take a deeper look at video games in search for ways that can improve the patient healing. He states that there are many uses for video games, such as: Distracting patients during a painful medical procedure, using simulations to improve the patient rehabilitation, using VR environments in therapeutic sessions, like treating phobias and many more.

A more concrete example of these type of games is *Ballade på Badebroen* which is a shooting VR game on which the player has to shoot water balloons at seagulls stealing fish from the player's boat. As the player is immersed in the game, he is distracted from the needle and

there are reports of children not even noticing the needle injection[6], showing the game effectiveness.

Once again, the design in this type of games is very important, the game designer had to take into the account that the player couldn't move one of its arms and that the gameplay couldn't create situations that made the player fidgeting or turning to look backwards. This was accomplished by having a fun and immersive VR experience that requires only one controller to interact with.

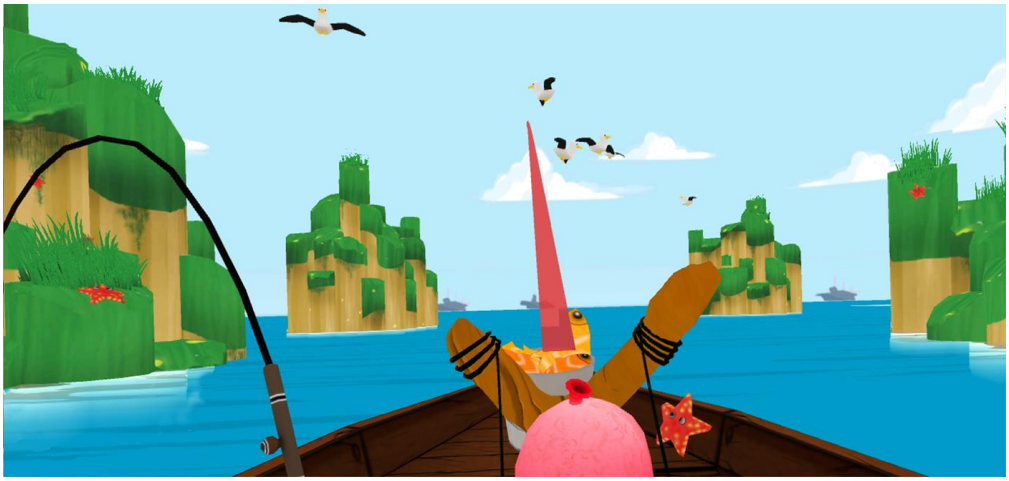


Figure 2.9: Picture from *Ballade på Badebroen* [Rig18]

2.3. Pervasive Games

A pervasive game is a type of game that amplifies the game experience to the real world. These games can range from smart toys, like Zowie's playset *Redbeard's Pirate Quest*, to more recently AR games [Che05].

These types of games, in contrast to the traditional computer and console games, are typically location-based games and require the player to move and interact with the real world, thus they are mostly played using mobile devices, such as smartphones [Opp16].

A straightforward and simplistic pervasive game is *Geocaching*. This location-based game is an adaptation of a treasure hunt, where players have to open *caches* that can be found, by following GPS coordinates. The simplicity of the game makes it possible to be adapted to fit in various contexts. In fact, there are instances of the game being used as an educational tool. An example of that is the use of *Geocaching* by Ellis Reyes in her lessons[7]. According to her, a lesson

[6] Specially designed virtual reality game for children who are afraid of needles. https://www.rigshospitalet.dk/english/news-and-media/news/Pages/2018/march/specially-designed-virtual-reality-game-for-children-who-are-afraid-of-needles.aspx (last access 2019)

[7] Geocaching Finds Its Way To the Classroom. https://www.geocaching.com/blog/2011/08/geocaching-finds-its-way-to-the-classroom/ (last access 2019)

involving geocaching, tasks users to use several skills, especially problem solving and advanced math skills. She also says that her students love using *Geocaching* to learn and that they look forward to the next lesson using *Geocaching*.

Figure 2.10: Lesson plan from Ellis Reys that uses *Geocaching* **[**Geo11]

There is also an instance of this game being adjusted to tourism. As this is an outdoor location-based game, it perfectly fits the context of exploring various landmarks of a region. The city council of Nordeste, in São Miguel island, Açores, realized this opportunity and it is using *Geocaching* to engage tourists and promoting the visit to different landmarks in the region[8].

[8] Geochaching no Nordeste. https://cmnordeste.pt/turismo/natureza/geocaching/ (last access 2019)

Figure 2.11: Picture of "Faja do Araujo" that helps tourist find the *Geocaching cache* [GeoAzores11]

The use of Augmented Reality in these types of games is increasing as technology advances and the popularity of games like *Pokemon Go*[9] and *Father.IO*[10] grows.

The company *Niantic*[11] is an example of this evolution. This company created *Ingress Prime*[12], which is a location-based game, where the player starts by choosing a faction and then have the objective of capturing *portals* for his faction. To do that the player has to move to the physical location of those *portals*, which are points of artistic or historical interest. To be able to capture the *portals* the player needs *exotic matter* which the player can get by walking around the city.

Figure 2.12: In-game screenshot showing the map in *Ingress Prime* [The17]

[9] 'Pokémon GO' Is More Popular Than It's Been At Any Point Since Launch In 2016. https://www.forbes.com/sites/insertcoin/2018/06/27/pokemon-go-is-more-popular-than-its-been-at-any-point-since-launch-in-2016/ (last access 2019)

[10] Father,IO. http://father.io/ (last access 2019)

[11] Niantic. https://www.nianticlabs.com/products/ (last access 2019)

[12] Ingress Prime. https://ingress.com/game/ (last access 2019)

The positive effects of *Ingress Prime* are, according to Morschheuser [Mor17], promoting cooperation and according to Chess [Che14], enabling its players to become more engaged with the spaces in their region. This work would be applied in *Niantic* next product *Pokemon Go*.

In *Pokemon Go* the player takes the role of a *pokemon* trainer with the object of capturing all the *pokemons* in the game and capture as many gyms as the player can. To find *pokemons* the player has to physically move around until it founds a *pokemon* to catch. After finding one, the player proceeds do capture it, which involves throwing a *pokeball* against the *pokemon*.

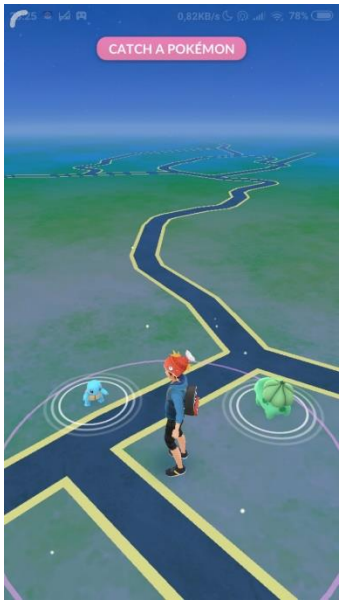


Figure 2.13: In-game screenshot of the map in *Pokemon Go*

The reason *Pokemon Go* is similar to *Ingress Prime* because it has similar gameplay, like *poketstops* that are points of artistic and historical value, just like *portals* in *Ingress Prime*, having the player position being detected using GPS, requiring the player to move in the real world to progress the game and having factions as an in-game feature, thus having similar effects like *Ingress Prime* has.

Pokemon Go may also be considered an evolution of *Ingress Prime* because the introduction of AR in the gameplay, according to Samji [Sam18], gave players high levels of immersion and presence. In AR mode, the *pokemon* shows through the camera, as it was in front of the player. There is also an AR+ mode, where the *pokemon* is displayed in the ground, at a fixed point in the real-world environment. In this mode, the *pokemon* is aware of the distance the player is from the *pokemon* position in the real world, and if the player gets too close, the *pokemon* disappears, thus making this mode even more realistic and immersive.

Figure 2.14: *Pokemon Go* AR+ mode [Pok17]

Father.IO is another example of the increasing popularity in AR games with its funding surpassing 640% of the goal on Indiegogo, making it an impressive $484,611 raised by the community backers[13]. The game currently has two game modes: FPS and Tactical Map.

In FPS mode, the player enters a PVP battle where the objective is to eliminate his enemies. The camera together with *The Inceptor* act as the weapon.

Figure 2.15: Screenshot from video showing *Father.IO* FPS mode

[13] father.io: Massive Multiplayer Laser Tag. https://www.indiegogo.com/projects/father-io-massive-multiplayer-laser-tag#/ (last access 2019)

The Inceptor is an infrared accessory, which has an extra cost that could be a negative aspect for some players.

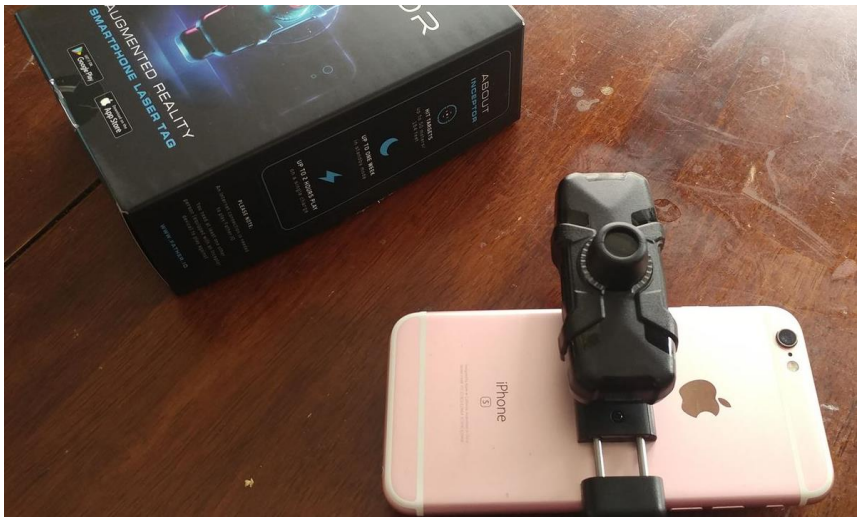


Figure 2.16: Picture of *The Inceptor* attached to an iPhone

To counter this requirement, the Tactical Map mode was created. This game mode has the player move around the city in a similar way to *Pokemon Go* and *Ingress Prime*, tracking your location via GPS, to capture *zones*. These *zones* are areas of the city that when captured, generate in-game resources. Some of those areas have points of interests like restaurants, historical landmarks and buildings of importance to the region, that increase the amount of in-game resources generated in a *zone*.

Figure 2.17: Ingame screenshot of *Father.IO* Tactical Map mode

The common ground around the games referred in this section is that they are designed to make the player cooperate, creating a more social experience, and that the use of location based

systems promotes the exploration and interaction with the regions around the player. These are objectives to have, as stated before, when creating an application with the purpose of promoting outdoor interaction and tourism applications, on which the study case "Parque Biológico de Gaia" fits well.

According to Kysela [Kys15], AR is a new technology which offers effective and attractive ways to educate with the possibility to interact with environment and user, thus not retaining the full attention of the user, which makes it a good complementing way to enhance the experience and immersion.

2.4. Game Design and User Engagement

Developing an engaging game is a key challenge on the core of game design, which can become even more complex when having pedagogical objectives as a focus [Söb17].

When considering building AR games for mobile devices, it has to be considered that the technological aspects can be overwhelming to first-time players [Wet11].

In Erenli [Ere13] work, it is shown that is possible to develop games for educational purposes, but educators have to collaborate with experienced people in-game design, so the game doesn't become boring to the player, thus failing its mission of engaging and making a fun learning environment.

According to Jesse Schell [Sch08], the game designer must know what their audience will and will not like. He says that all individuals are unique but can be grouped by using demographics, on which the most important for game designers, are the ones that are based on age and gender. He also points out that external factors should be considered. In the case of study of this thesis, the outdoor environment on which the application will be trying to enhance should be considered in the experience.

Jesse Schell [Sch08] and Kiili [Kii12], in their work, both state the importance of the state of "flow", in which the player is focused, interested, engaged and enjoying the experience. Kiili [Kii12] points out that the flow has an important role in the pedagogical objectives of educational games.

Both of them state that to put a player into a flow state the activity in hand has to follow four key components:

- **Clear goals** – With clear goals, the player knows that his actions are useful or not and he is able to be more easily focused.
- **No distractions** – Distractions directs the focus out of the activity.
- **Direct feedback** – If the feedback takes a long time, the player will lose focus on the activity and can feel that his actions aren't important, distracting him from the task.
- **Continuously challenging** – The challenge must be achievable, but at the same time not too easy. If the challenge is hard, the player will feel frustrated, if the challenge is very easy, the player will feel bored.

Jesse Schell [Sch08], states that anxiety and boredom aren't positive experiences and that to combat those states the challenges should be attached to progression, for example, starting with low difficulty challenges (A_1) that would progress as the same speed the player learns and adapts to the game, so that if the task starts to be too easy (A_2), a harder challenge is presented thus moving the player from the boredom state to the flow state, and never letting him reach a state of anxiety (A_3).

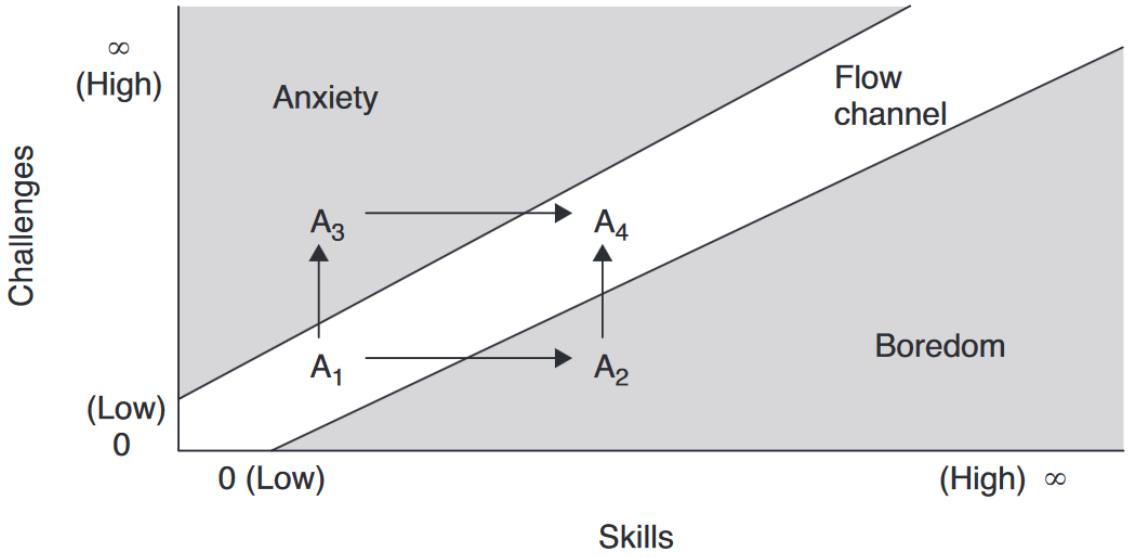


Figure 2.18: Visualization of the flow state [Sch08]

When designing games with learning as a focus, there are more components that have importance for the pedagogical aspect of the game. According to Perrotta [Per13], the best way to integrate gaming with teaching is as follows:

- "Place learning activities and academic content within the video game's fictional and entertainment context, maintaining a balance between fun and learning" [Per13];
- "Make the academic content integral to the game rather than an add-on. Content-specific tasks work better when embedded in the fictional context and rules ('mechanics') of the game" [Per13];
- "Carefully plan the roles that you and your learners will take on in the game. Teachers should play roles that allow them to mediate the experience for learners: providing guidance when needed; ensuring that rules are followed; and maintaining a respectful atmosphere" [Per13];
- "Don't try to divorce decontextualized components of a game (such as badges, scores or leaderboards) from the fictional context and rules of the game (the 'mechanics')" [Per13].

Gunter [Gun06], brings attention to the importance of focusing on the context and didactic goals. He cites the Multivalent Model of Interactivity, which are: "Cognitive Interactivity (the

psychological, emotional, and intellectual engagement of the player), Functional Interactivity (the structural interactions with material components of the system), Explicit Interactivity (participation with designed choices), and Beyond-the-Object Interactivity, (the participation in the culture of the game outside the direct experience of gameplay)" [Gun06]. According to Gunter [Gun06], although entertainment games can be successful targeting the last three referred models, serious games requires the design to support "Cognitive Interactivity", as this is the model that allows the pedagogic aspect of the game to succeed in its knowledge dissemination objective.

More considerations should be taken when the objective is to develop an AR game for mobile devices. These types of games are not confined in the user screen and depend heavily on the user movements, both the rotation and positioning of the device [Wet11].

There are also limitations that can affect usability and turn into issues affecting the user experience.

Tsai [Tsa16], states some problems like small device displays can become an issue, so in order to prevent issues that can affect usability in AR application for smartphones, he points out five usability principles, which are:

- **User-information** - The application needs to provide clear and suitable visually information;
- **User-cognition** – The application needs to allow users to learn the application easily and minimize users' use of memory, creating expected and recognizable actions;
- **User-support** – Useful information should be provided by the application to help users and error messages should be minimized;
- **User-interaction** – The application should provide feedback with minimum manipulation;
- **User-usage** – The operations and manipulations of the application should be focused on the usage of the AR experience and allow a certain degree of freedom.

AR games that have a strong location-based component should attend principles that are aimed for those types of games.

In Ardito's [Ard10] stated design guidelines for location-based games for learning, the common principles, like focusing in engagement, allow the game to be easy to learn. In these principles, Ardito reiterates guidelines already described and adds to them with important new guidelines.

For the learning aspects, Ardito states:

- "Consider to include a pre-game activity to prepare players" [Ard10];
- "Tasks should require players to link areas, locations, physical objects to concepts, topics, etc" [Ard10];
- "Include a debriefing phase after the game to allow players to reflect on the game experience. Design it as an individual/collaborative game/activity that supports players to clarify and consolidate the game experience" [Ard10].

Ardito [Ard10] also encourages the presence of social aspects in this type of games, and for those aspects, he recommends the following:

- "Team players (if any) should be selected based on players' social relations (e.g. friends to maximize collaboration) or according to their skills. Involve in this process a person that knows them very well (e.g. a teacher)" [Ard10];
- "Assign responsibilities and tools (e.g. mobile devices, maps, etc.) among team members to induce collaboration. Consider to force, forbid or allow responsibilities exchange among team members" [Ard10];
- "Consider to permit, force or neglect the competition among players/teams" [Ard10].

2.5. Informative Augmented Reality Applications

Augmented Reality has many uses but is limited by its numerous issues. According to Zendjebil [Zen08] the errors associated with sensors, mainly GPS, accelerometers, gyroscopes, in conjunction with an unknown environment, originates problems on the representation of the virtual object in relation to the physical world. He also mentions that the limited computational power, storage and limited interface capability in devices like smartphones, introduces challenges that can affect the user experience.

The existence of these limitations doesn't seem to stop creative developers who take advantage of AR capabilities to improve the dissemination of knowledge in ways never done before.

After several earthquakes that affected the city of Christchurch in New Zealand, destroying important historical landmarks, the search for solutions to revive those destructed buildings led to the creation of *CityViewAR* [Lee12].

This smartphone application, designed for outdoor AR, provides geographical information, with texts and images, related to landmarks.

It contains a map on which the user can see its GPS acquired position, showing the nearby points of interest. The user can then select those POI to see more information about them, or physically move to their location and use the AR view to see the reconstructed buildings in a digital environment overlaid, through the smartphone screen, on the physical world.

Figure 2.19: Visualizing a destructed building in *CityViewAR* AR View [Lee12]

Figure 2.20: *CityViewAR* map [Lee12]

In the AR view, there is also a *timeline* option, which users can use to see how that particular location changed with time. This way it is possible for the population and tourists to continue experiencing the cultural heritage lost in environmental disasters, like the one that happened in Christchurch.

The ability to use AR as a means to propagate knowledge can take many shapes which are determined by the focus of creative designers.

Skin & Bones is another smartphone AR application that communicates scientific knowledge to the visitors of the Bone Hall at the Smithsonian's National Museum of Natural History. In the application the user can select the animal they are interested in from the map of the hall, which will present a menu of "immersive audiovisual experiences, including videos, animations and activities" [Lay15].

There is also an AR mode that when selected, the user can point the device camera to the skeletons which would trigger an overlay of the animal in 3D graphics, animated or static, that,

in conjunction with sound effects, creates a representation of the external anatomy of the animal, and highlights particularities of functional anatomy [Mar15].

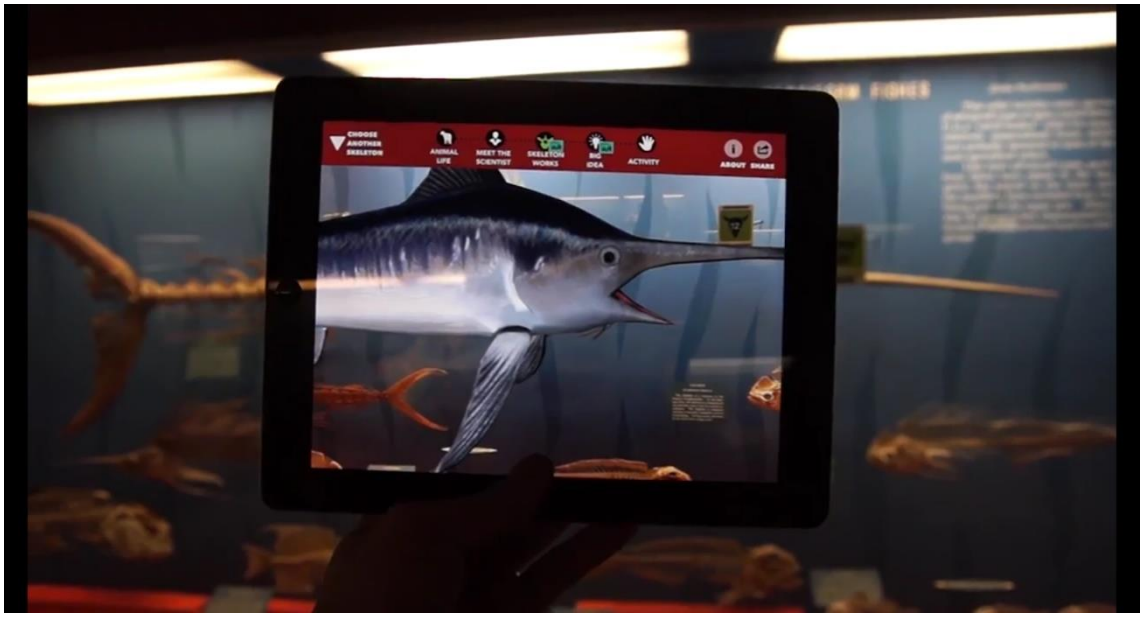


Figure 2.21: Screenshot of video showing AR mode of *Skin & Bones*

According to Marques [Mar15], in the year of 2015, a study was conducted to evaluate the users' experience with *Skin & Bones*, where willing participants were selected among visitors that entered the exhibit. The results showed [Mar15] that there was an unanimous positive reaction on the value of the application with even some participants stating that, the recontextualization that the AR mode provided helped better understand and retain the information provided in the audio-visual interaction.

2.6. Summary

Serious games are an effective and adaptative pedagogic tool which motivates and engages the learner in the educational context. This is done by giving the player an interactive set where he can test and put in practice the knowledge that the educator is fostering.

These games can be enriched with the introduction of new technologies such as Augmented Reality and location-based systems.

Augmented Reality is a good tool to introduce information about the physical world, in an interactive and helpful way, as seen with the examples of *CityViewAR* and *Skin & Bones* which successfully achieve their purpose of informing about their respective subjects.

Location-based games can be used as a way to make the player navigate between different landmarks and introduce cooperation in the activities, which, as pointed in the start of this chapter, is essential for tourism-oriented applications.

These location-based games that track and involve the location of the player in the gameplay, when combined with Augmented Reality elements create great immersive and entertainment games, like the example of the very popular game *Pokemon Go*.

It is also stated the importance of the design process that can work well on an application, or not at all. When designing a tourism-oriented application, the designer has to develop the application in a way that can guide the visitor through an unknown environment. More considerations should be taken if the application involves Augmented Reality as this technology can be overwhelming for new users or distract from the task in hand.

In the serious games' design, it is important to relate the educational content with the gameplay or the game may lose its effectiveness as a pedagogical tool.

The conjuncture of all these mentioned aspects, support the possibility for the creation and development of a successful application in the scope of this dissertation.

Chapter 3

Outdoor Park Exploration Solution

The purpose of this chapter is to detail the proposed solution, which was implemented and resulted in a mobile application made for the nature park "Parque Biológico de Gaia".

This chapter starts by presenting the application requirements in section **3.1**. Section **3.2** then follows with the purpose of detailing and explaining the application design and how it works. It covers the principles needed to create an application with good usability and the focus which directed the application development.

For each isolated activity that forms this application, a subsection, namely subsection **3.2.1** for the *Map*, subsection **3.2.2** for the *Collectables*, subsection **3.2.3** for *Vida no Muro* and subsection **3.2.4** for *Rapinas AR*, goes further in detail about how they work, their design and mechanics, with further information about the implementation of these activities being detailed in chapter **4**.

3.1. Requirements

This application was developed with the nature park "Parque Biológico de Gaia", in Vila Nova de Gaia, Portugal as its case study. With an extensive area populated with numerous species of animals and plants living in a wild state, the park presents itself as having good potential for the creation of a location-based game.

To create a bigger connection between the park and the user, Augmented Reality can be used to create new experiences and enhance the user's visit of the park, by binding digital information with the real world.

Thought the possibilities in the design of new experiences, by combining these two concepts of having location-based activities with Augmented Reality elements, are immense, the park's type of visitors is very broad and can be considered as general public. Thus, the design of the application must be simple to use and understand.

Having a long circuit to explore (3 kilometres in length), led to the need of creating an objective that would unify all the application activities, while at the same time not deviating from the application objective of further teaching about the park's extensive fauna and flora.

Considering all of these objectives, to guide the development of the prototype, the following user and system requirements were defined.

3.1.1 User Requirements

These main user requirements were specified based on the related work researched (chapter **2**), in order to guide the development and design of the prototype. They are the following:

Map – The user must be able to view and interact with the map of the park.

Localization – The user must be able to localize itself in the park in the map using the GPS.

Information – The user must be able to access the information available on the application online or offline and with no need to be present in the park.

Games – The user must be able to play games with AR elements and based on the device localization systems.

Rewards – The user must be able to unlock rewards by playing the application games.

Progression – The user must be able to store and retrieve his progress online or offline and with no need to be present in the park.

Compatibility – The user must be able to use the application in smartphones that have a camera and GPS.

Following these requirements, it ensures the application integrates the basic features necessary to achieve the application objective.

3.1.2 System Requirements

To the development and implementation of an efficient prototype, the following system requirements were defined:

Battery – The application must use the minimum battery needed to run.

Efficiency – The application must respond to the user interaction with minimum delay possible and using the minimum system resources it needs to operate.

Usability – The application must be easy to use and understand to the general public.

Availability – The application must be deployable, at least, in smartphones running Android that have a camera and GPS.

Read device data – The application must be able to read data from the device vital for its operation, namely: touch screen input, GPS, gyroscope, accelerometers and the camera.

Save/Retrieve progression – The application must be able to store and retrieve relevant data to a database.

Being that this prototype is developed for Android, consideration about the battery drain is important. To reduce battery use, the device needs to be efficient, using the minimum resources it can possibly use while still maintaining the desired behaviour. Following these system

requirements, allow for a better planning on the implementation of the prototype, thus leading to the development of an efficient prototype.

3.2. Designing the application

To design a good application, some usability principles should be followed. These can be resumed in the following [Usa05]:

- **Usefulness –** The system should provide necessary utilities and address the real needs of the users. The information and functions provided should be relevant to the user's task and context;
- **Consistency –** Appropriate standards and conventions for the platform and the type of product should be followed. Actions, terminology and commands should be used consistently and be presented in a way that can be commonly understood. Examples of that are using terms, metaphors and following real-world conventions (when it seems appropriate), showing the information in a natural and logical order;
- **Simplicity –** The system should be simple, with the most commonly used options visible and easily accessible. It must be designed in a way that a user, with no prior experience with the system, can use it without instructions;
- **Communication –** User's actions should be provided with appropriate, clear and timely feedback with the result of said action, so that they know what is going on with the system and don't feel lost. The system should also be constructed in a structured and sequenced manner, by grouping related things together and sequencing the actions with a beginning, middle and end. By doing this, it ensures the users don't feel lost, allowing them to know when they are done and gives them the satisfaction of accomplishment. Help and documentation, with clear, concise and focused instructions, should also be available and easily accessible;
- **Error Prevention and Handling –** The system should be designed in a way that prevents the user from making serious errors. When errors or warnings are presented, they should be clear and simple messages, describing the problem and its solution. There should also be available the option to redo/undo/exit an unwanted action. With this ability to reverse actions, it relieves the user's anxiety and encourages them to explore unfamiliar options and actions;
- **Efficiency –** The system should not hold back experienced users and should be designed in a way that make the user the initiator of actions, with the information accessible in a fast manner;
- **Workload Reduction –** What can be automated in the system, should be automated. The application should encourage recognition rather than recall, reduce complex actions and reduce uncertainty.

As the application contains gaming elements, to enrich those type of experiences, they should contain *Juice*. This term *Juice*, is a term used in the game development world which

consists of using animations, transitions, effects and other types of tricks to improve the experience, attractiveness and the game feel of a game, as according to Gray [Gra05], "a juicy game feels alive and responds to everything you do (…) it makes the player feel powerful and in control of the world, and it coaches them through the rules of the game by constantly letting them know on a per-interaction basis how they are doing."

Other consideration that was taken when designing the application, was that it should help and guide new visitors. Not familiar with the park, these users need an easy and accessible way to quickly learn and locate what the park has to offer. Therefore, the need for a map that can act as a guide and inform the visitor about what the park has to offer was introduced.

Following the stated requirements and usability principles as a guide, trying to design an application that can complement the park information and improve the visitors' experience while at the same time disseminate scientific knowledge about the park's fauna and flora. This led to the design of a prototype, which consists of an application for Android that has the user collect virtual representations of the park's species and information about them, as its main objective. In order to accomplish this objective, the user has to perform the activities and play the minigames that are available in specific locations of the park. These different activities can only be initiated when the user is physically located in the area that triggers those respective experiences. Currently, there are two Augmented Reality activities developed, namely *Vida no Muro* and *Rapinas AR*.

The first thing the user sees when the application starts, is the map. At this point, the user has access to a lot of information about the park, including the activities *Vida no Muro* and *Rapinas AR*.

As the collectables are the centre part of the application, application's flow was designed with its accessibility in mind, thus the user can see the information about the collectables from any activity in the application, as shown in Figure **3.1**.

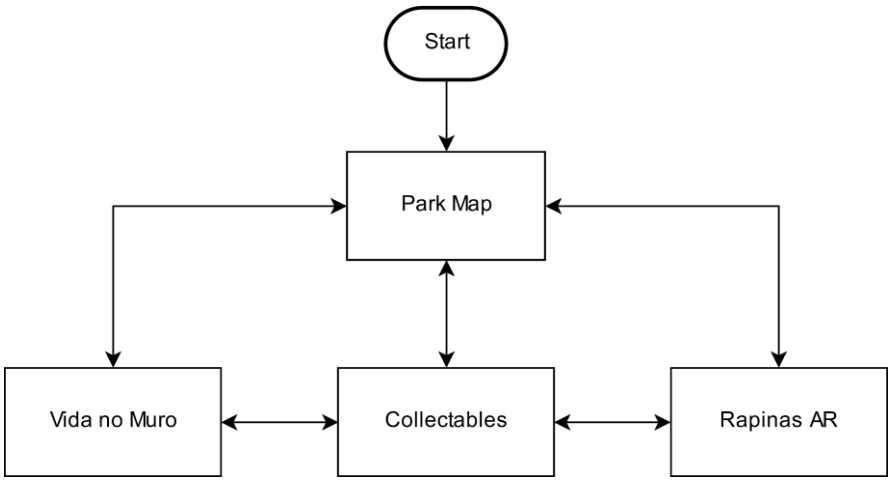


Figure 3.1: Application's main flow

To ensure the simplicity and consistency of the application user interface, the buttons location in the screen were strategically placed as follows:

- **A –** General application actions, such as opening the help panel, accessing the *Collectables* and closing the opened screens, in the top right corner of the screen;
- **B –** Specific activity options in the screen's top left corner;
- **C –** Specific activity actions in the bottom centre of the screen.

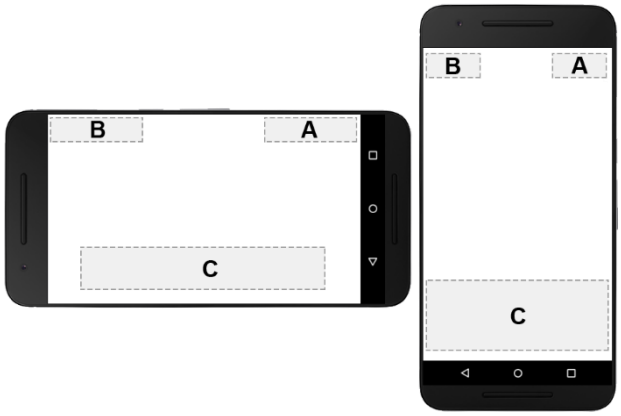


Figure 3.2: Layout for the buttons, in landscape and portrait mode

All the buttons are made of images that follow real-world conventions and represent their respective actions. Their colours were also purposely chosen to have high contrast with the rest of the screen, thus being highly visible for the user.

As the general application actions buttons (**A**) are commonly used across all the application, their order is also maintained throughout the application, improving the efficiency of the user interaction with the application. The order of the buttons, from the right to the left of the screen, is as follows: exit button, collectables button, help button.

When a resource can take too long to load, such as loading *Vida no Muro* or *Rapinas AR*, an animated loading screen is presented. This loading screen is essential so that the user doesn't feel confused about the state of the application. It communicates to the user that everything is working correctly. Using a loading screen with a fast animation instead of a static image, according to Khagawal [Kha17], will psychologically make the user think data is getting loaded faster and makes them have more patience, thus contributing for good user experience.

3.2.1 Park Map

This stylized map is the starting point of the application. The choice to use the stylized map, instead of satellite view of the circuit, or a more accurate representation of the park's circuit is that this stylized map, shown in Figure **3.3**, does a good job highlighting the park's point of interest and it is the same map used in the park's signs scattered along its circuit, thus using the same map, avoids disconnecting the user from the park.

Figure 3.3: Park's stylized map

From here, the user can locate himself by seeing where the icon, representing his location, shown by Figure **3.4**, is on the map. The user can also use the blue field of view representation that this icon also shows, to orient oneself in the right direction the user intends to move.

Figure 3.4: User's location icon and its blue field of view

The map also has points of interest, represented by green points with letters or numbers, shown in Figure **3.5**, in which the user can tap to see more information about them. This information is displayed with an animated pop-up, as other informational pop-ups, thus the introduction of *Juice*, making the interaction more appealing to the user.

Figure 3.5: Example of point of interest in the map and its displayed information when interacted with

One important feature that was added to the application map was the ability to record the path taken by the user. By recording the path taken and showing it to the user, he can know in a future visit to the park, how much of the park's circuit he already completed and in which paths and points of interest s/he already visited. This recorded path is shown to the user in the map with an orange dashed line, as seen in Figure **3.6**.

Figure 3.6: Dashed line representing the path made by the user

Having location-based activities, they are also shown in the application's map with their own representative icons, as shown in Figure **3.7**. When the user is outside the trigger area, their icons are coloured in grayscale and when the user interacts with those icons in that state, an animated pop-up informs the user that they need to be in the activity area to start it. When the user is in the activity trigger area, the icon turns white with an animated colourful outline and when the user interacts with the icon in this state, the correspondent activity starts.

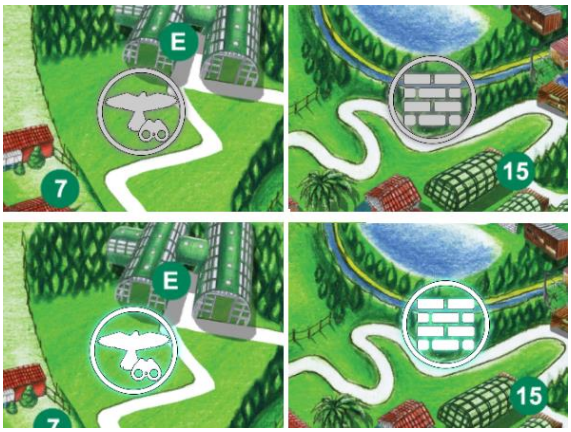


Figure 3.7: *Vida no Muro* and *Rapinas AR* icons, in the application's map, when the user isn't in the trigger area and when the user is in the trigger area

On the top right corner of the screen, the user can see the help button that, when interacted with, will show helpful information on how the to use the map, as shown in Figure **3.8**. In the same corner, there is also the *Collectables* button, which will start the *Collectables* if the user interacts with this button.

Figure 3.8: Map's help information

In Figure **3.9**, a more detailed representation of the application's map flow is shown.

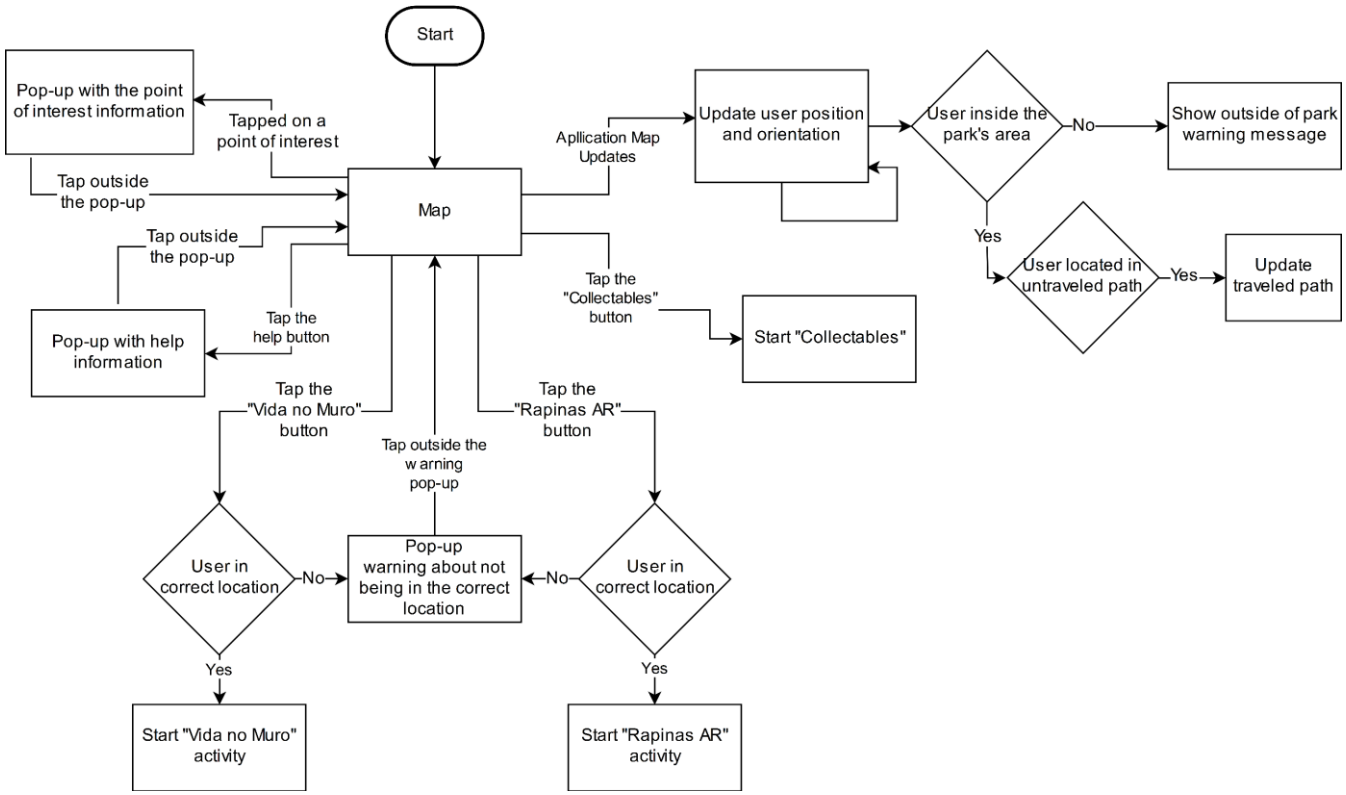


Figure 3.9: Application's map flow

3.2.2 Collectables

In this part of the application, the user can see his/hers collectables. These collectables are unlocked when the user interacts with the species that appear in the application's Augmented Reality activities.

Each of these collectables is related to a particular specie that lives and can be found in the park. After unlocking them, the user can interact with the collectable and learn more information about the unlocked species.

To access the *Collectables*, the user must interact with the button representing this scene, shown in Figure **3.10**.

Figure 3.10: *Collectables* icon

From here, as shown in Figure **3.11**, the user has access to his collectable species and see what species were already discovered and how many are still yet to be discovered.

Figure 3.11: *Collectables* scene with three discovered species

As shown in Figure **3.11**, the unlocked species are represented with their representative image and scientific name. When the user interacts with an unlocked collectable species, it will be shown that species information, as shown in Figure **3.12**.

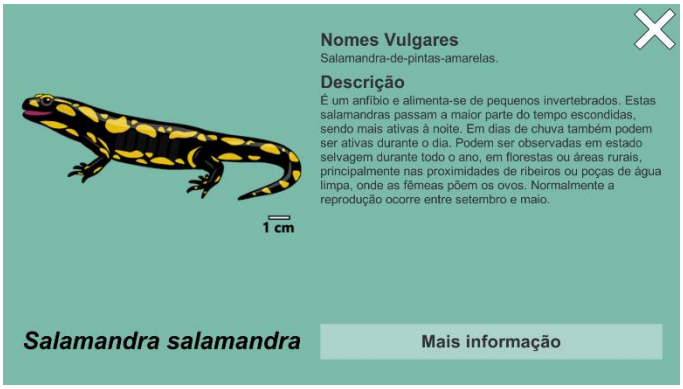


Figure 3.12: *Salamandra salamndra* species information

Some species have more information than others, but the presented information layout is always the same, with, on the left side of the screen, the species image with a scale to better inform the user about the species' dimensions and its scientific name in the bottom of said image. On the right of the screen, more details about the species. All the species have the same basic information shown on the right of the screen, that being common names and description, with a button on the bottom right side of the screen that leads the park's website page about that specie. Some species have more information, such as birds of prey, which have additional information, like their conservation status and curiosities.

The yet to discover species, as it can also be seen in Figure **3.11**, are shown with an image of a question mark, with three question marks as its name. As the collectables are categorized by activity and type of species, it makes it easier for the user to know where to look for them and what type of species he should be looking for.

To add a new species to its collection, the user needs to simply interact with the species when he finds it in throughout the *Vida no Muro* and *Rapinas AR* activities. When that happens, a yellow notification icon, with an unlocked padlock, as shown in Figure **3.13**, appears with a pulsing animation. This kind of notification, as it has *Juice* elements, grabs the attention for the *Collectables*, and isn't intrusive enough to interrupt the user actions in the *Vida no Muro* or *Rapinas AR* activities.

Figure 3.13: *Collectables* icon with a notification representing that some collectable species were unlocked

In Figure **3.14**, a more detailed representation of the *Collectables* flow is shown.

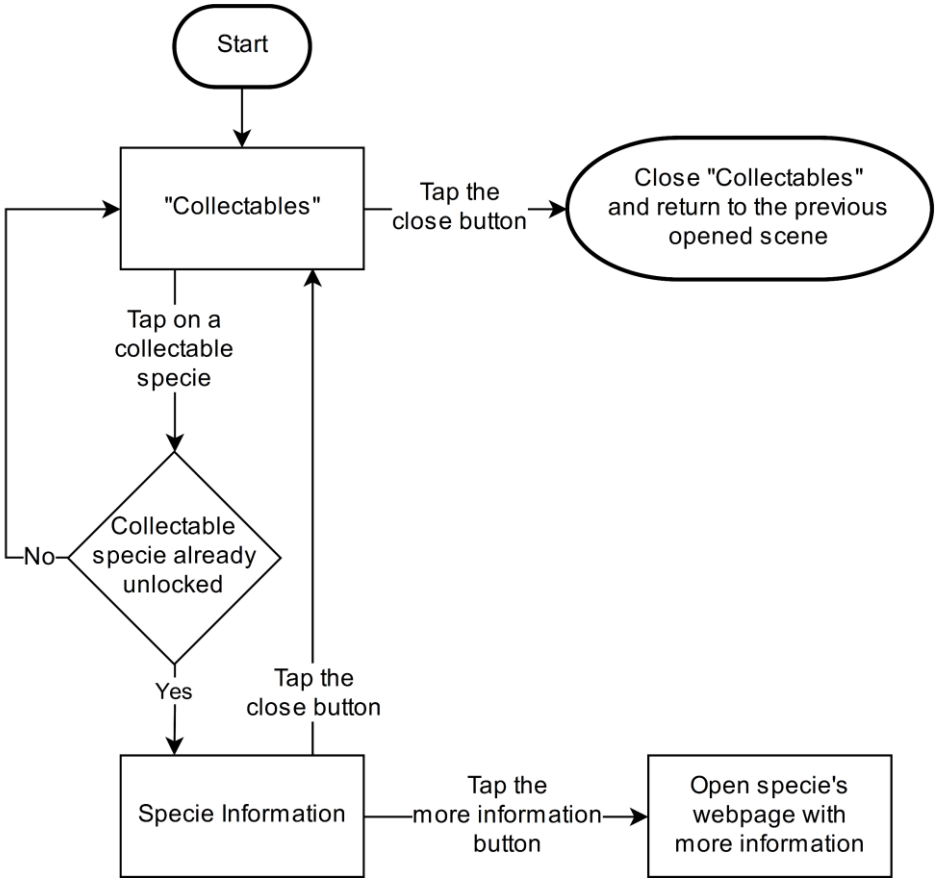


Figure 3.14: *Collectables* flow

3.2.3 "Vida no Muro"

In this activity, the user has to scan the wall in the park which will then show, through the camera's device, the species living in the wall, as shown in Figure **3.15**.

Figure 3.15: *Vida no Muro* wall with scan done, showing day species

These species are augmented digital representations of the real species, that the user can interact with, discovering more information about them and adding them to the user collection. They are shown at scale, like they are part of the wall, so the user can manipulate his device by moving it, rotating it and reducing the device's distance to the wall, to see the species at a closer distance, or increasing the device's distance to have a broader field of view to more easily search for other species in that wall.

When the user interacts with the augmented species of the wall, by taping in them through the screen, that species' information is shown to the user, and, if one of those species isn't already discovered, it is unlocked and added to the user collectables.

To start this activity, the user needs to be in the location show in Figure **3.16** and interact with the *Vida no Muro* icon, shown in Figure **3.7**.

Figure 3.16: *Vida no Muro* location in the illustrative map on the left, and a photo of the location in the park

When it starts the user is presented with an instructions screen, as shown in Figure **3.17**, which then the user can see what the activity consist and how it works. This instructions screen

can be accessed again in this activity when the user interacts with the help icon in the top right corner of the screen.

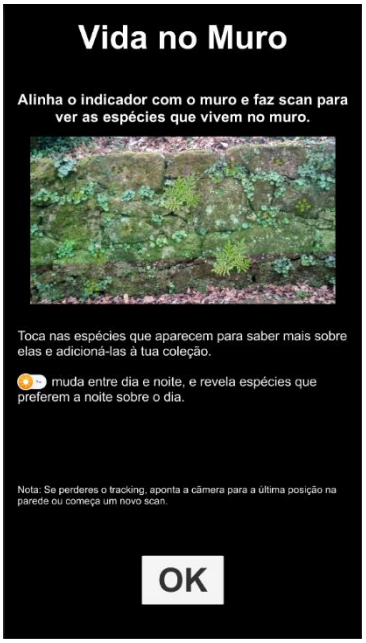


Figure 3.17: *Vida no Muro* instructions screen

The user then taps on the "OK" button to close the instructions screen and start the scan process.

In this stage, it is shown an aligner with helpful text detailing which side should be aligned with the top and the bottom of the wall. The user then aligns the top and bottom of the wall with the aligner and press the scan button, which takes the whole screen. The augmented species will then be shown through the phone camera, in the wall.

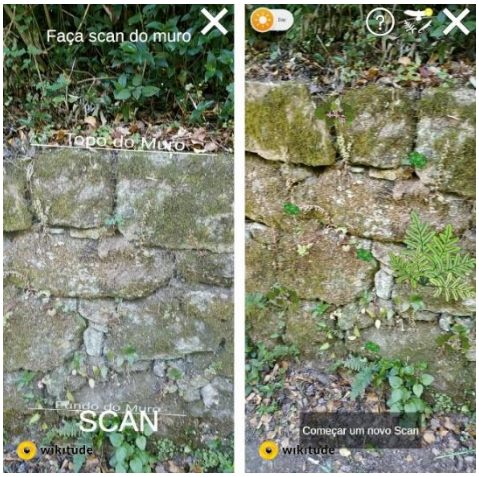


Figure 3.18: *Vida no Muro* screenshots of the scan process and the result of the scan

There are species that only appear in the wall at night, so *Vida no Muro* has a button, in the top left corner of the screen, than can toggle the scene between day and night mode. Toggling

between day and night mode, the user can see different species, thus learning about their behaviours and when it's the best time to spot those species in the park's wall.

To make the scene feel more alive, *Juice* was introduced to species like *the Luciola lusitanica*. This augmented firefly can be seen when the night mode is activated, and acts like a real firefly, flying around the wall with a pulsating light. There is also a scan effect animation that is being shown during the augmentation of the wall, so that the user can know that the augmentation is still running, working properly, and show the area where it is probable to see the augmented species.

Figure 3.19: *Vida no Muro* night mode with a glowing firefly in screen

To better guide the user and avoid the user feeling lost, warning messages are shown to the user when the tracking is lost and when the user is not turned to the wall.

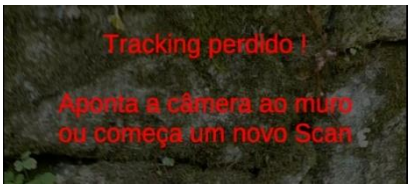


Figure 3.20: *Vida no Muro* screenshot of the tracking lost warning message

During the scan, the user also has access to a button, at the bottom centre of the screen, that triggers a new scan process. This allows the user to rescan the wall at will.

In Figure **3.21**, there is the detailed flow of the *Vida no Muro*.

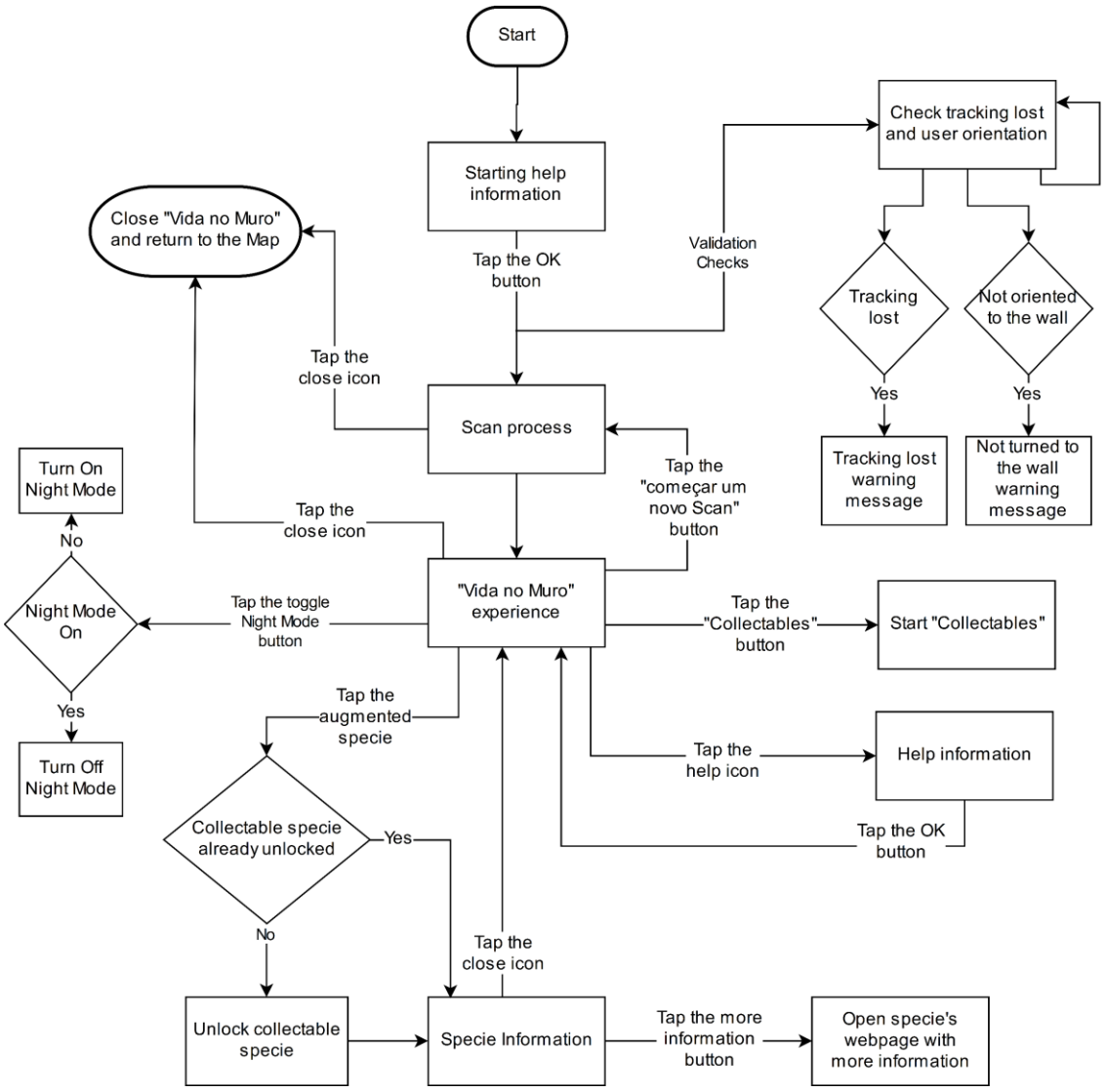


Figure 3.21: *Vida no Muro* flow

3.2.4 “Rapinas AR”

This minigame engages the user to search for augmented birds of prey with the user’s device camera and correctly guess the species’ name. The objective is to, in 60 seconds, accumulate the highest score possible.

The score is determined by the answers given by the user, if the user correctly guesses the species’ name, he gains points, if the answer give is wrong, points are decremented. The number of points added/subtracted is based on the difficulty of the bird and its distance to the user, more details about how the points are calculated are shown in chapter **4**.

Figure 3.22: *Rapinas AR* in-game screenshot

To access this minigame, the user must be in the location, shown in Figure **3.23**, and through the application map tap the *Rapinas AR* icon.

Figure 3.23: *Rapinas AR* trigger location in the illustrative map on the left, and a photo of the location in the park

It will start by showing the instructions screen of the *Rapinas AR*, which is closed when the user interacts with the “OK” button. This screen can be accessed again if the user interacts with the help icon on the top right corner of the screen.

Figure 3.24: *Rapinas AR* instructions screen

After closing the instructions screen, the game will start a countdown, which gives time for the user to be prepared to the start of the game.

When the countdown ends, birds of prey will randomly spawn and fly around the player. Green arrows indicators are shown in the edge of the screen to guide the player, to point the camera to the birds that are offscreen.

If a player sees a bird, he then has to tap on the bird through the device's screen. This will select the bird and make three buttons with the answers show up in an animated pop-up.

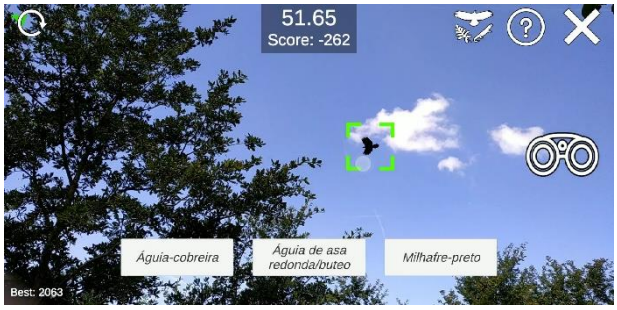


Figure 3.25: *Rapinas AR* in-game screenshot with a selected bird

The player then selects the answer which s/he thinks is the correct one, and an animated pop-up with a green correct mark, or a red cross, will show up, depending on if the answer is correct or not. The score, shown at the top centre of the screen, below the timer, is also updated with each answer given.

As the difficulty is in differentiating the birds, by their silhouette, to make it easier to observe those differences, the player has the option to use the "binoculars". This option is activated if the player interacts with the "binoculars" icon that is located in the centre right side of the screen. When activated, it will zoom in, acting like real binoculars, and makes it easier for the player to see the bird's unique attributes that differentiate them from other birds.

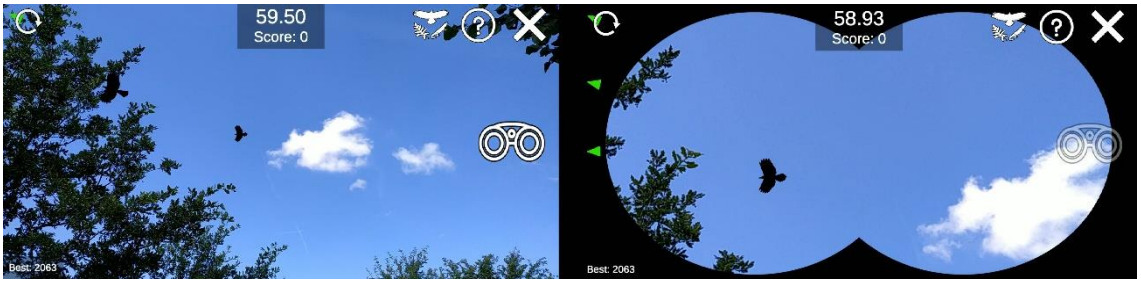


Figure 3.26: *Rapinas AR* in-game screenshot comparison of using the "binoculars" and not using "binoculars"

When the player first selects a bird, it will be immediately unlocked and added to the player collectables. The player then can access the *Collectables* and view more information about the newly discovered bird and learn how we can differentiate it from other birds of prey. Accessing the *Collectables* in the middle of a game will pause the gameplay, so the player doesn't have the pressure of viewing the bird's information and learning more about them.

Another gameplay feature implemented to make the player quickly distinguish the birds of prey is mixing the possible answers every time the player selects a bird, this way at the cost of losing time, the user can repeatedly select and deselect the same bird, constantly showing a new mix of answers. By doing this, the user can spot the answer that is always showing, thus realizing that it is the correct answer and associating the name of the bird to its silhouette without having to go to the *Collectables* to have access to that information.

At the end of the 60 seconds, the end game screen appears with the score the player made and his highest score. From this screen, the player can then, play another round, access the *Collectables* or exit the minigame.

Figure 3.27: *Rapinas AR* endgame screen "saying Times' up!"

The minigame also registers the highest score, as according to Fratteso [Fra11], encourages replayability, thus more engagement in the game and probably leading to the player better associate the birds' silhouettes and its distinguishable features, to the respective birds.

In Figure **3.28**, the flow of the *Rapinas AR* is presented in a more detailed manner.

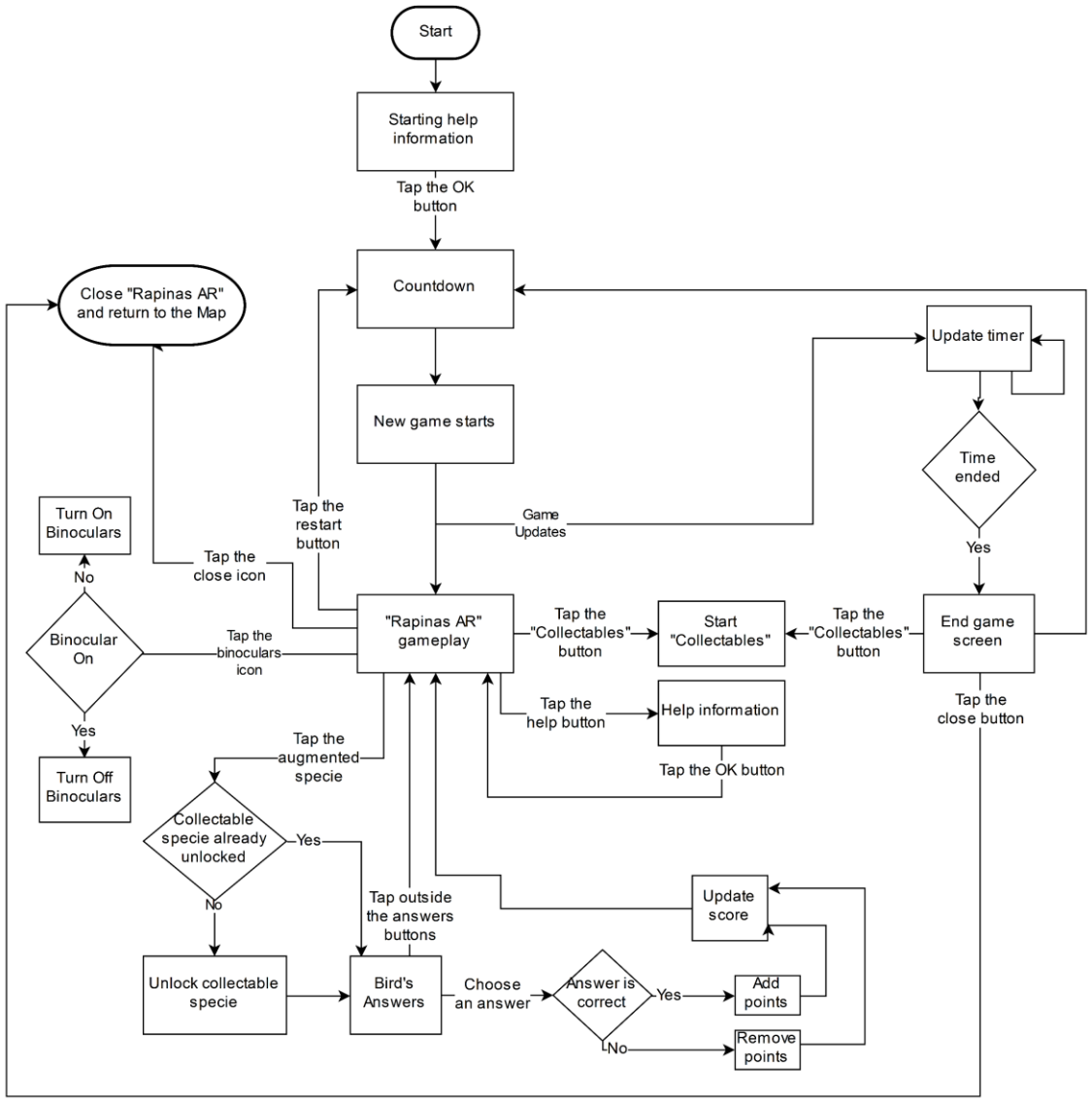


Figure 3.28: *Rapinas AR* flow

3.3. Summary

This chapter started by presenting the requirements that would lead to the design choices done through the development of the prototype. It then details how the application is designed, describing for each of the application's section, how it works, its design choice and considerations taken to improve its use.

The following chapter will go in more detail about the technical aspects of the application, its structure and how it was implemented.

Chapter 4

Implementation

In this chapter, the development and implementation of the application will be reported in more detail. It starts with section 4.1, which present the tools and technologies used and why they were chosen for the development of the prototype. It also goes in more detail on how the application is structured in scenes and then goes in more detail about the implementation of each of those scenes, namely, "Preload Scene" in section **4.2**, "Park Map Scene" in section **4.3**, "Collectables Scene" in section **4.4** , "Vida no Muro Scene" in section **4.5** and the "Rapinas AR Scene" in section **4.6**.

4.1. Development tools and Technologies

The application was developed using the *Unity*[14] game engine. This game engine can be used to create 2D, 3D, virtual and augmented reality applications, simulations and many more types of experiences. All of which can be built to a very broad range of platforms and devices screen types, using only one code base.

A *Unity* application is made of scenes, on which these scenes are composed of *gameobjects*, controlled by components and scripts. These components and scripts are what determine the objects' behaviours, thus as *Unity* already is bundled with a broad range of these components and scripts, that covers a lot of common problems when developing applications or games. Example of that is the *Animator* component which allowed the development and use of animations without needing to use third party solutions, minimizing dependency and conflict problems, thus allowing the development to be more focused in design and implementation of application features.

This game engine also supports the use of prefabs and prefabs variables. Prefabs are *gameobjects* that can be instantiated at runtime. They are useful to encapsulate a set of behaviours in an entity that can be used at any given time. Prefabs variants ingrate the prefabs set of

[14] Unity, https://unity.com/ (last access 2019)

behaviours and can be customized to serve its own needs. This workflow allowed the addition of multiple species in the *Vida no Muro* and *Rapinas AR* that have similar behaviours. It also allowed fixing their behaviours, by just editing the master prefab, thus minimizing the probability of issues and time consumed editing each *gameobject*.

The developed prototype has 5 scenes, each made with its own objective. These scenes are the following:

- **Preload Scene –** Handles the setup of all the application;
- **Park Map Scene –** It is responsible for showing the park's map and all its related behaviour, such as handling the user's location and orientation;
- **Collectables Scene –** Allows viewing the collectable's information, as their own state on the application;
- **Vida no Muro Scene –** Handles the *Vida no Mur*o activity;
- **Rapinas AR Scene –** Handles the *Rapinas AR* minigame.

Each scene also has its own manager, which handles each of its own scene behaviours internally. There is a singleton[15] *GameManager* that handles all the behaviours common throughout all the application.

The following Figure shows the flow of these modular scenes that make the application.

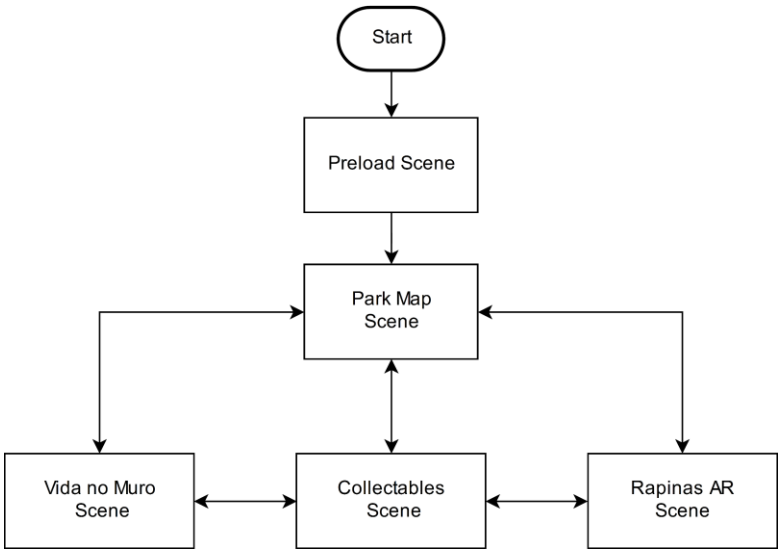


Figure 4.1: Scenes flow

In Figure **4.2** it can be seen the architecture of those scenes.

[15] Singleton, https://pt.wikipedia.org/wiki/Singleton (last access 2019)

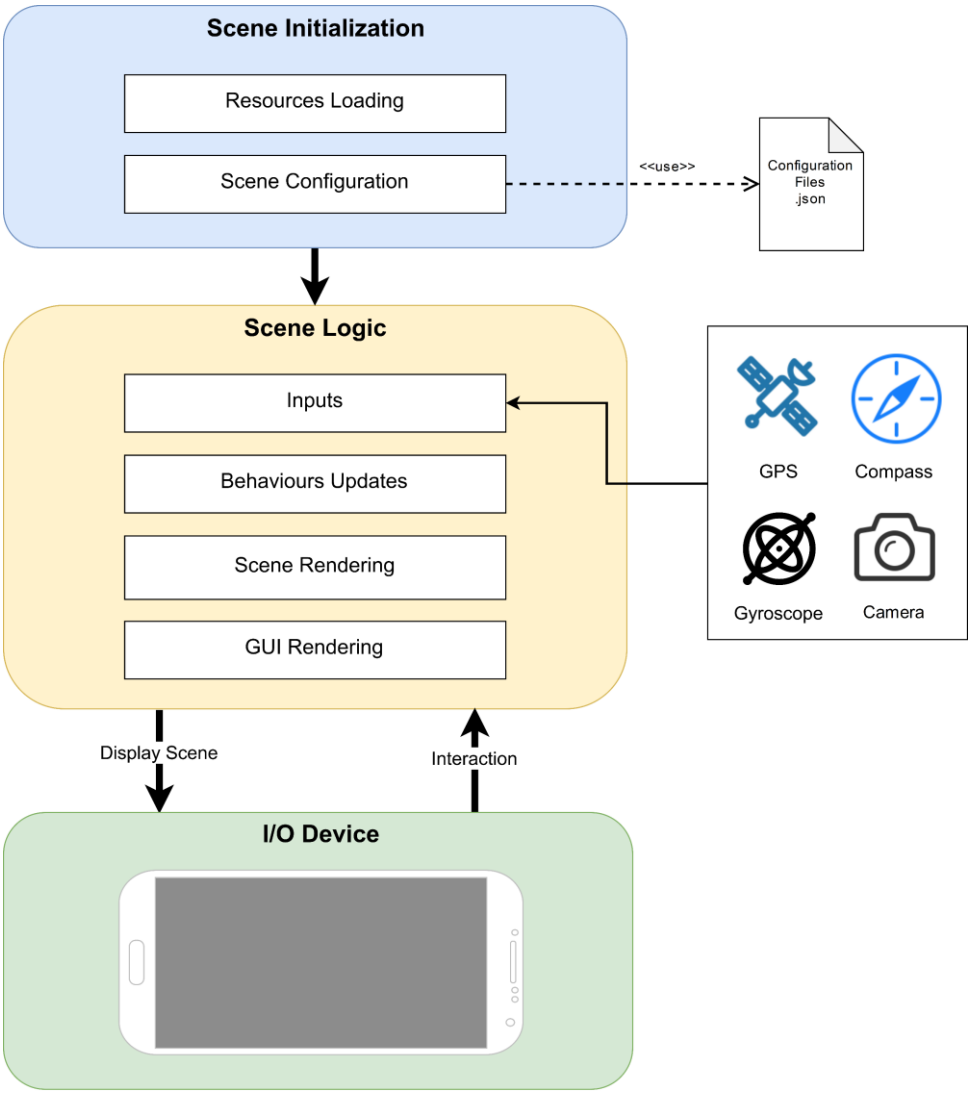


Figure 4.2: Scenes architecture

4.2. Preload Scene

This scene is only run at the start of the application, before everything else. It ensures that all the files required to run the application, and the application settings, are correctly set up. It is also here that the *GameManager* is instantiated and it will run until the application is closed.

As the application was developed for Android devices, permissions need to be granted so the application can access some of the device's capabilities. These permissions, to have access to the device's camera, GPS and ability to save and load data from the device storage, are also requested when running this scene. If the user refuses to grant any of the requested permission, a warning message will show to the user, not letting run the application without granting all the required permissions.

If the system detects that everything is correctly set up, it will start the *Park Map Scene*.

4.3. Park Map Scene

When this scene starts, it will first load the "mapMarker" JSON file. As the application map is an abstract version of the park's layout, the map is not correctly scaled, nor the paths shown in the map fully represent the actual paths in the park. To resolve this issue, strategically discrete GPS coordinates were recorded in the park, and then, were mapped to the application map so that the application can correctly calculate the user's location in the stylized map of the park. This recorded information was then added to the "mapMarker" file as a JSON block of data. This format was chosen because of the serialization capabilities of unity and, because it allows to easily and rapidly add, remove and edit any data in the file with a simple text editor, thus enables the customization of the path if the park changes its circuit again.

An example of this file is as follows:

```
{
  "mapRealLocationMarkerInfoDataList": [
    {
      "name": "entrada",
      "latitude": 41.097461,
      "longitude": -8.556281,
      "x": 39.64,
      "y": -19.67,
      "lineFillVal": 0
    },
       ...
    {
      "name": "fim do percurso",
      "latitude": 41.0975431,
      "longitude": -8.557046,
      "x": 30.72,
      "y": -19.29,
      "lineFillVal": 1
    }
  ]
}
```

`mapRealLocationMarkerInfoDataList` is an array that contains all the recorded points. The array doesn't have a limit of points it can load. Those recorded points are a JSON object that contain the following:

- `name` – This is a string that helps the developer know which point it refers to;
- `latitude` – Recorded GPS coordinate latitude;
- `longitude` – Recorded GPS coordinate longitude;
- `x` – Point position relative to the x-axis of the illustrative map image;
- `y` – Point position relative to the y-axis of the illustrative map image;
- `lineFillVal` – Ranges from 0 to 1, it's the percentage of the path at which that point is located. It is used by the application for optimizations purposes.

Figure 4.3: Park map in debug mode, showing the "mapMarker" file loaded, with its points overlaid in the map as purple squares

It then follows with loading the path already made by the user, that is saved in the *PlayerPrefs*[16] as a set of the recorded visited points. Using the *PlayerPrefs* to save this kind of data, ensures that if the application is updated, the user doesn't lose his progress.

After loading this information, the application starts to locate the user using the device GPS coordinates. To minimize battery drain, the application only updates the location of the user if the user is actively moving and only every 0.5 seconds when that situation occurs.

At each location update, the application calculates, from the nearest points relative to the last location calculation result, the pair of points closest to the GPS coordinates of the device. It then interpolates the location of the device between those two points, thus acquiring the location of the devices GPS coordinates in the illustrative map of the application. If the device is outside the park's area, these calculations aren't done, and a warning message is shown to the user stating that he is out of the park limits.

The orientation is calculated, simply getting the devices compass value and decrementing an offset so the orientation is correctly aligned with the illustrated map.

It should be noted that "GPS-enabled smartphones are typically accurate to within a 4.9 m" [GPS17], therefore the location of the user may sometimes be incorrect.

In order to have a workflow that could easily enable the addition of new activities to the application, prefabs were used to create the *MapActivity*. This prefab allows the addition of a new activity to the application map. By just dragging this prefab to the *Unity* inspector and using the *Unity* editor to place it in the correct position, a new location-based activity is added to the application map. The prefab was also created in a way to be simple to set up, by just using the inspector and changing the *MapActivity* script attached to the prefab as shown in Figure **4.4**.

[16] PlayerPrefs, https://docs.unity3d.com/ScriptReference/PlayerPrefs.html (last access 2019)

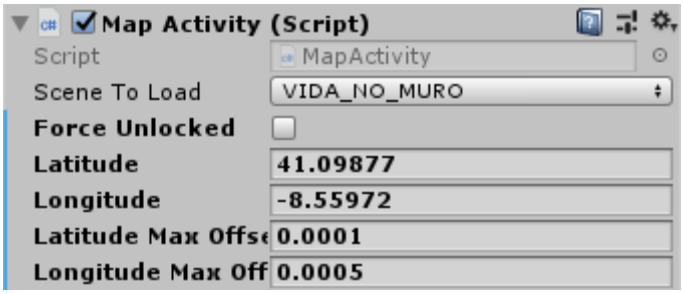


Figure 4.4: Setting up *Vida no Muro MapActivity*

The needed values to set up the *MapActivity*, as shown in Figure **4.4** are the following:

- **Scene to Load –** This dropdown is used to choose the scene to be loaded with this prefab;
- **Force Unlocked –** If enabled, it ignores location checks and the activity can start immediately;
- **Latitude –** GPS coordinate latitude of the park location where the activity will be performed;
- **Longitude –** GPS coordinate longitude of the park location where the activity will be performed;
- **Latitude Max Offset –** Maximum offset the device latitude can have in order to be considered inside the playable area;
- **Longitude Max Offset –** Maximum offset the device longitude can have in order to be considered inside the playable area.

After finishing adding the correct values of the *MapActivity*, the activity is set up correctly and integrated in the application's map.

4.4. Collectables Scene

The loading of this scene is made additively, which means the scene is loaded on top of already loaded scenes. As *Unity* scenes are independent from each other, doing this allows to load the collectables scene on top of the other scenes without altering their states. This allow a seamlessly transaction between scenes without the overhead and processing that happens when saving and loading a scene state. This is important, because accessing the collectables can be done at any time by the user at almost any point when using the application.

Other advantage of loading the scene additively is allowing to simply disable other scenes, thus reducing the device's resources usage and minimizing the device's battery drain.

Being used a lot by this application, the collectables loading was optimized to be done by the *GameManager* only one time at the start of the application, as their information is constant.

The format of the data chosen is JSON for the same reasons specified in subsection **4.3**. The JSON file is named "SpeciesInfo" and an exemplifying file is as follows:


```
{
  "specieInformationList": [
    {
      "specieID": 1,
      "isUnlocked": true,
      "imagePath": "SpeciesInformation/Images/Umbilicus_rupestris_IMG",
      "scientificName": "Umbilicus rupestris",
      "commonNames": "Conchelos, Umbigos-de-Vénus, Orelha-de-Monge.",
      "description": "É uma planta mediterrânica, carnuda, que se pode ver em
escarpas, muros e troncos de árvores. As flores podem ser observadas de abril
a junho.",
      "curiosities": "",
      "conservationStatus": "",
      "specieURL": "https://www.parquebiologico.pt/animais-
plantas/flora/item/conchelos?category_id=236",
      "specieCategory": 0
    },
       ...
    {
      "specieID": 13,
      "isUnlocked": false,
      "imagePath": "SpeciesInformation/Images/Milvus_migrans_IMG",
      "scientificName": "Milvus migrans",
      "commonNames": "Milhafre-preto ",
      "description": "Predador de roedores e aves, também se alimenta de peixe
e cadáveres. Vive em bosques e pastagens nas encostas das serras.",
      "curiosities": "Fica por vezes suspenso no ar aproveitando as correntes
de ar ascendente. No Parque Biológico de Gaia, um grande choupo junto ao rio
Febros foi escolhido por um casal de milhafres há vários anos para estabelecer
o seu ninho. Estarão por cá até aproximadamente setembro/outubro, época em
que, de novo, migram para África.",
      "conservationStatus": "Não preocupante.",
      "specieURL": "https://www.parquebiologico.pt/animais-
plantas/fauna/item/milhafre-preto-2?category_id=232",
      "specieCategory": 2
    }
  ]
`
```


`specieInformationList` is an array that contains all the collectable species and its information. The array doesn't have a limit of collectable species, so there is no limit to the collectable species that can be added to the application.

Each of those JSON objects in the array is a collectable species represented as the following:

- `specieID` – This is an integer unique identifier for the JSON object;
- `isUnlocked` – A Boolean that dictates if a species is already collected or not;
- `imagePath` – The path in the application files where the species image is located;
- `scientificName` – Scientific name of the specie;
- `commonNames` – Names commonly used by the population when they refer to the specie;
- `description` – A description and general information about the species;

- `curiosities` – Curiosities about the species. This field doesn't need to be filled;
- `conservationStatus` – Conservation status of the species. This field also doesn't need to be filled;
- `specieCategory` – This is an integer identifier that represents the species in the collectable's category. As at this moment there are 3 categories: "Vida no Muro – Plants", "Vida no Muro – Animals" and "Rapinas AR – Rapinas". Their values are 0, 1 and 2 respectively.

By having the collectables species being loaded this way, the addition or removal of new species is a simple and fast process that helped updating the application content.

4.5. Vida no Muro Scene

This scene handles the *Vida no Muro* activity described in subsection **3.2.3**. As the wall in the park is constantly changing due to the appearance and disappearance of the species that make that wall their home, the use of a markless solution for the tracking in the Augmented Reality scene needed to be used. This led to the use of the *Wikitude*'s[17] SLAM[18] technology.

Unity's *AR Foundation*[19], which uses *Google*'s *ARCore*[20], for Android devices and *ARKit*[21] for Apple's devices, was the selected tool for the implementation of the AR elements of this scene. It is natively supported by *Unity* and the required functionality and few tracking problems, as it is optimized for the supported devices. The issue with using *AR Foundati*on is that the supported devices are limited to a few selected smartphones, thus going against the requirements stated in subsection **3.1.2**. *Wikitude* offers similar technologies but with the added advantage of supporting any Android device that has a camera and that is running Android 4.4 KitKat or above.

This comes at a cost of not having the devices optimizations that *ARCore* does for each of its supported devices. Thus, the scene tracking ability has the possibility of being less reliable.

The tracking in the Augmented Reality scene is done when the user performs the scan, explained in subsection **3.2.3**. The aligner is important in this process, as it is what makes the augmentation being scaled and tracked properly. This aligner is made to be used in the park's wall, which has 1.4 meters in height and more than 15 meters of width. Using *Unity*'s editor scale, the aligner was made so that its dimensions would correspond to the wall's dimensions.

To ensure the aligner is easy to understand and to use, a test, with three different aligners was created (further detailed in section **5.3**). The analysis of its results resulted in the choice to use the aligner shown in Figure **4.5** for the application.

[17] Wikitude. https://www.wikitude.com/about/ (last access 2019)
[18] SLAM, https://www.wikitude.com/wikitude-slam/ (last access 2019)
[19] ARFoundation, https://docs.unity3d.com/Packages/com.unity.xr.arfoundation@1.0/manual/index.html (last access 2019)
[20] ARCore, https://developers.google.com/ar/ (last access 2019)
[21] ARKit, https://developer.apple.com/augmented-reality/ (last access 2019)

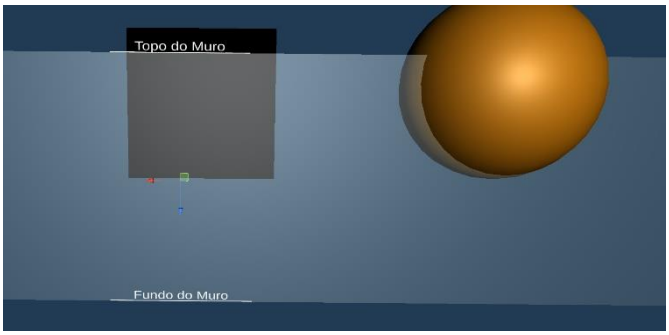


Figure 4.5: Aligner used in the final build of the application (in its test scene)

To facilitate the addition of new content and customization of the spawning process, prefabs were used for the interactive augmented species that spawn at the wall.

By just creating a prefab variant of the *WallSpecie* prefab, changing the prefab image to the correspondent species image and configuring their values of the *WallSpecie* script, shown in Figure **4.6**, a new species is added to the *Vida no Muro*.

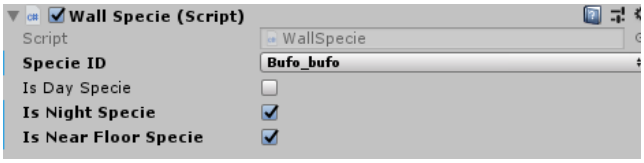


Figure 4.6: Example of the *Bufo bufo* specie *WallSpecie* script

To configure a species, using the *Unity* inspector, the only needed change is to change the "Specie ID" to the corresponding species. The checkboxes "Is Day Specie", "Is Night Specie" and "Is Near Floor Specie" will determine when and where in the wall the species is shown. Also, all the species are scaled to their real-life size using *Unity*'s metrics of 1 unit equals 1 meter.

This workflow, which is integrated with the highly customizable created spawn system, shown in Figure **4.7**, allows for simple and fast customization of the *Vida no Muro* species that appear to the user on the wall when doing the respective activity.

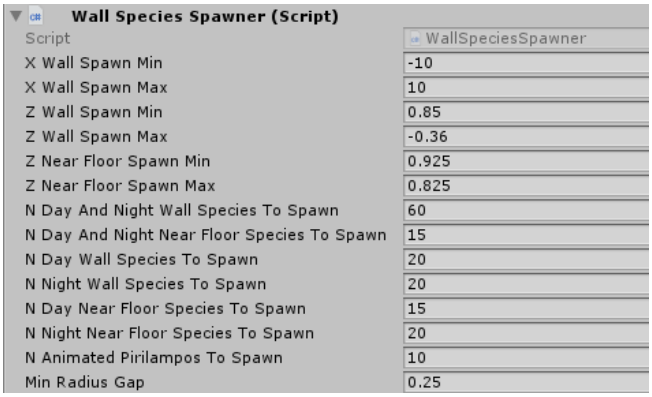


Figure 4.7: *WallSpecieSpawner* script in the inspector showing its customizable variables

The first 6 variables, namely the “X Wall Spawn Min”, “X Wall Spawn Max”, “Z Wall Spawn Min”, “Z Wall Spawn Max”, “Z Near Floor Spawn Min” and “Z Near Floor Spawn Max” define the spawnable area of the wall referenced from the centre of the wall. The first 2 are used to define the width and the remaining 4 to the height.

The following 7 variables, namely the “N Day And Night Wall Species To Spawn”, “N Day And Night Near Floor Species To Spawn”, “N Day Wall Species To Spawn”, “N Night Wall Species To Spawn”, “N Day Near Floor Wall Species To Spawn”, “N Night Near Floor Wall Species To Spawn” and “N Animated Pirilampos To Spawn”, are used to customize the quantity of species that appear in the augmentation.

The last one, “Min Radius Gap”, is the minimum distance the species should have from each other.

To save battery, the camera is disabled when not needed and reenabled when needed again. An example of this is when the user interacts with an augmented species and the information of said species is shown to the user. The state of the augmentation is preserved, so the user doesn’t notice this optimization happening.

4.6. Rapinas AR Scene

The purpose of this scene is to handle the minigame *Rapinas AR* described in subsection **3.2.4**.

This scene uses the camera, the device’s gyroscope and the *Unity* ability to simulate a 3D environment, to create an Augmented Reality minigame where the birds would fly around the player. The birds’ sizes are simulated in the 3D space to be the same as their real-life species. This was done by using the *Unity* scale unit of 1 unit equals 1 meter.

The scene is constructed with the scene camera being placed at the centre of the scene. The camera is then constantly being rendered at the background of the screen, with the gyroscope used to tell how the camera should rotate in the scene. This makes the scene camera correctly render the 3D simulation on top of the camera rendered image, thus giving the illusion of 3D simulated birds. Figure **4.8** shows an example of this process with a cube and a sphere representing the rendered 3D objects, with the green background that would be the device’s camera feedback.

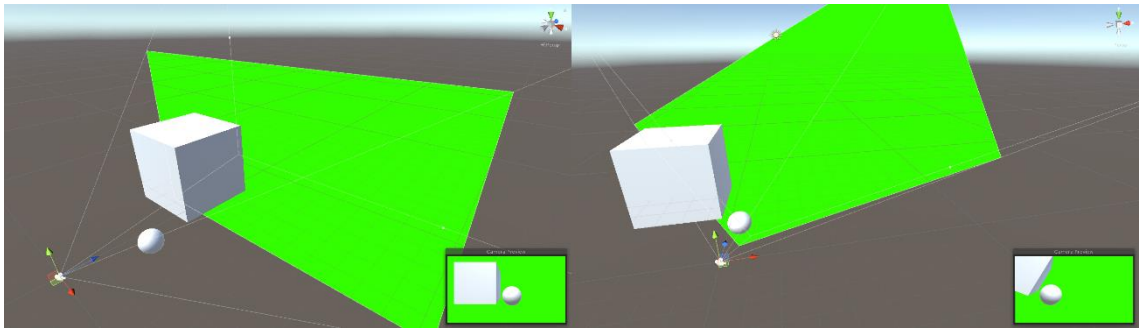


Figure 4.8: Example of a scene with the camera rotated in different angles, with each of its camera preview, rendering the 3D simulated world on top of the green overlay

Similarly to the approach explained in section **4.5**, prefabs were used to simplify the addition and removal of interactive birds in this minigame.

To add a new interactive bird to the game, a new prefab variant should be created, following by changing its image and configuring the *Bird* script shown in Figure **4.9**.

Figure 4.9: Example of the *Bird* script of the *Circaetus gallicus* species

Using the *Unity* inspector, the *Bird* script can be easily configured as it only needs to variables to be changed. They are the "Specie ID" dropdown, that dictates which species the prefab refers to, and the "Base Points", which is the base points of the bird that is going to be used in the calculation of the score.

An easy to use spawn system was also built in order to integrate this prefab workflow and allowing fast changes with real-time gizmos to help visualize the changes as shown in Figure **4.10**.

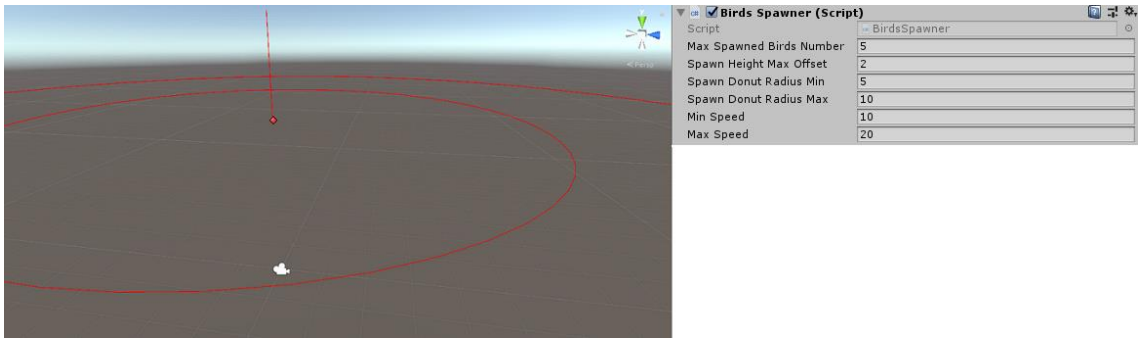


Figure 4.10: *Rapinas AR* configurable spawn system

The left side of the image is a screenshot of the gizmos shown in the editor, which gives a better representation of birds spawnable area around the player. The *BirdsSpawner* script, shown in the right side of the image, is the script that manipulates this spawnable area.

This script has 6 customizable variables, that do the following:

- **Max Spawned Birds Number –** Dictates how many birds can be spawned at a given time.
- **Spawn height Max Offset –** Represented by the red line that goes upwards from the centre, in Figure **4.10**. Dictates the maximum height, in meters, the bird can spawn.
- **Spawn Donut Radius Min –** Represented by the smallest red circle around, in Figure **4.10**. Dictates the minimum distance, in meters, from the centre the bird can spawn.

- **Spawn Donut Radius Max** – Represented by the biggest red circle around, in Figure **4.10**. Dictates the maximum distance, in meters, from the centre the bird can spawn.
- **Min Speed** – Minimum speed a bird can have when spawned.
- **Max Speed** – Maximum speed a bird can have when spawned.

Being spawned at different distances from the player, thus changing the difficulty when trying to spot the birds, it's only fair to adjust the score calculation, in order to take those variations into consideration.

To tackle this issue the score calculated in a given answer considers multiple variables to give a fairer score. When the answer is wrong, to avoid discouraging the player, the penalty is also reduced with the increase in difficulty.

The following pseudocode shows how the score is added and removed respectively:

```
pointsToAdd = (birdBasePoints + birdHorizontalDistance + birdVerticalDistance) *
birdSpeed
```

```
if bird is hard to guess:
       birdBasePoints = birdBasePoints / 2

distancePenalty = maxSpawnableHorizontalDistance – birdHorizontalDistance

pointsToRemove = (birdBasePoints + birdVerticalDistance – distancePenalty) *
birdSpeed
```

Another consideration that should be pointed out is the "binoculars" ability, as it does not actually use the device's camera zoom capabilities, instead, when the user uses this ability, the scene just renders part of the device's camera feedback and scales it to fill the screen, thus making that image appear zoomed. Because the zoom magnitude isn't very big, doing this optimization doesn't affect the image quality, thus bringing only the advantages of having an instant and predictable zoom across the different supported devices, while using fewer resources, therefore minimizing the device's battery drain.

This trick can't be applied to the scene camera that renders the scene's 3D simulation as it would affect the image quality, so the zoom in that camera is made by adjusting the field of view parameter so it zooms with the correct magnitude.

4.7. Summary

This chapter presented the tools and technologies used, as well as the description of the workflow used to implement some of the solutions.

It also describes how the application is structured in scene, making the application modular and then goes in more detail, for each of those scenes, about its implementation, methodology and considerations that were taken during their development.

The next chapter will describe the tests done during the development of the prototype, the resulting changes that resulted from the analysis of the results. The final test, which was done inside the “Parque Biológico de Gaia” to try and replicate a real user experience, in order to evaluate the application, is also described in this next chapter.

Chapter 5

Evaluation

This chapter described in detail the user tests done on the developed prototype, presenting their protocols, results and the corresponding analysis. There were multiple tests done, three of which were done in the middle of the development in order to evaluate isolated parts of the application to improve them and detect issues. This methodology goes in favour of the process of user-centred design as according to Abras et al. [Abr04], "it is only through feedback collected in an interactive iterative process involving users that products can be refined".

Doing this, improved the application so that in the final test, described in section **5.4**, the application would be in a more refined state, thus a more representative evaluation of the user experience.

The three tests done in the middle of the development, described in sections **5.1**, **5.2** and **5.3**, all had 34 participants.

The final test, which was done in the park to better represent the user's experience when using the application, had 27 participants.

5.1. "Rapinas AR" Indicators Test

In order to evaluate the indicators designed to guide the player to the birds' location in the *Rapinas AR* minigame, thus possibly increasing the interaction with said birds, and the overall experience of the *Rapinas AR* minigame, a usability test was conducted. In this test, the users had to try two different versions of the same activity, one with indicators and one without indicators.

The test, with an average duration of 4 minutes, was done in an open area in the middle of the day to try to replicate the park's location where this activity would take place. The device used was a smartphone, namely the Redmi Xiaomi 4X, a mid-range Android device from 2017.

The participants of this test were invited through direct contact, with a brief explanation of the context of the test and the tasks they would be performing.

5.1.1 Protocol

In this test, a total of 34 participants were asked to try two different versions of the game with the objective being to touch the maximum number of birds in under 60 seconds. To minimize the primacy and recency effect, the task order for each user was randomized.

Before the test each participant was informed that the participation is voluntary, that s/he can for any reason interrupt or cancel the test and that any information gathered with the questionnaires and by the system would be used confidentially and exclusively for the evaluation of the application. After that, a consent form reiterating these conditions was given to the users in order to be signed if they understood and agreed with the conditions.

During each of the tasks, every user comment was noted by the observer. The application also registered, for each task, the number of birds touched by the user. The time of each task was also controlled by the application, ensuring that there is no discrepancy on the tasks time.

At the end of the tasks, the participants filled a questionnaire regarding demographics and their opinion about the experience.

These two tasks were very similar, with the only exception of one having indicators that would help guide the user to point the camera to the birds, and the other not having these indicators.

In the test, the birds are scaled to their real-life size using Unity's scale, on which 1 scene unit equals to 1 meter in real life. The total number of birds spawned, flying around the player at every instant is 5. They spawn at random position around the player at a minimum distance of 5 meters and a maximum distance of 10 meters with their spawn height ranging from 5 to 8 meters. There were 5 types of birds in the spawn pool, their wing spans range from 0.65 meters to 1.65 meters.

Each of the two tasks would have a countdown that after reaching 0, would indicate the start of the task. It then would start with birds spawning. After spawning, these birds fly in a circular trajectory around the player always maintaining their starting height and distance, to the player.

When the user taps on the bird, the bird disappears, the number of birds touched is noted by the application and another random bird is spawned.

After 60 seconds of the start of the task, an end screen announcing to the user the end of the task is shown.

5.1.2 Results and Analysis

Gathering data in each test session was made with the use of a questionnaire. There was also data, registered by the application, related to the interactions with the birds, and the notes taken by the observer with his form.

The questionnaire had seven questions, with three of these using a modified Likert scale in the text form, as follows: "Strongly Disagree", "Disagree", "No opinion", "Agree" and "Strongly Agree". These are valued from 1 to 5 respectively, being 1 the most negative result and 5 the most positive result.

In the questionnaire, the first question had the objective of registering the participants' ages. The total number of participants in the test were 34 with ages ranging between 11 and 61 years ($\bar{x} = 36.29 \pm 15.09$).

The second question tried to find out how comfortable the participants are when using mobile applications (Figure **5.1**). This information could then be used as a comparison point in other questions.

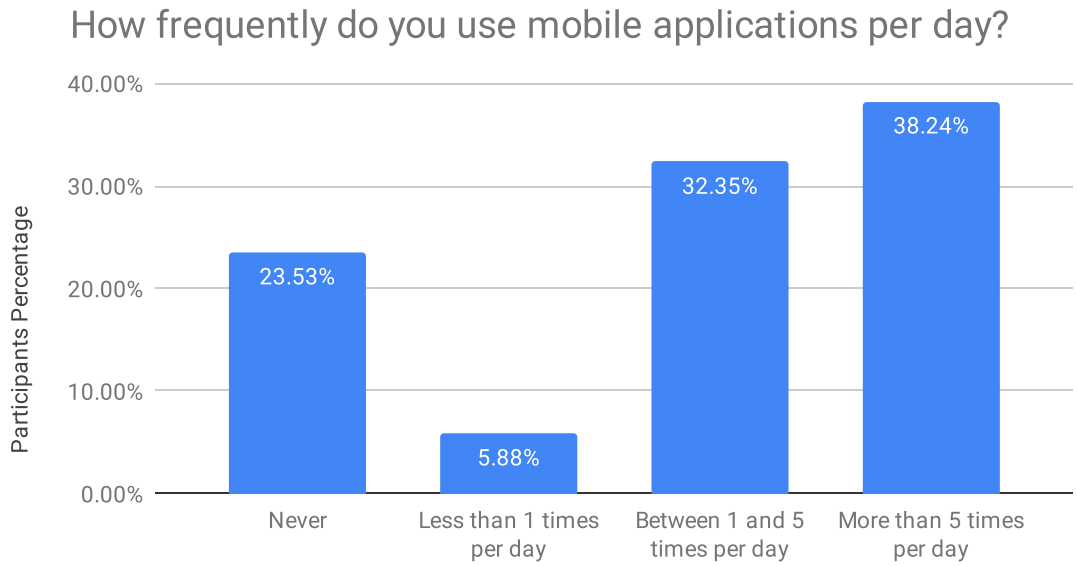


Figure 5.1: Frequency in the use of mobile applications by the participants

The following questions have the purpose of gathering information about the application, the first one being about the game's controls. As shown in Figure **5.2**, the response was very positive with a large percentage either responding with "Agree" or "Strongly Agree" and a median of "4" (Q1: 4, Q3: 5).

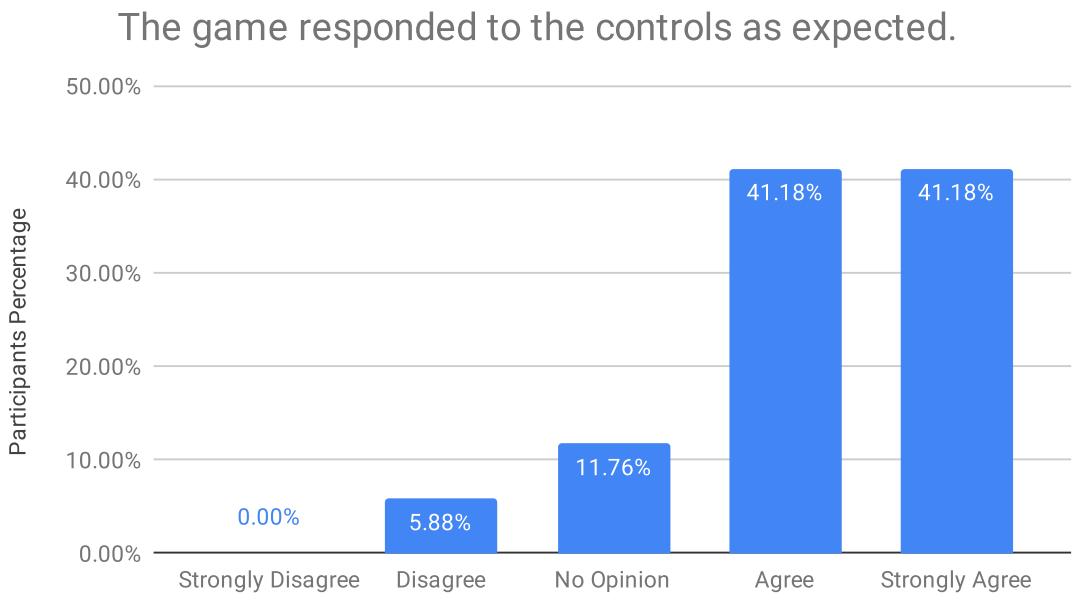


Figure 5.2: "The game responded to the controls as expected" responses

Not only the game controls have to work as expected by the player, but the game must be fun, or it can fail on providing an enjoyable experience. To evaluate this, the participants were asked if they thought the game was fun to play. The response, as shown in Figure **5.3**, is very positive, having more than half responded with "Strongly Agree" and a median of "5" (Q1: 4, Q3: 5).

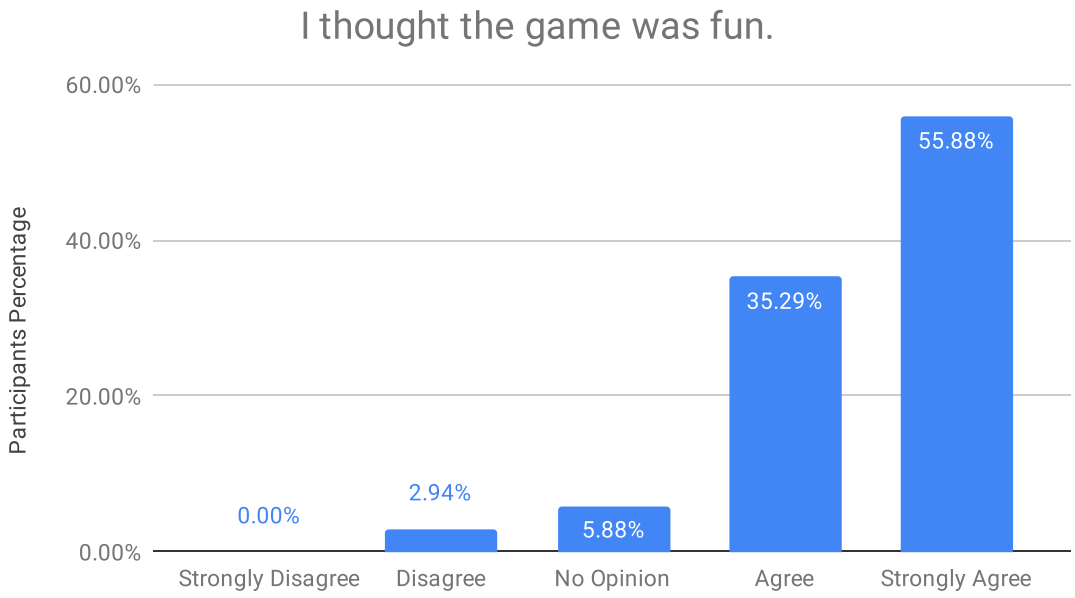


Figure 5.3: "I thought the game was fun" responses

The third question was related to the game visuals and the participants' opinion on the matter. The response, as shown in Figure **5.4**, was also very positive with more than half of the participants responding with "Strongly Agree" and a median of "5" (Q1: 4, Q3: 5).

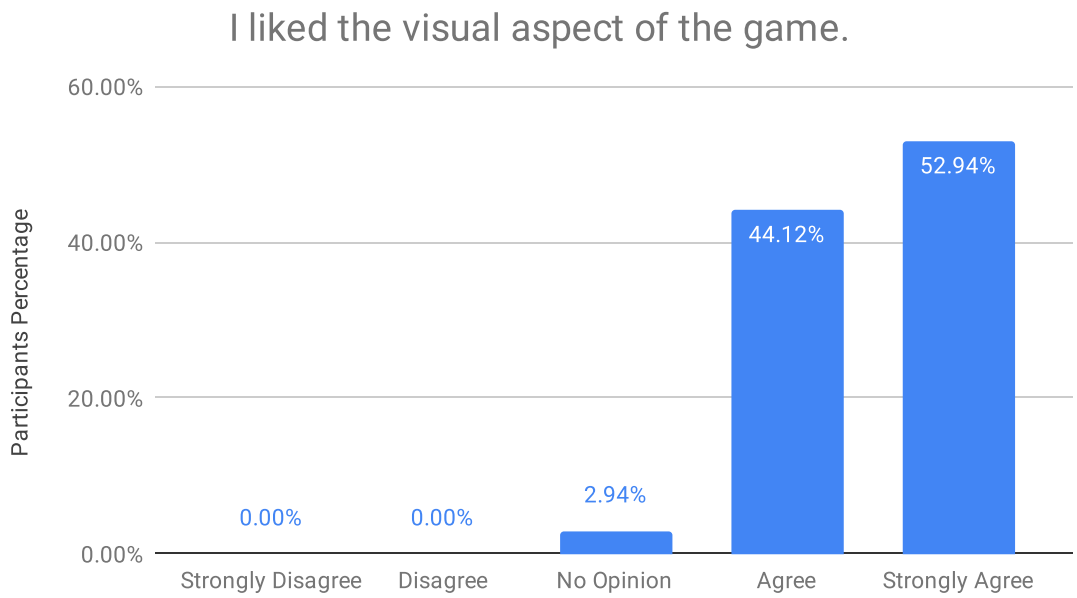


Figure 5.4: "I liked the visual aspect of the game" responses

The remaining of the questionnaire was optional with one of the questions being to indicate the age group the participant think is best suitable for the experience done. They could choose more than one age group. The results, as it can be seen in Figure **5.5**, shows that the majority of the participants thinks the game is suitable for a young audience, being that more than half of the participants selected the age groups of "Less than 18" and "18-35".

Although some participants recommended older age groups, their percentage was significantly less.

The tendency was to a participant select its own age group and age groups of lower age. At the exception of one participant with the age of 29 that thought the game was suitable for every age group, all the participants that thought the game was suitable for the age group of "More than 65" were 50 or more years old.

This information in conjunction with the comments noted in the experience, about the tiredness felt by participants, that fit in the age group of 35+ years old, because they had their arms extended too high for the duration of the gameplay, could mean that the gameplay needs to be adjusted in order to reduce tiredness felt by the players.

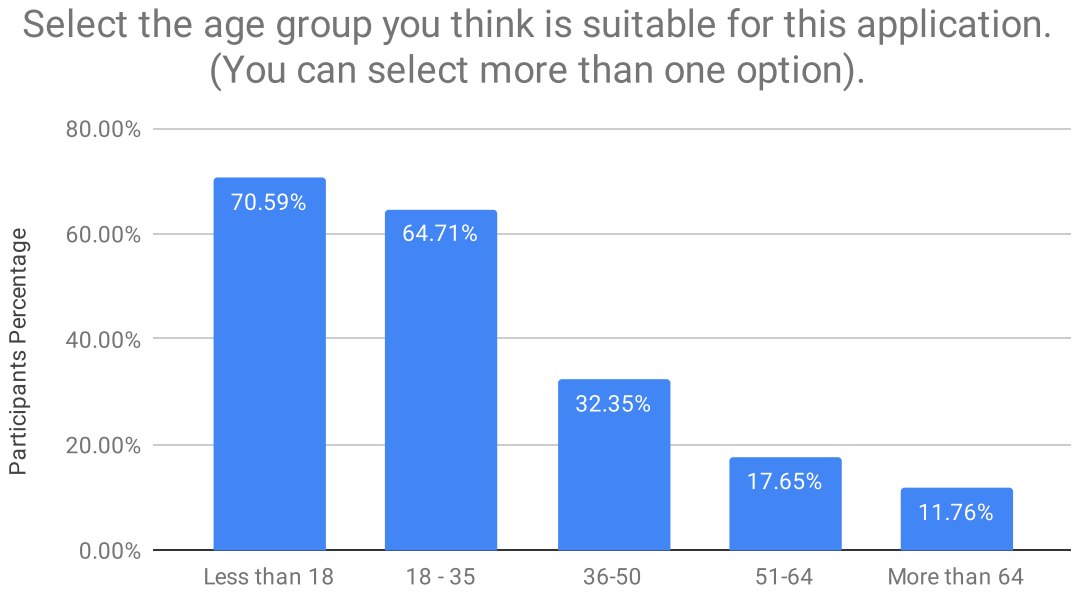


Figure 5.5: Recommended age groups

At the end of the questionnaire, there was an optional comment and suggestions section, where the users could freely write what they wanted. In this section, there were only three answers, one of them being that they liked the game, and the other two being that the game needed to show more birds and that a participant felt dizzy playing it because he had to rotate himself a lot so he could see more birds.

The last data gathered in this information was the number of interactions with the birds, each user had in each of the two game sessions. As shown in Figure **5.6**, the majority of the participants saw an increase in interactions with the birds when using the indicators as opposed to only 4 of the 34 participants seeing an increase in numbers of interactions when not using indicators.

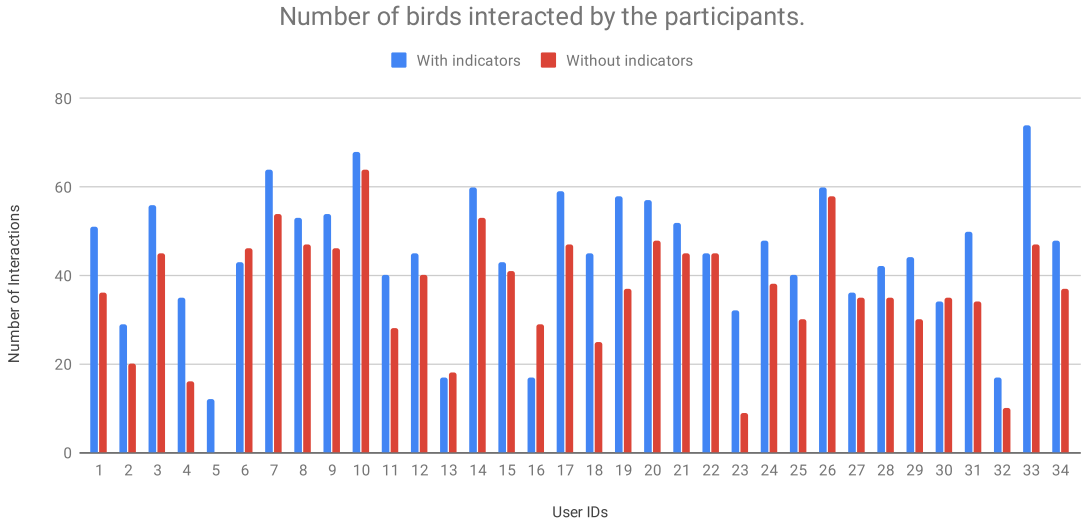


Figure 5.6: Number of birds the participants interacted with in each gameplay session

There were instances where the difference in the number of interactions was greater than 50% which could be the result of the user better understand, from one game session to the other, how to more efficiently play the game.

By removing these big differences, thus normalizing the gathered data, the resulting information was that, when using the indicators, the participants that had an increase in the number of birds interacted with, had an average increase of 21.82% ± 14.68%. The 4 participants that had an increase in the number of birds that they interacted with, had an average increase of 5.27% ± 2.09%.

This result led to the use of the indicators in the *Rapinas AR* minigame, as it was shown that using indicators increase the number of the interactions the user has with the birds, thus increasing exposure to said virtual species.

The following table (table **1**) recaps the questionnaire questions that could lead to modifications in the application.

Table 1: "Rapinas AR" Indicators Test summary table

Questionnaire questions about the experience	1st Quartile	Median	3rd Quartile
The game responded to the controls as expected.	4	4	5
I thought the game was fun.	4	5	4
I liked the visual aspect of the game.	4	5	5

Although the results of these questions, in table **1**, were positive there were changes introduced to the minigame.

As briefed before, during the test, there were comments made by the participants of tiredness for having the arms extended too high for the duration of the test. By also considering the

comments and suggestions section in the questionnaire, the following changes were introduced to the *Rapinas AR* minigame:

- Increase in the minimum number of birds that are spawned at any given instance during the game by 20%.
- Changed the spawn height range from [5 - 8] meters, to [3.5 - 5.5] meters.
- Changed the spawn algorithm from randomly spawning behind the player's field of view, to spawning near the edges of the player field of view with the direction of flying through the player's field of view.

These changes make the birds appear in front of the player more often and at a lower height, thus not requiring the player to turn a lot to see a bird, and allows for their arms to be positioned in a more comfortable position.

5.2. Application Map Test

To evaluate the design of the map in the application and detect possible points to improve, a usability test, where participants were asked some questions was conducted.

This short test, taking an average of 3 minutes to complete, was done with each participant starting oriented to the south and with the device GPS coordinates set with a fake GPS application, to be in a specific location in the park, to better replicate the experience of being in the real location of the park. These coordinates are the same throughout all the tests, to avoid having the starting conditions influencing the results. The device used was a smartphone Redmi Xiaomi 4X, a mid-range Android device from 2017.

The participants of this test were invited through direct contact, with a brief explanation about the context of the test and the test they would be performing.

5.2.1 Protocol

A total of 34 participants were subject to the test, where they had to simply answer a few questions asked by the observer. During the test, the observer recorded the responses to these questions to the observer form. Also, after finishing this test, the participants filled a questionnaire.

Before the test, the user was informed that the participation is voluntary, that s/he could for any reason interrupt or cancel the test and that any information gathered with the questionnaires and by the system would be used confidentially and exclusively for the evaluation of the application. Reiterating these conditions, a consent form was given to the users to be signed if they understood and agreed with the conditions.

At the start of the test, the user was asked to point out the nearest point of interest to his location. The user can obtain more information about what a point of interest is, by interacting with the help icon in the top corner of the screen or asking further explanation to the observer of the test. The observer then takes notes if the user succeeded or not on the task.

After that, the user is asked to rotate himself to be faced to the direction of the nearest point. This task should be noted as succeeded if the user points or orientates himself from the starting direction of the south to west. If the user didn't succeed in the first task, before starting this second task, the observer must explain and make sure the user knows where he is located in the map, and where is the nearest point of interest to him.

Finally, the user was asked about the orange dashed line in the map, what does s/he thinks it means. The observer then fills the form with the result of the user correctly or incorrectly guessing the purpose of that line.

If the user answered incorrectly, their response and comments are also filled in the correspondent text field of the form.

5.2.2 Results and Analysis

In this test, the data was gathered with the use of a questionnaire. The observer also had a form where it was noted standardized information about the questions and any comment said by the participants that observer thought was relevant.

The questionnaire filled by the participants of the test had nine questions in total, the first two being demographic questions, the following two being about the participant's smartphone usage and how much at ease the participant is with navigation applications. The remaining five questions are about the test, the last one being an optional comments and suggestions field.

Analysing the first two questions of the questionnaire, the 34 participants have an age between 11 and 61 years old ($\bar{x} = 34.97 \pm 15.14$), with 41.18% being male and 58.82% female.

The third question had the participants fill how frequently they use their smartphone, by having them select from 1 to 7, "1" being "Never (I don't have a smartphone)" and "7" being "Multiple time throughout the day". With a median of 6 (Q1: 4, Q3: 7), the results, as seen in Figure **5.7**, show that the majority of the participants use their smartphone very often.

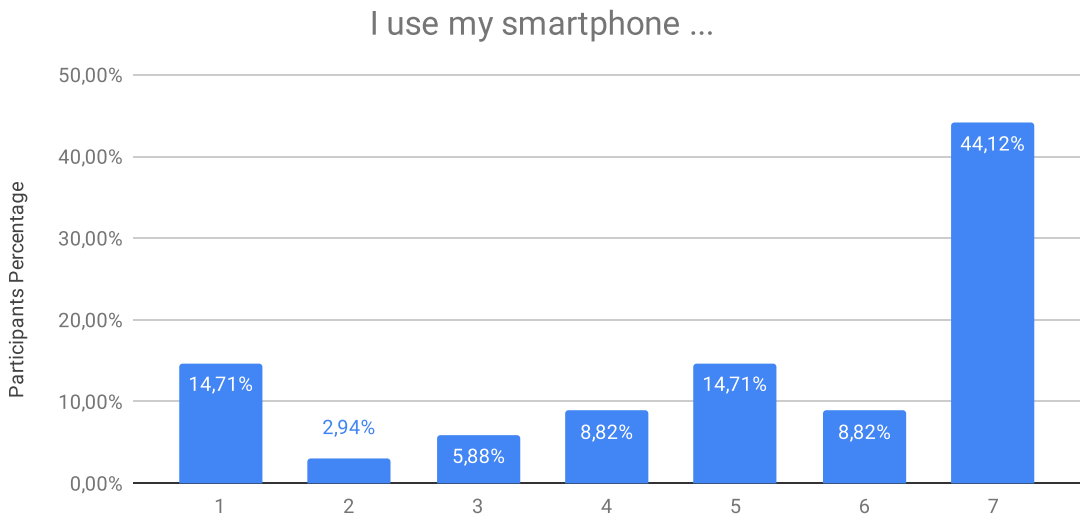


Figure 5.7: Frequency of smartphone usage (1- Never (I don't have a smartphone), 7- Multiple time throughout the day)

In the fourth question, to know more about the participants at ease when using navigation applications, the participants had to select from 1 to 7, "1" being "I'm not comfortable (I do not know any)" and "7" being "Very comfortable (I use frequently)", one number that better represented their thoughts. From the results shown in Figure **5.8**, it is possible to conclude that the participants' response was mixed, with a median of 5 (Q1: 3.25, Q3: 6).

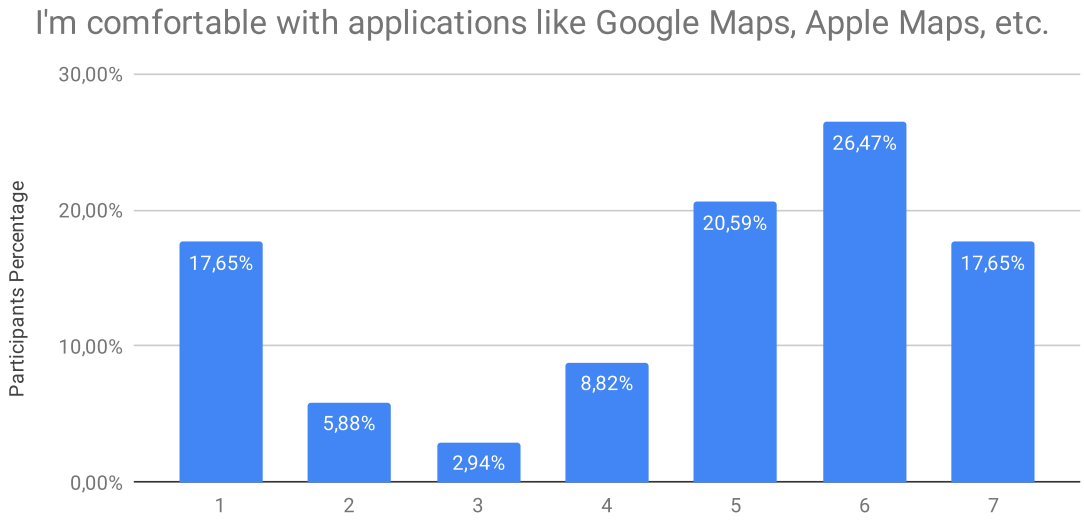


Figure 5.8: State of comfort with navigation applications (1- I'm not comfortable (I do not know any), 7- Very comfortable (I use frequently))

The remaining questions, except the one related to the recognition of the activities icons and the optional commentaries and suggestions fields, use the 7 point Likert scale, ranging from "Strongly disagree" to "Strongly agree". The first of these questions were related to how easy the participant thought to locate himself on the map. The results as it can be seen in Figure **5.9**, show that, with a median of 7 (Q1:5.25, Q3:7), the majority of the participants thought it was easy to locate themselves in the map with some of the participants having difficulties in the localization.

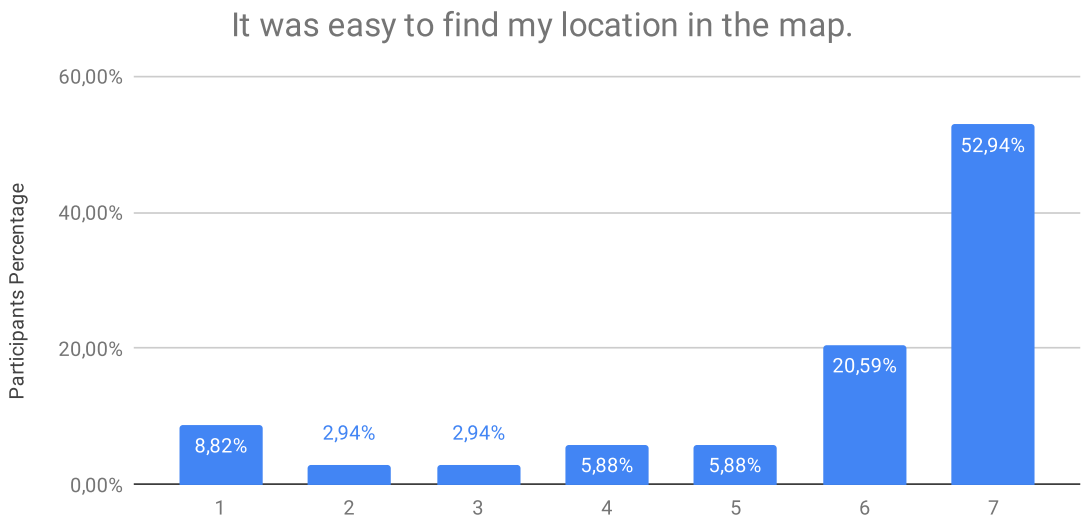


Figure 5.9: "It was easy to find my location in the map" responses (1- Strongly disagree, 7- Strongly agree)

The participants that selected "3" or less in this question, in the fourth question, regarding how to ease the participants are with navigation application, all selected "3" or less, with 60% selecting "1". This means that those participants that couldn't locate themselves in the map of the test are simply not comfortable with navigation applications.

The following and sixth question was made in order to determine if the orientation of the user on the map is easy to see and understand. As shown in Figure **5.10**, the response was very positive, with a median of 7 (Q1: 6, Q3: 7).

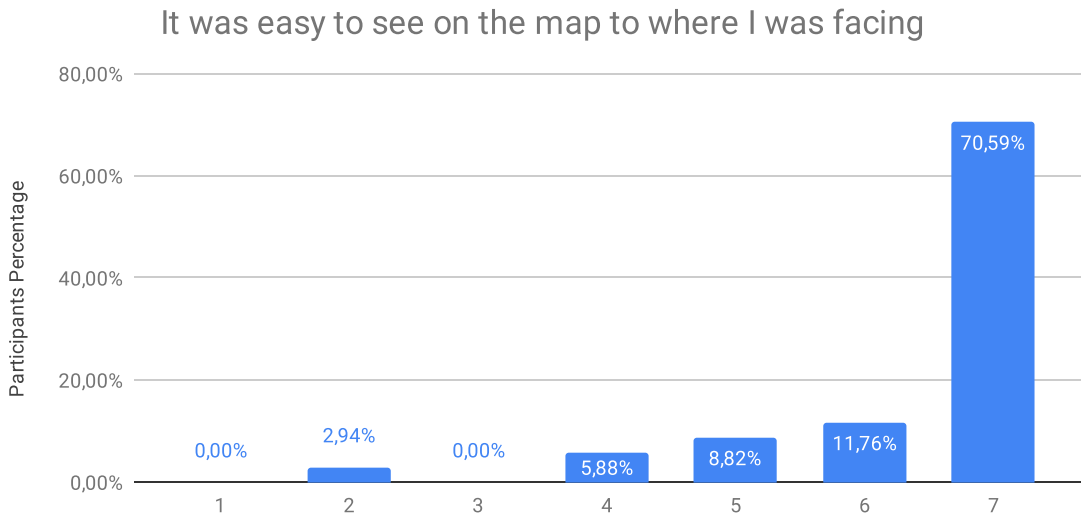


Figure 5.10: "It was easy to see on the map to where I was facing" responses (1- Strongly disagree, 7- Strongly agree)

The seventh question, in order to evaluate the need to redesign the activity icons, the users were shown, in the questionnaire, the two activity icons and asked to specify which of the icons they had noticed. The Figure **5.11**, which show the responses given in this question, show that the icons are visible enough to stand out in the map, as never in the test, the user was encouraged or directed to take notice on the icons.

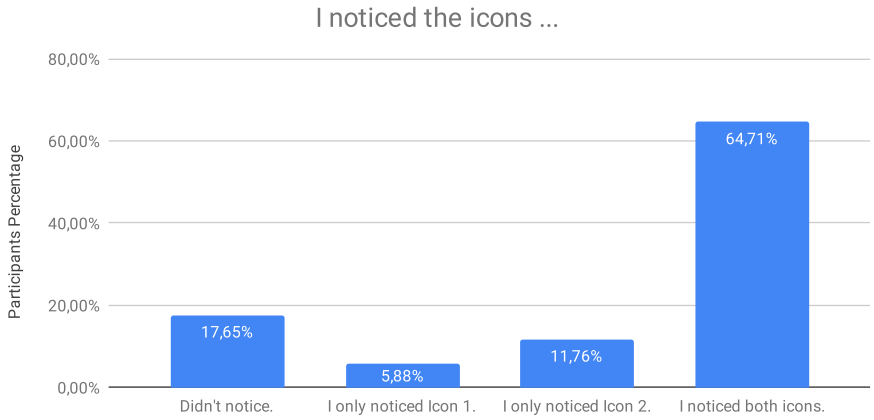


Figure 5.11: Noticed icons

The following, and the eighth question is about the participants thoughts about the visuals of the application in the tested experience, which resulted, as shown in Figure **5.12**, with a median of 7 (Q1:7, Q3:7) that the response was overwhelmingly positive.

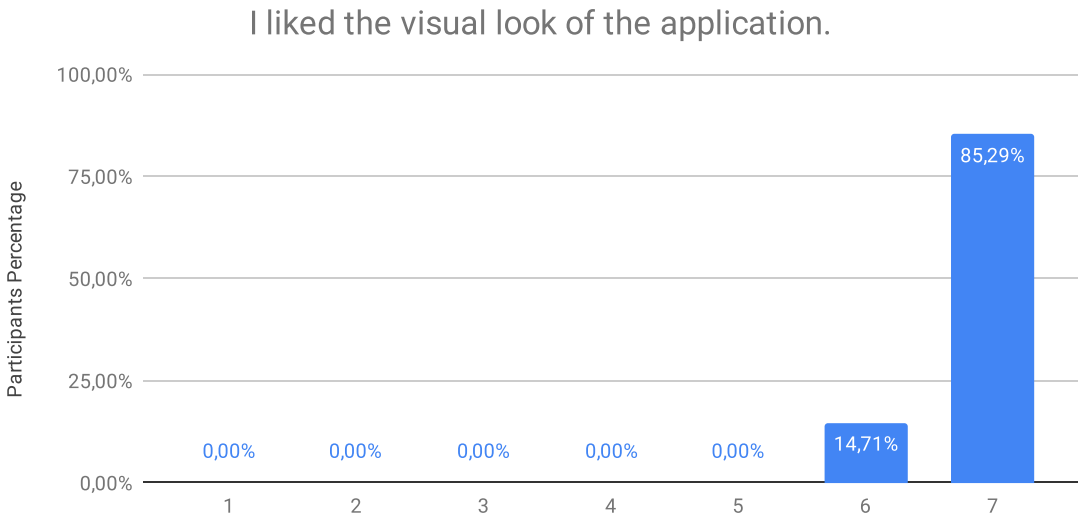


Figure 5.12: "I liked the visual look of the application" responses (1- Strongly disagree, 7- Strongly agree)

The last question was an open-ended question for the participants to give their opinions and suggestions. None of the participants filled this optional field.

The following table (table **2**) recaps the questionnaire questions that could lead to modifications in the application.

Table 2: Application Map Test summary table

Questionnaire questions about the experience	1st Quartile	Median	3rd Quartile
It was easy to find my location in the map.	5.25	7	7
It was easy to see on the map to where I was facing.	6	7	7
I liked the visual look of the application.	7	7	7

The "It was easy to find my location in the map" question had positive results, but not as positive as expected. As analysed before, this could have been related to some users not being accustomed to using navigation applications.

Given that, and according to the notes taken with the observer form, 85.29% of the participants could locate themselves in the map, there were no changes on the icon representing the user location in the map.

The form filled by the observer, also detected that, 94.12% of the participants understood their orientation in the map and could correctly orient themselves in the map. It also confirmed that the users associate the dashed line to the representation of the path taken by the user, having a total of 82.35% of the participants responding with that association. The remaining 17.65% of the participants all associated the dashed line with the path to take.

Overall, the test results confirmed that the design and implementation of the application's map does a good job in being an easy way for the users to locate and guide themselves through the park and so, no new changes were introduced.

5.3. "Vida no Muro" Aligners Test

To improve the usability of *Vida no Muro* and minimize incorrect scans, thus maximizing the number of *Vida no Muro* AR experiences showing the wall species at their correct location in the wall, with their correct sizes, a test was conducted where the participants would have to scan a wall, with dimensions representing the ones from the park's wall, using one of three designed aligners.

This test of short duration, having an average completion time of 3 minutes, was done after the completion of the "Application Map Test", described in subsection **5.2**, and used the same device, namely the Redmi Xiaomi 4X, a mid-range Android device from 2017.

After they were invited to participate in "Application Map Test", the participants were informed that they could also participate in this test. The invitation was done in the same way as the test done before. Having explained that this test was also of short duration, all the 34 participants in the "Application Map Test" also participated in this test.

5.3.1 Protocol

In this test, each participant did one scan using one of the aligners. The use of the aligners in each of the tests were done alternated so the number of tests done with each of the aligners maintained equal for each aligner. The aligners used are the ones shown in Figure **5.13**, with their names being "Normal", "Normal without text" and "Inverted". Being there were a total of 34 participants, the number of tests using each of the aligners were the following:

- **"Normal" –** 12 tests;
- **"Normal without Text" –** 11 tests;
- **"Inverted" –** 11 tests.

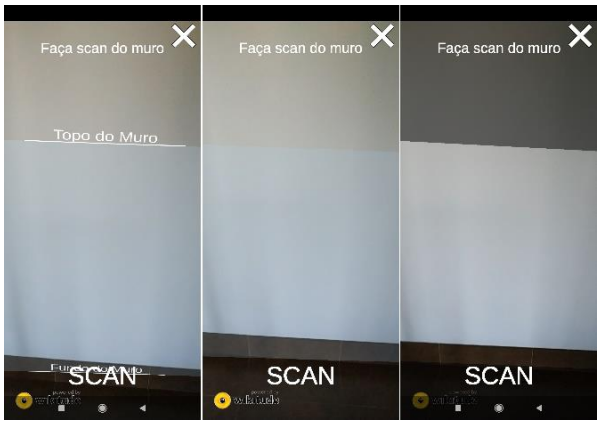


Figure 5.13: Screenshot of the three aligners types, "Normal", "Normal without text" and "Inverted" respectively against a white wall

Before starting the test, the consent information explained in the "Application Map Test" was reiterated and the user was informed that the test falls in those same guidelines he had read and signed. It was also informed that he would have to fill another questionnaire at the end of the test.

This test, similarly to the "Application Map Test", has the observer give a task to the participant and then fill the form about the responses and actions of said participant. The test proceeded as follows:

The user is taken to a wall, which has 1.4 meters in height and 7 meters in width. The dimensions are important because, in order to correctly test the aligners, the wall should have the same height of the park's wall, which is 1.4 meters in height, and enough with so that the wall can't be all seen by the smartphones camera.

After being faced to the wall, the user is given the application with the scan process ready to be started. The scan will use one of the three aligner type shown in Figure **5.13**.

The user is then informed that by performing a scan of the wall, illustrations of plants and animals will appear on said wall. The user is then let to perform the scan by himself, with the knowledge that if he feels lost or doesn't know what to do, he can ask the observer on how to do the scan.

This will lead to the user performing the scan, or not knowing what to do and asking for help, which then the observer will have to fill the form accordingly.

After the scan is performed the observer then visually evaluates the scan and fills in the fields on the observer form corresponding to the scan being correctly made or not.

5.3.2 Results and Analysis

Similarly to the data gathered for "Application Map Test", as described in subsection **5.2.1**, the data gathered in this test was obtained with the use of a questionnaire filled by the participants and any information noted by the observer.

In the questionnaire filled by the participants, there are a total of seven questions, being the first two about demographics the fourth and fifth about how much at ease the participants are with a smartphone and Augmented Reality respectively. The last three are about the experience in the test, being the last one and optional field where the participants can freely comment and give suggestions.

As stated in section **5.3** the participants were the same that participated in the "Application Map Test", described in section **5.2**, thus the total of 34 participants demographic data gathered was the same, with their ages ranging from 11 to 61 years old ($\bar{x} = 34.97 \pm 15.14$), them being 41.18% male and 58.82% female.

As in the questionnaire of the "Application Map Test", described in subsection **5.2.1**, the third question had the participants fill how frequently they use their smartphone, by having them select from 1 to 7, "1" being "Never (I don't have a smartphone)" and "7" being "Multiple time throughout the day". The answers were slightly different from the ones gathered in the "Application Map Test" as it can be seen by comparing Figure **5.14** with Figure **5.7**. However, the results were the same, with median of 6 (Q1: 4, Q3: 7), the results of this question, as seen in Figure **5.14**, show that the majority of the participants use their smartphone very often.

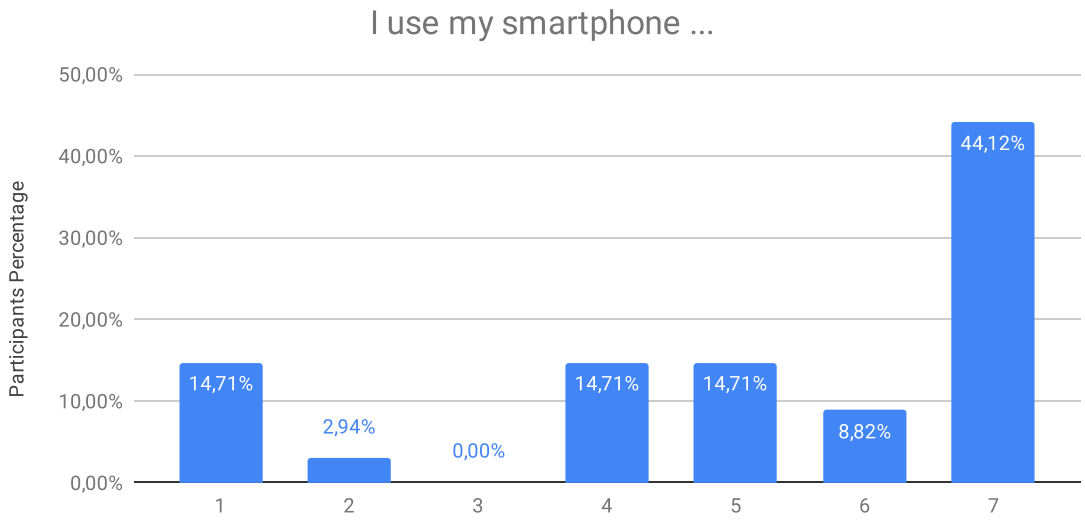


Figure 5.14: Frequency of smartphone usage (1- Never (I don't have a smartphone), 7- Multiple time throughout the day)

The fourth question is used to know how comfortable the participants are with Augmented Reality applications. The participants had to select from 1 to 7, "1" representing "I'm not comfortable (I do not know any)" and "7" being "Very comfortable (I use frequently)".

In our study the participants had a very diverse AR experience with a slight tendency for not having experience as shown in Figure **5.15**, with a median of 3 (Q1: 1, Q3: 5).

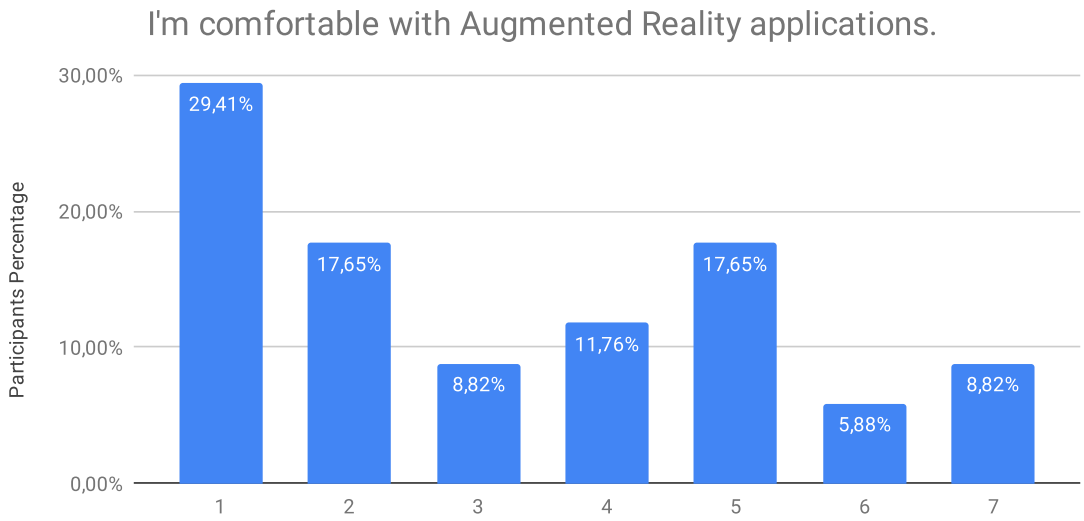


Figure 5.15: "I'm comfortable with Augmented Reality applications" responses (1- I'm not comfortable (I do not know any), 7- Very comfortable (I use frequently))

The following two questions use the 7 point Likert scale, ranging from "Strongly disagree" to "Strongly agree". The first of these questions was created in order to compare the participants' responses, and their thoughts on the scan being done correctly, with the observation that was done by the observer.

The responses that were given by the participants have, a median of 6 (Q1: 5, Q3: 6) and, as can be seen in Figure **5.16**, are positive, with some of the participants showing some indecision in their response.

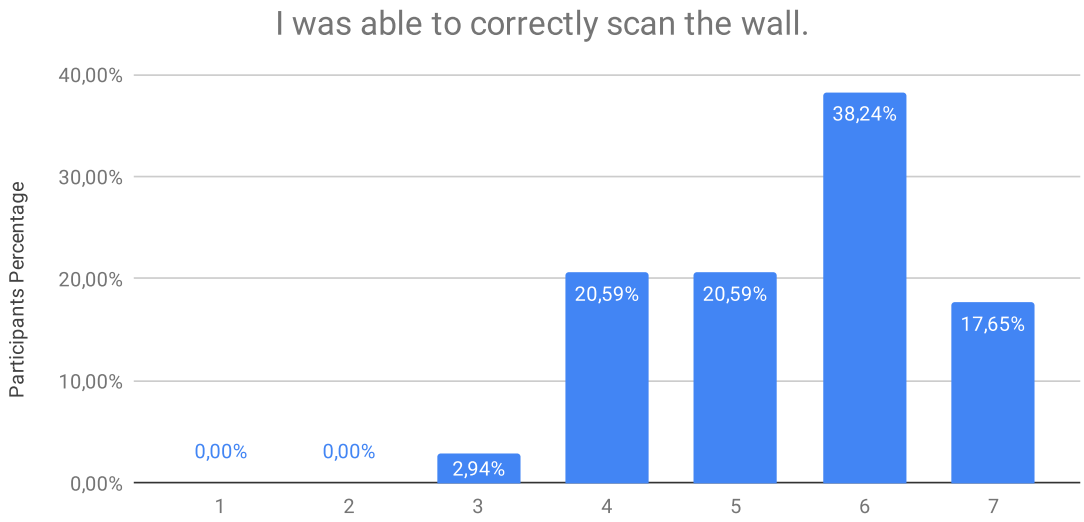


Figure 5.16: "I was able to correctly scan the wall" responses (1- Strongly disagree, 7- Strongly agree)

In the data gathered by the observer, a total of 41.18% of users incorrectly scanned the wall. Of these users, 14.29% used the aligner "Normal", 71.42% used the aligner "Normal without text" and the remaining 14.29% used the aligner "Inverted".

As the aligner "Normal without text" showed to allow a high percentage of incorrect scans, it was discarded as being a choice.

Being that all the participants that used aligner "Normal" selected "4" or less, contrary to the participants that used aligner "Inverted", on which all selected "6", the aligner that was chosen to be used as final by the application was the aligner "Normal". The results show that between the two, the aligner "Normal" is less confusing for the user to know if s/he was correctly using it. This decision would also be backed up by the results of the questionnaire's following question.

This seventh question had the objective to determine how easy for the users it was to understand that they had to align the top and bottom of the aligner, with the top and bottom of the wall. As shown in Figure **5.17**, with a median of 6 (Q1: 4.25, Q3: 7), the results were also mixed.

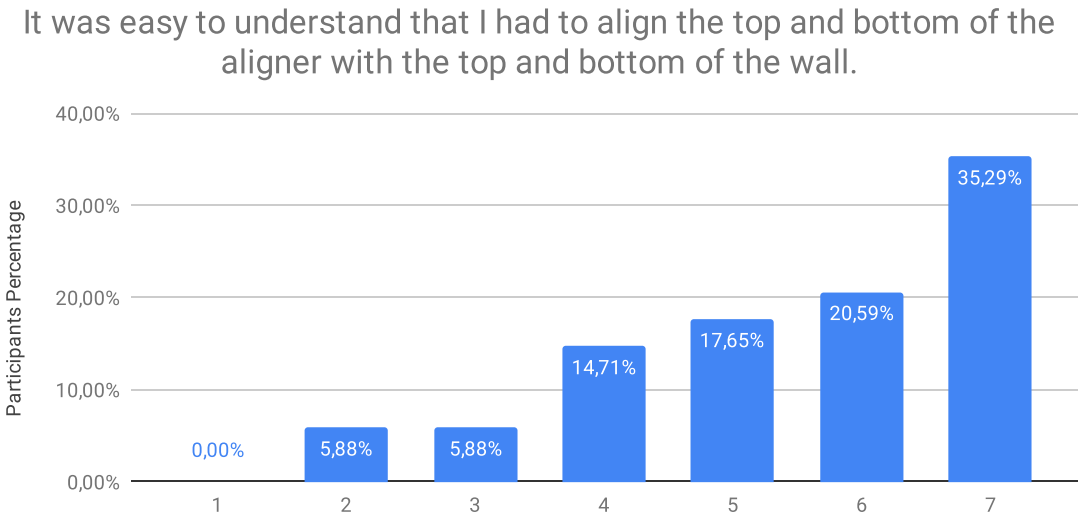


Figure 5.17: Aligning the aligner responses (1- Strongly disagree, 7- Strongly agree)

Further analysing and comparing with the data gathered by the observer, all the participants that used aligner "Normal", selected "4" or less in this question. contrary to the participants that used aligner "Inverted", on which 50% selected "6", thus again, showing the aligner "Inverted" is more confusing to use than the aligner "Normal".

The final question in the questionnaire was an optional field where the participants could write comments and suggestions. The participants left this optional field blank.

The following table (table **3**) recaps the questionnaire questions that could led to modifications in *Vida no Muro* scan process.

Table 3: "Vida no Muro" Aligners Test summary table

Questionnaire questions about the experience	**1st Quartile**	**Median**	**3rd Quartile**
I was able to correctly scan the wall.	5	6	6
It was easy to understand that I had to align the top and bottom of the aligner, with the top and bottom of the wall.	4.25	6	7

According to the results of the form filled by the observer, 82.35% of the participants correctly performed the scan process of *Vida no Muro*, without any help. For this reason, and taking into consideration the positive analysis of the results, no further modifications were introduced to the scan process.

5.4. Test in the park

This final test was designed to fully evaluate the application usability. This usability test, had a duration of 20 minutes on average to complete and, was done in the "Parque Biológico de Gaia", in Avintes, Porto.

The participants of this test were invited through direct contact and with invitations using instant message application and email. In the invitation, it was given a brief explanation of the context of the test and the tasks they would be performing. The participants would then reserve a timeslot in a spreadsheet that was used to organize the test schedule.

Some of the participants were asked to participate in the test directly, at the entrance of the park. The tests were done throughout a period of three days.

5.4.1 Protocol

A total of 27 test participants walked over a specific path while using the application and stopping in two specific points to try the *Vida no Muro* and *Rapinas AR* activities, described in section **3.2.3** and **3.2.4** respectively.

Before the start of the test, each participant was informed that they would test a prototype of a mobile application designed for the park and in the end, fill a paper questionnaire. They were also told that, for any reason, they could interrupt or cancel the test, and that any data gathered would be maintained anonymously and would only be used for the purpose of evaluating the prototype. After that, a consent form reiterating these conditions is given to the participant, to be signed if they understood and agreed with the conditions.

Since the locations of the test activities locations, that are part of the test, were in opposite sides of the park at a distance of 1.6 kilometres from each other, an alternative shorter route, that offered the same conditions as those locations, was chosen to make this test, as shown in Figure **5.18**.

Figure 5.18: Comparison of shorter path of the test, with the shorter path involving the activities locations

This required the activities to be accessible without the need for the participant to be in their intended physical location. To allow that, these activities trigger area was changed to the new locations intended to be used during the test.

Also, for this test purpose, before each participant started the test and, to ensure the most similar experience between the participants, the application path that is recorded and shown to the user as the orange dashed line, would be cleared. Also, any of the collectables unlocked during the test would be reset. When resetting the collectables, they would all be locked at the exception of three specific species that, would be used as an example during the explanation of the test activities.

The test would start at the entrance of the park, where each participant was given a smartphone with the prototype already running, showing the application map. The participants would then be taken through the same path, shown in left side of the image in Figure **5.18**. During the walk, the participants would be explained that they were free to explore the application and showed the *Collectables*, described in subsection **3.2.2**. At that time, the participants were told that some of those collectables were already unlocked so that they could interact with them. Also, the others that were locked could be collected in the activities that the participant would soon experience.

The first task was to try the *Vida no Muro*, described in subsection **3.2.3**. When arriving at the location of the wall, the participants were explained that they were not doing the activity in the intended location of the activity because of the distance. It then would be shown what happens when the activity changes from the state where it cannot be started, to the state of being in the activity trigger are, enabling it to be started. After that, the participant was told the purpose of the activity and what they could expect from it. They were also given the objective of trying to find a firefly that only appeared in the night mode. The participant then would freely experience the *Vida no Muro* activity.

Next, the participant would be taken to an open area, at the end of the test path, to play the minigame *Rapinas AR*, described in subsection **3.2.4**.

During the walk it was explained to the participant the rules of the game and what they could expect from the minigame. It was also explained that the intended location of the *Rapinas AR* is also an open area, but located in the opposite side of the park, and that the activity would be unlocked the same way as explained for the *Vida no Muro*.

The participant would then play the minigame and the test would end with the participant filling a paper questionnaire.

5.4.2 Results and Analysis

In this test, the data which was then analysed was gathered by having the participants fill a paper questionnaire at the end of the test. The observer also noted any relevant comments and suggestions pointed out by the participants.

The questionnaire had two parts, being the first one related to the participants and their opinion about the application, with a total of sixteen questions. The second part had the ten questions of the System Usability Scale (SUS) in order to measure the application usability. At the end of the questionnaire, there was also an optional comments and suggestions field, so that the participants could freely share their detailed opinions about the application.

The test had 27 participants wit and according to the first two questions in the questionnaire, their ages ranging from 14 to 79 years old ($\bar{x} = 42.15 \pm 16.31$), them being 55.56% male and 44.44% female.

The third question had the participants fill how frequently they use their smartphone, by having them select from 1 to 7, "1" being "Never (I don't have a smartphone)" and "7" being "Multiple times throughout the day". The results, shown in Figure **5.19**, with a median of 7 (Q1: 6, Q3:7) show that the majority of the participants, use their smartphones very often throughout the day.

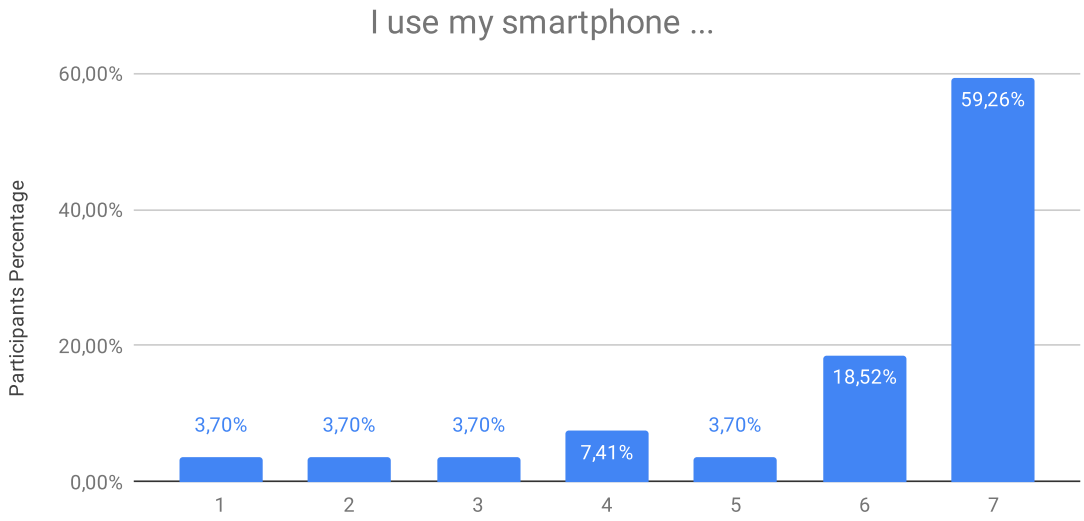


Figure 5.19: Frequency of smartphone usage (1- Never (I don't have a smartphone), 7-Multiple times throughout the day)

The following questions in the first part of the questionnaire, except the fifth question that is about the need of a tutorial, use the 7 point Likert scale, ranging from "Strongly disagree" to "Strongly agree".

The first of these questions, the fourth in the questionnaire, as it can be seen in Figure **5.20**, with a median of 7 (Q1: 6, Q3:7), had a very positive result in relation to the application behaviour.

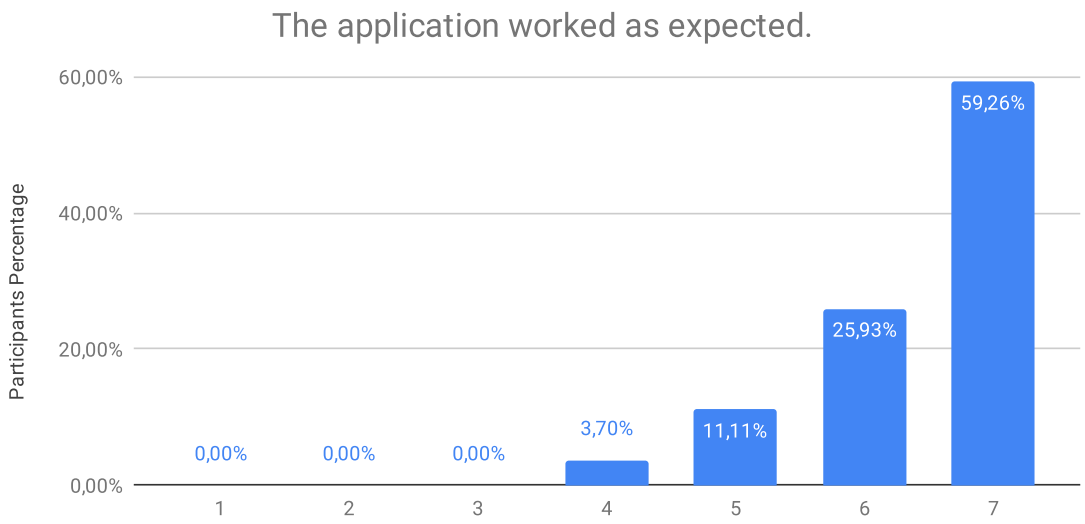


Figure 5.20: "The application worked as expected" responses (1- Strongly disagree, 7- Strongly agree)

The fifth question was about the need for a tutorial to use the application. The participants could choose yes or no. If yes was chosen, they had a space to specify which task they thought needed a tutorial.

In total 33% selected that they thought they needed a tutorial to use the application, with 44% percent of those participants specifying the task they thought needed a tutorial. From those participants that specified which task needed a tutorial, totalling four participants, two wrote that the application should give a better signal when the user is in the activity area, and the other two wrote that the *Rapinas AR* needed a tutorial to show the relationship between the birds' silhouettes and their names, before starting with the gameplay.

The following three questions were related to the map, starting with the sixth question in the questionnaire, which is about the usefulness of the map. Analysing Figure **5.21**, and with a median of 7 (Q1:7, Q3:7), the results were very positive.

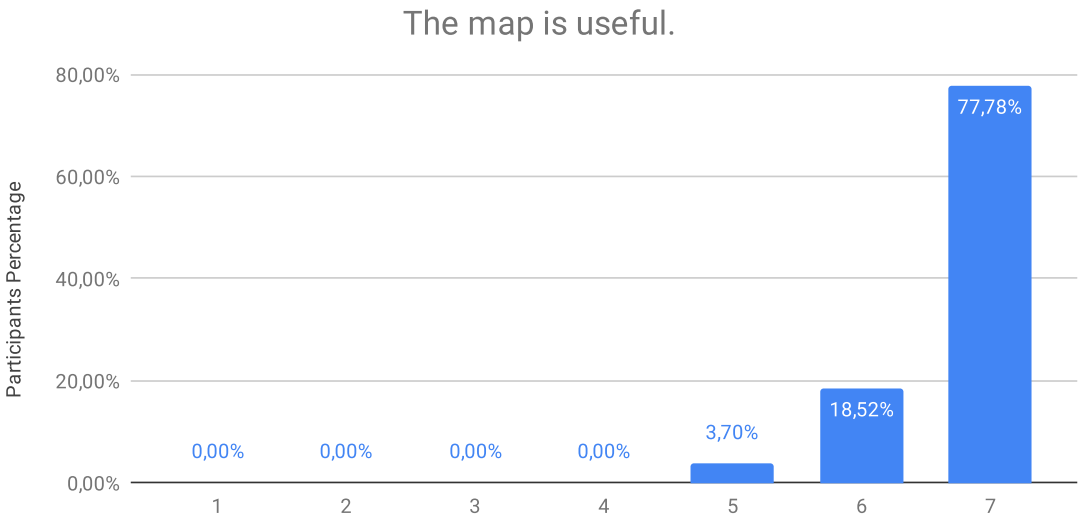


Figure 5.21: "The map is useful" responses (1- Strongly disagree, 7- Strongly agree)

It then followed with the seventh question, related to the map's ease of use. The results, as shown in Figure **5.22**, with a median of 7 (Q1: 6, Q3:7) were also very positive.

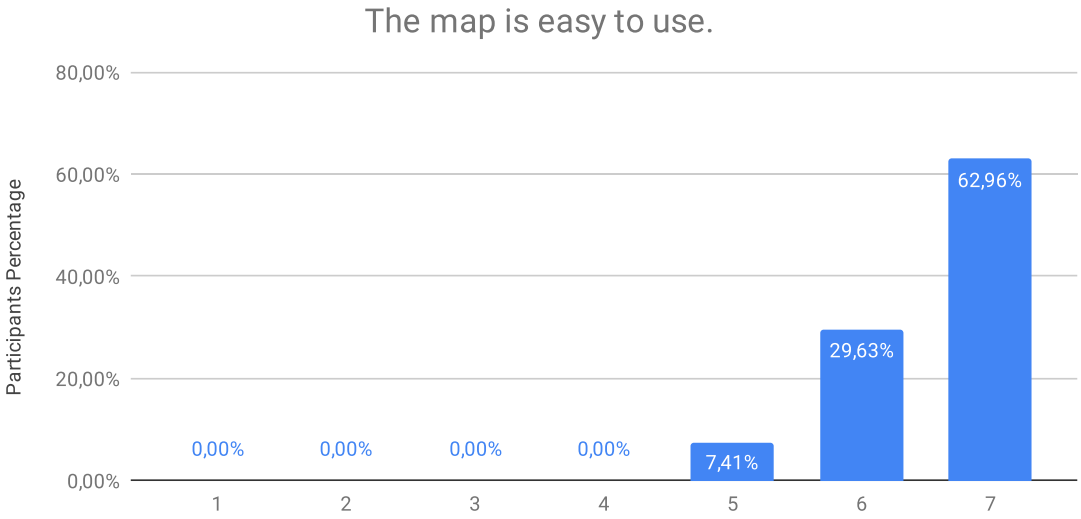


Figure 5.22: "The map is easy to use" responses (1- Strongly disagree, 7- Strongly agree)

The eighth question was about the dashed line which records the path taken by the user. Although the results were positive with a median of 6 (Q1: 5.5, Q3:7), and as shown in figure **5.23**, some participants, when they got to this question while filling the questionnaire, pointed out that they didn't notice the dashed line, which could have impacted this question negatively.

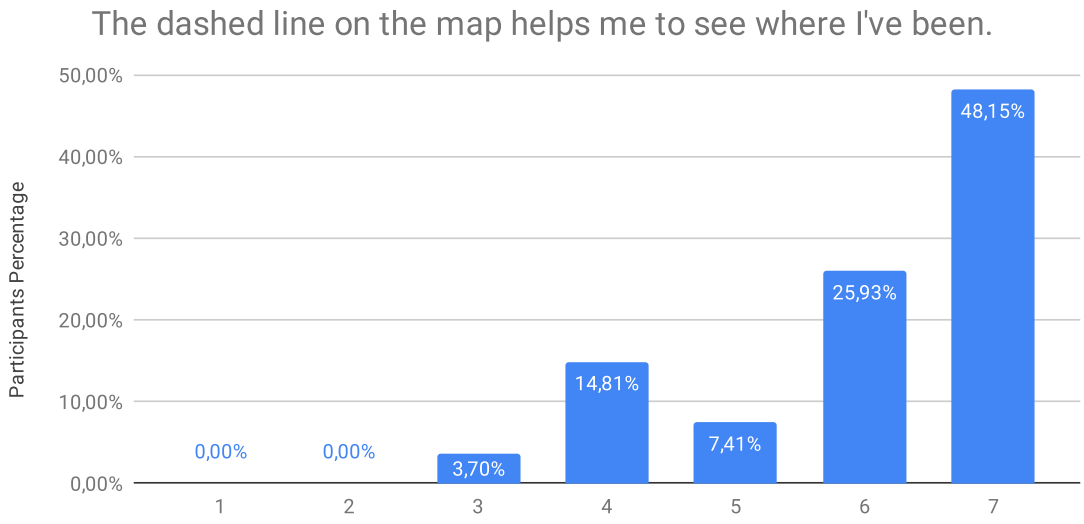


Figure 5.23: "The dashed line on the map helps me see where I've been" responses (1- Strongly disagree, 7- Strongly agree)

The ninth question was about the *Vida no Muro* and how it helped understand more about which species reside in the park's wall. The results were extremely positive, with a median of 7 (Q1: 7, Q3: 7), and as shown in Figure **5.24**.

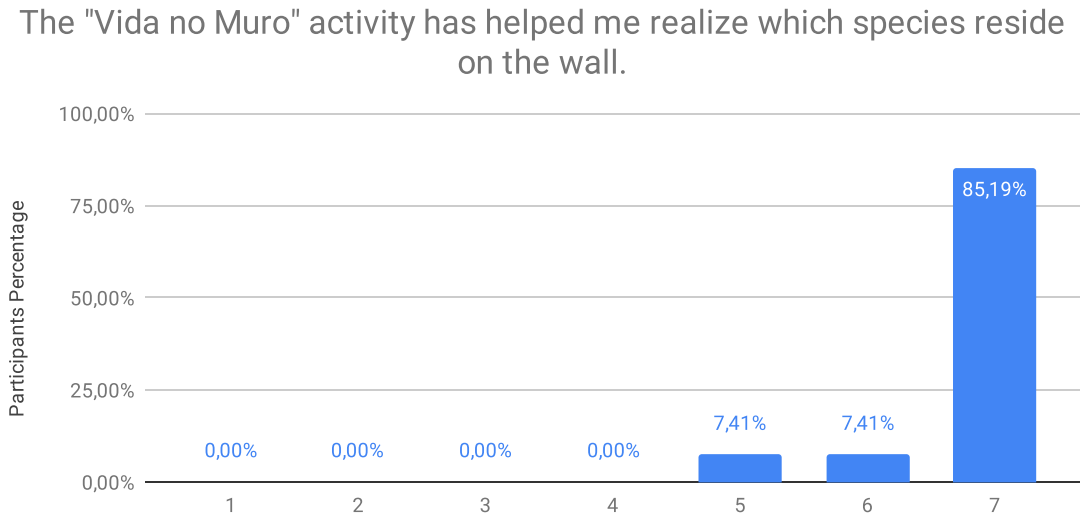


Figure 5.24: "The *Vida no Muro* activity has helped me realize which species reside on the wall" responses (1- Strongly disagree, 7- Strongly agree)

The following and tenth question was about how the *Rapinas AR* game leads to the birds' silhouettes being associated with the respective bird's name. The results, although not as positive as the question before, they were also very positive, with a median of 7 (Q1: 6, Q3: 7). Figure **5.25** shows the distribution of the responses given.

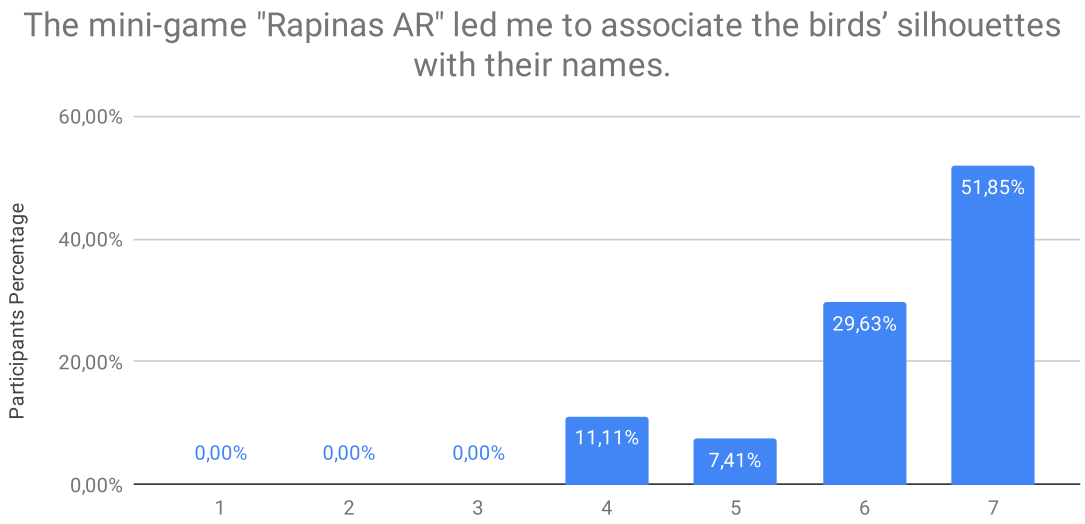


Figure 5.25: "The mini-game *Rapinas AR* led me to associate the birds' silhouettes with their names" responses (1- Strongly disagree, 7- Strongly agree)

It then followed with the eleventh question, which was related to using Augmented Reality in the activities and if the use of AR made the experience more memorable. The results, shown in Figure **5.26**, with a median of 7 (Q1: 6, Q3: 7) shows that the overwhelming majority of the participants agreed that using Augmented Reality made the experience more memorable. Being that the experience is more memorable using AR, this application can, possibly, lead to better absorption of the scientific knowledge that it is trying to disseminate.

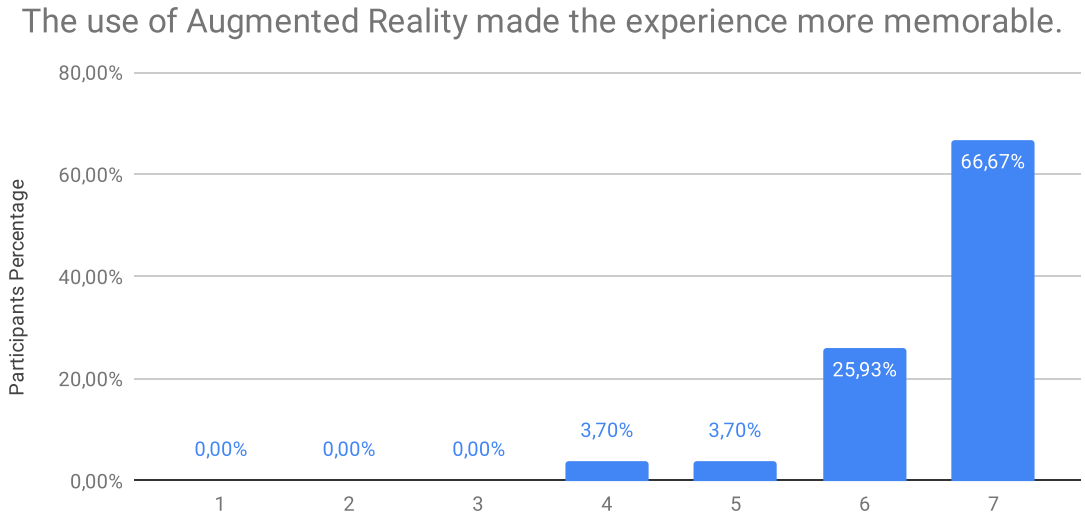


Figure 5.26: "The use of Augmented Reality made the experience more memorable" responses (1- Strongly disagree, 7- Strongly agree)

The twelfth question was done to evaluate the effectiveness of the notification that happened when a new collectable species was unlocked. Although the results, shown in Figure **5.27**, were positive, with a median of 6 (Q1: 4.5, Q3: 7), they weren't as positive as expected, thus the respective notification needs to be improved.

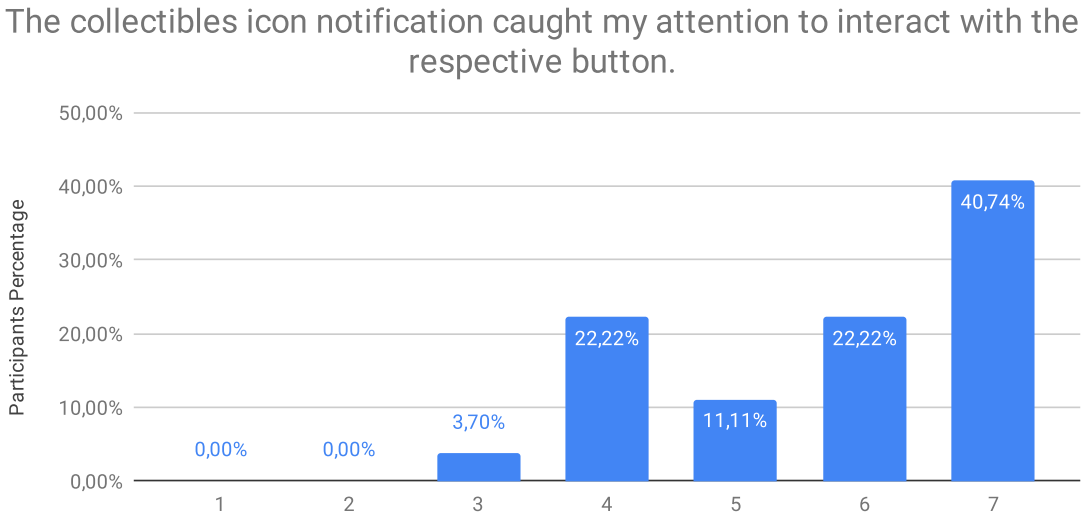


Figure 5.27: "The collectibles icon notification caught my attention to interact with the respective button" responses (1- Strongly disagree, 7- Strongly agree)

The following and thirteenth question was about the effectiveness of having collectables in order to make the users want to try all the park's activities. The positive results, shown in Figure **5.28**, with a median of 6 (Q1: 6, Q3: 7), shows that having collectable species can probably entice exploration.

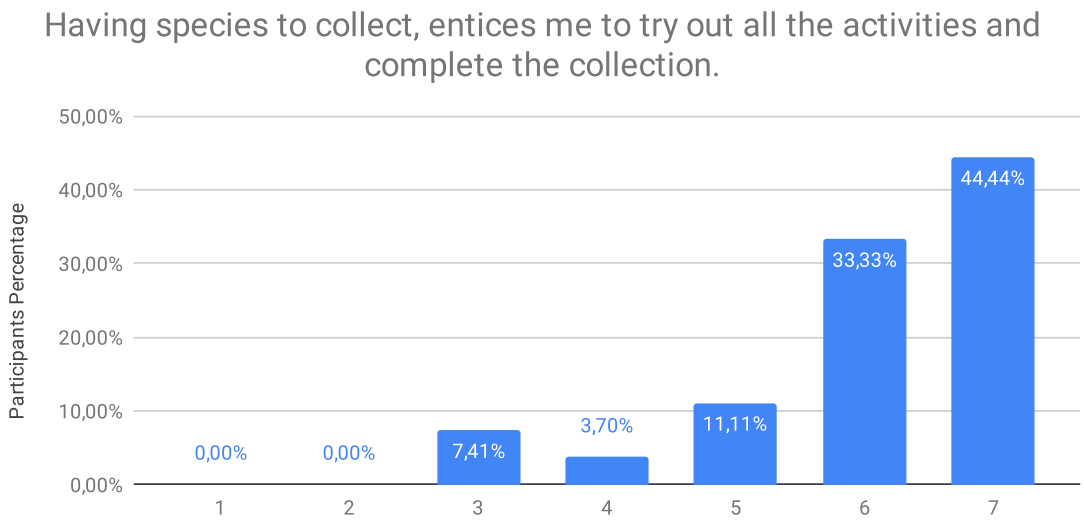


Figure 5.28: "Having species to collect, entices me to try out all the activities and complete the collection" responses (1- Strongly disagree, 7- Strongly agree)

Related to the species information presented by the application, the results of question fourteenth (Figure **5.29**), with a median of 7 (Q1: 6, Q3: 7) show a very positive outcome.

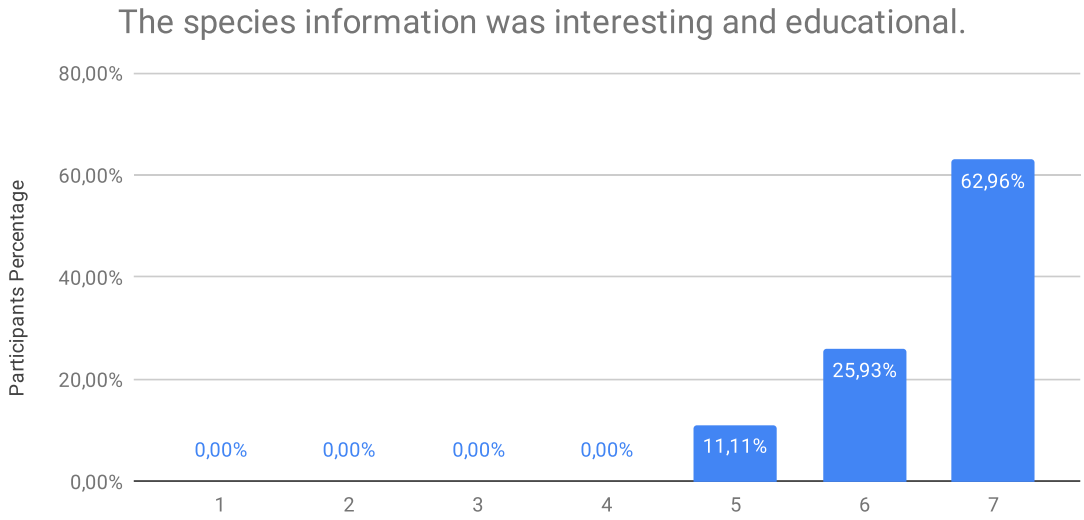


Figure 5.29: "The species information was interesting and educational" responses (1- Strongly disagree, 7- Strongly agree)

Also, with only positive responses, the fifteenth question, as shown in Figure **5.30**, with a median of 7 (Q1: 6, Q3: 7), tells that the participants thought the application had an effective educational component, which goes in favour of the application goal, stated in section **1.2**, of disseminating scientific knowledge.

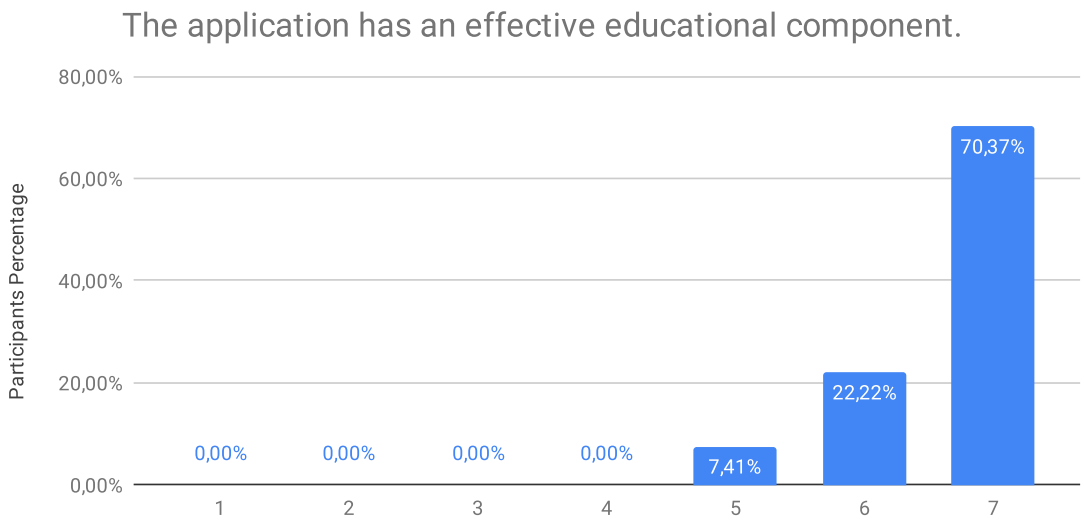


Figure 5.30: "The application has an effective educational component" responses (1- Strongly disagree, 7- Strongly agree)

Finishing the first part of the questionnaire, the sixteenth question, related to the application visuals, as shown in Figure **5.31**, and with a median of 7 (Q1: 6.5, Q3: 7), also had very positive results.

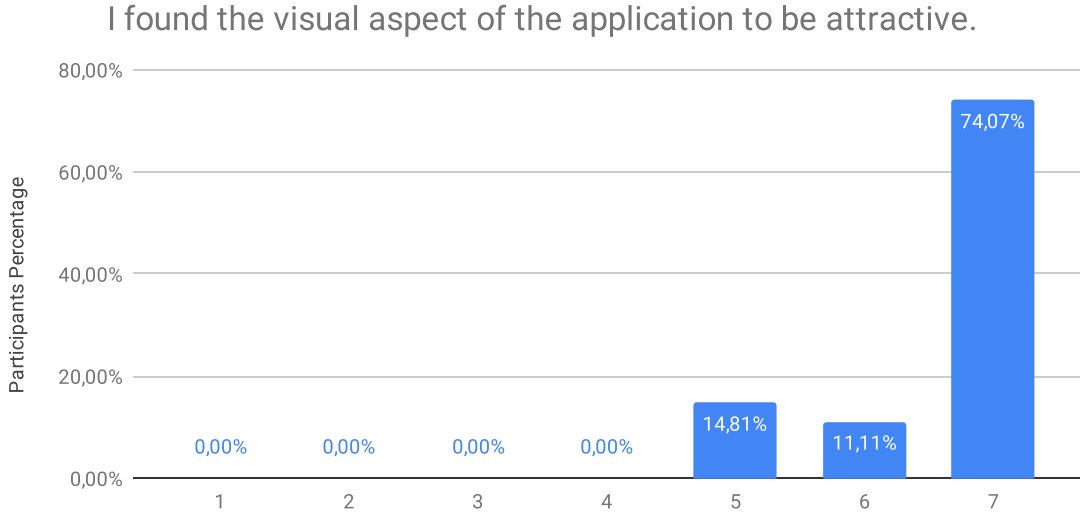


Figure 5.31: "I found the visual aspect of the application to be attractive" responses (1- Strongly disagree, 7- Strongly agree)

The second part of the questionnaire used the System Usability Scale (SUS). The average score was 85.74 ± 12.80, which means that, as it's above 68, its above average. Since it is also above 80.3, according to Sauro [Sau11], it ranks in the top 10% of the scores with an A grade (ranking goes A+ to F).

The final and optional field in the questionnaire had the participants write comments and suggestions. Contrary to previous tests, there were a lot of comments and suggestions, which can be grouped as the following: Appreciation comments, UI improvement comments and *Rapinas AR* tutorial comments.

- **Appreciation comments –** In these type of comments, the participants just wrote that they liked the experience and the application, with some of them writing that they would like to see the application being expanded with more activities throughout the park and supported in other operating systems like IOS and Windows. There were also multiple instances of participants asking from where they could install the application into their device.
- **UI improvement comments –** These comments had the common theme of being related to notifications. They were all requests to make the dashed line of the map and the notification of the activities more visible. There was also one participant that wrote that he felt confused with the "x" icon that is used to close the species information screen as he didn't know if it was closing the application or returning to the previous screen.
- ***Rapinas AR* tutorial comments –** This type of comments was made by multiple participants, stating that they felt the need for some kind of tutorial that would better introduce the birds, before the gameplay started.

The following table (table **4**) recaps the questionnaire questions that could lead to modifications in the application.

Table 4: Test in the park summary table

Questionnaire questions about the experience	1st Quartile	Median	3rd Quartile
The application worked as expected.	6	7	7
The map is useful.	7	7	7
The map is easy to use.	6	7	7
The dashed line on the map helps me to see where I've been.	5.5	6	7
The *Vida no Muro* activity has helped me realize which species reside on the wall" responses.	7	7	7
The mini-game *Rapinas AR* led me to associate the birds' silhouettes with their names.	6	7	7
The use of Augmented Reality made the experience more memorable.	6	7	7
The collectibles icon notification caught my attention to interact with the respective button.	4.5	6	7
Having species to collect, entices me to try out all the activities and complete the collection.	6	6	7
The species information was interesting and educational.	6	7	7

The application has an effective educational component.	6	7	7
I found the visual aspect of the application to be attractive.	6.5	7	7

Following the table **4** and the analysis of the results made, the application overall had very positive results. This show that no major modifications are needed. Additionally, it confirms the positive effects of the modifications made, that were the results of the analysis of the tests described in sections **5.1**, **5.2** and **5.3**. An example of that being the *Rapinas AR* and the lack of comments about tiredness or any type of discomfort while playing the minigame during this test.

The results of this test also show that there is a need for some kind of tutorial or previous information that can lead to the association of the birds and their silhouettes, before the start of the *Rapinas AR* gameplay.

In addition, the results show that some modifications to the user interface should be made. Those modifications include, making the dashed line more visible and improving both notifications of being in an activity area, and of unlocking a new collectable species, to make them more noticeable to the user.

Chapter 6

Conclusions

Many people don't leave from home without having the certainty that their phone is in their pocket. These portable devices have changed the world with the way they evolved, from being simple communication devices to tools full of functionalities to help their users. Being equipped with a lot of features, such as, cameras, internet access, GPS, gyroscope and running operating systems capable of performing tasks similar to the more traditional desktop operating systems, these now called smartphones permit almost limitless opportunities to develop solutions to the more varied type of tasks.

Some of these tasks can be the proliferation of educational content, helping their users navigate and explore an unknown place, or simply entertaining their users. These last-mentioned tasks are a common theme throughout any tourist experience.

A tourist is anyone visiting a place outside their everyday environment trying to experience recreational and pleasant activities. Nature parks are among the places visited by those type of people, and being vast open areas, these types of parks have difficulties showing their visitors, what they have to offer.

With 35 hectares populated with hundreds of species living in a wild state, the nature park "Parque Biológico de Gaia", located in Avintes, Porto, is an example of that said tourist location. Its course, of about 3 kilometres, was designed to expose the park's visitors for the various components of the Natural and Cultural Heritage of the region, but because of the park's size, a lot of that information can't be highlighted and thus, it is not noticed by the visitors.

This situation opens an opportunity that led to the focus of this dissertation and the tackle of the research question established in section **1.2**. Having set the objective of answering that question, a need to research the topic related to the question arouse, which then served as a basis for the design and implementation of the proposed solution, which was described in chapter **3**.

This proposed solution resulted in a prototype of a mobile application, designed to be used in the "Parque Biológico de Gaia" as its content is directly related to the park.

The prototype, as shown in chapter **5**, was tested multiple times in the middle of its development, so that issues, being them design or implementation issues, could be detected and fixed.

A final test (described in section **5.2**), more representative of the experience a park's visitor would have when using the prototype was performed, in order to evaluate the application. Therefore, the results of this test would give an answer to the established question "Can a location-based mobile application integrating augmented reality and gamification elements improve the visitors' experience while at the same time disseminate scientific knowledge?".

The very positive results of this test, shown in subsection **5.4.2**, indicate that the answer to that question is yes and that the developed prototype is an example of said application, but it must be noted that the small sample of users in the test doesn't allow for this conclusion to be definitive. A bigger sample of users during the test would indeed help to prove such claims.

6.1. Future Work

As said in subsection **5.4.2**, although the results were overall very positive, there were some issues raised by the test participants, thus the resolution of said issues could improve the overall user experience.

One of these issues was the lack of a tutorial or some kind of information that would help the users associate the birds and their silhouettes, before the start of the *Rapinas AR* gameplay.

There were also some problems detected with the dashed line on the map and the notifications not being visible enough. For the dashed line, an increase on its thickness would increase its visibility and probably resolve its visibility problem.

A solution for the notification visibility problem could be solved by using the addition of sounds and vibration when the user is near, or at the location of an activity.

The application can also be improved with the addition of support of *ARKit* and *ARCore*. The support could be added as an additive to the current Augmented Reality solutions by supporting the *Wikitude*'s SMART functionality. The SMART functionality is a technology that checks the phone support for either *ARKit* or *ARCore* and uses them if supported, thus allowing the supported devices to take advantages of the features of *ARKit* or *ARCore*.

This added support would also go in favour of the request by some of the users to expand to IOS as *ARKit* is only compatible with *Apple*'s iPhones.

Optimizations should also be done to the assets, in order to reduce the final application size. There are also some aspect ratios that aren't fully supported. These are mainly the new aspect ratios appearing in the market, mostly widescreen variations such as 18:9, 18.5:9, 18.7:9, 19.5:9, 19:9, 21:9 and other similar variants that aren't identical to the tested and most common aspect ratio 16:9.

In these devices the application can be stretched or cropped depending on the version of Android the device uses, thus compromising the visual fidelity of the application and its content.

A solution would be to have the application detect the aspect ratio and adjust the UI elements and the viewport accordingly and without stretching.

Some features that could be added are the ability to zoom in on the map and the addition of variable zoom to the binoculars instead of as it is now.

Also, as the park is constantly being visited by tourists from the various corners of the world, the application should support more languages other than Portuguese.

References

[Est17] Estatísticas do Turismo 2017. Instituto Nacional de Estatística, I. P. Lisboa: INE, I. P., 2018. ISBN:978-989-25-0447-6.

[Ken12] Kennedy-Eden, H., & Gretzel, U. (2012). A taxonomy of mobile applications in tourism. *E-Review of Tourism Research*.

[Gee06] Gee, J. P. (2006). Why game studies now? Video games: A new art form. *Games and Culture*. https://doi.org/10.1177/1555412005281788

[Car11] Carmigniani, J., Furht, B., Anisetti, M., Ceravolo, P., Damiani, E., & Ivkovic, M. (2011). Augmented reality technologies, systems and applications. *Multimedia Tools and Applications*. https://doi.org/10.1007/s11042-010-0660-6

[Avo12] Avouris, N., & Yiannoutsou, N. (2012). A review of mobile location-based games for learning across physical and virtual spaces. *Journal of Universal Computer Science*. https://doi.org/10.1016/j.compedu.2011.04.006

[Bro03] Brown, B., & Chalmers, M. (2003). Tourism and mobile technology. In ECSCW 2003. https://doi.org/10.1007/978-94-010-0068-0_18

[San17] Santos, L., Pereira, D., Beça, P., Nóbrega, R., & Coelho, A. (2017). Aplicação móvel para divulgação do património natural no turismo. *Revista Turismo & Desenvolvimento (RT&D)/Journal of Tourism & Development*.

[Han17] Han, Dai-In & Tom Dieck, M. Claudia & Jung, Timothy. (2017). User Experience Model for Augmented Reality Applications in Urban Heritage Tourism. Journal of Heritage Tourism. 10.1080/1743873X.2016.1251931.

[Sos13] Sosyal, A., & Dergisi, A. (2013). Gökçe Dislen the Reasons of Lack of Motivation from the Students' and Teachers' Voices. *The Journal of Academic Social Science*.

[Leg06] Legault, L., Green-Demers, I., & Pelletier, L. (2006). Why do high school students lack motivation in the classroom? Toward an understanding of academic amotivation and the role of social support. *Journal of Educational Psychology*. http://doi.org/10.1037/0022-0663.98.3.567

[Shu12] Shute, V. J., & Ke, F. (2012). Games, learning, and assessment. In Assessment in Game-Based Learning: Foundations, Innovations, and Perspectives. https://doi.org/10.1007/978-1-4614-3546-4_4

[Mic06] Michael, D., & Chen, S. (2006). Serious Games: Games That Educate, Train, and Inform. *Education*. http://doi.org/10.1021/la104669k

[Laa14] Laamarti, F., Eid, M., & El Saddik, A. (2014). An overview of serious games. *International Journal of Computer Games Technology*. http://doi.org/10.1155/2014/358152

[Sus07] Susi, T., Johannesson, M., & Backlund, P. (2007). Serious Games – An Overview. *Technical Report*. http://doi.org/10.1.1.105.7828

[Wik08] Wikimedia, Chess Starting Position 2008, https://en.wikipedia.org/wiki/Chess.

[XPl19] X.Plane, Copilot Approach Menu, 2019, https://www.x-plane.com/ .

[Stea19] Steam, America's Army: Proving Grounds, 2019, https://store.steampowered.com/app/203290/Americas_Army_Proving_Grounds/.

[Haa15] Haahtela, P. (2015). Gamification of Education: Cities Skylines as an educational tool for real estate and land use planning studies

[Hen13] Hendrix, M., & Backlung, P. (2013). Educational Games – Are They Worth The Effort ? In *5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)*. https://doi.org/10.1109/VS-GAMES.2013.6624226

[Ibr09] Ibrahim, R., & Jaafar, A. (2009). Educational games (EG) design framework: Combination of game design, pedagogy and content modeling. In *Proceedings of the 2009 International Conference on Electrical Engineering and Informatics, ICEEI 2009*. https://doi.org/10.1109/ICEEI.2009.5254771

[Dra19] DragonBox, Small Elements, 2019, https://dragonbox.com/products/elements.

[PIX10] PIXELearning's Blog - Serious Games and more, Hanger scene security suspects, 2010, https://pixelearning.wordpress.com/category/awards/.

[Rig18] Rigshospitalet, P*icture from the 'Ballade på Badebroen' (trouble on the jetty) VR game,* 2018, https://www.behance.net/gallery/63514283/Healthcare-VR-Game-Ballade-pa-Badebroen.

[Che05] Cheok, A. D., & Nilsen, T. (2005). Pervasive Games: Bringing Computer Entertainment Back to the Real World. *Computers in Entertainment – Theoretical and Practical Computer Applications in Entertainment*. https://doi.org/10.1145/1077246.1077257

[Opp16] Oppermann, L., & Slussareff, M. (2016). Pervasive games. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/978-3-319-46152-6_18

[Geo11] Geocaching, A "GEO-metry" lesson plan from Ellis Reyes, 2011, https://www.geocaching.com/blog/tag/geocachingedu/page/2/.

[GeoAzores11] Geocaching, Faja do Araujo [Sao miguel - Açores], 2011, https://www.geocaching.com/geocache/GC379W1_faja-do-araujo-sao-miguel-acores.

[The17] The Verge, IngressPrime screenshot comparison, 2017, https://www.theverge.com/2017/12/2/16725884/ingress-prime-update-niantic-pokemon-go.

[Mor17] Morschheuser, B., Riar, M., Hamari, J., & Maedche, A. (2017). How games induce cooperation? A study on the relationship between game features and we-intentions in an augmented reality game. *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2017.08.026

[Che14] Chess, S. (2014). Augmented regionalism: Ingress as geomediated gaming narrative. *Information Communication and Society*. https://doi.org/10.1080/1369118X.2014.881903

[Sam18] Samji, B. (2018). Analysing Immersion, Presence, and Interaction and its effects in Augmented Reality (AR) Mobile Games. Master. University of Dublin. https://scss.tcd.ie/publications/theses/diss/2018/TCD-SCSS-DISSERTATION-2018-061.pdf

[Pok17] Pokemon Go Wiki, Pokémon becomes aware, 2017, https://pokemongo.fandom.com/wiki/AR_Plus.

[Kys15] Kysela, J., & Štorková, P. (2015). Using Augmented Reality as a Medium for Teaching History and Tourism. *Procedia - Social and Behavioral Sciences*. https://doi.org/10.1016/j.sbspro.2015.01.713

[Söb17] Söbke, Heinrich & Hauge, Jannicke & Andreea Stefan, Ioana. (2017). Prime Example Ingress Reframing the Pervasive Game Design Framework (PGDF). 2384-8766. 4. 10.17083/ijsg.v4i2.182

[Wet11] Wetzel, R., Blum, L., Broll, W., & Oppermann, L. (2011). Designing Mobile Augmented Reality Games. In *Handbook of Augmented Reality*. https://doi.org/10.1007/978-1-4614-0064-6_25

[Ere13] Erenli, K. (2013). Gamify your teaching - using location-based games for educational purposes. *International Journal of Advanced Corporate Learning (IJAC)*. https://doi.org/10.3991/ijac.v6i2.2960

[Sch08] Jesse Schell. (2008). *The art of game design*. *The Art of Game Design: A Book of Lenses*. https://doi.org/10.1017/CBO9781107415324.004

[Kii12] Kiili, K., De Freitas, S., Arnab, S., & Lainema, T. (2012). The design principles for flow experience in educational games. In *Procedia Computer Science*. https://doi.org/10.1016/j.procs.2012.10.060

[Per13] Perrotta, Carlo; Featherstone, Gill; Aston, Helen; Houghton, E. (2013). *Game Based Learning: Latest Evidence And Future Directions*. *NFER (National Foundation for Educational Research)*. https://doi.org/10.1089/space.2013.0025

[Gun06] Gunter, G. A., Ph, D., Kenny, R. F., & Vick, E. H. (2006). A case for a formal design paradigm for serious games. *The Journal of the International Digital Media and Arts Association*.

[Tsa16] Tsai, T. H., Chang, H. T., Yu, M. C., Chen, H. T., Kuo, C. Y., & Wu, W. H. (2016). Design of a mobile augmented reality application: An example of demonstrated usability. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*. https://doi.org/10.1007/978-3-319-40244-4_19

[Ard10] Ardito, C., Sintoris, C., & Raptis, D. (2010). Design Guidelines for Location-based Mobile Games for Learning. *... for Life Long Learning*. https://doi.org/10.1145/3202185.3205871

[Zen08] Zendjebil, I., Ababsa, F.-E., Didier, J.-Y., Vairon, J., Frauciel, L., Hachet, M., … Delmont, R. (2008). Outdoor Augmented Reality: State of the Art and Issues. *10th ACM/IEEE Virtual Reality International Conference (VRIC 2008)*.

[Lee12] Lee, G. A., Dunser, A., Kim, S., & Billinghurst, M. (2012). CityViewAR: A mobile outdoor AR application for city visualization. In *11th IEEE International Symposium on Mixed and Augmented Reality 2012 - Arts, Media, and Humanities Papers, ISMAR-AMH 2012*. https://doi.org/10.1109/ISMAR-AMH.2012.6483989

[Lay15] Lavery, R. (2015). *Smithsonian Brings Historic Specimens to Life in Free "Skin and Bones" Mobile App*. [online] Smithsonian. Available at: https://www.si.edu/newsdesk/releases/smithsonian-brings-historic-specimens-life-free-skin-and-bones-mobile-app [Accessed 7 Feb. 2019].

[Mar15] Marques, D., & Costello, R. (2015). Skin & bones: an artistic repair of a science exhibition by a mobile app. *MIDAS. Museus e estudos interdisciplinares*, (5).

[Usa05] Usability Body of Knowledge. (2005). *Principles for Usable Design*. [online] Available at: https://www.usabilitybok.org/principles-for-usable-design.

[Gra05] Gray, K., Gable, K., Shodhan, S. and Kucic, M. (2005). How to Prototype a Game in Under 7 Days. Available at: https://www.gamasutra.com/view/feature/130848/how_to_prototype_a_game_in_under_7_.php?page=3 [Accessed 20 Jun. 2019].

[Kha17] Khagwal, N. (2017). *How Progress Bars or Loaders Impacts the User Experience?*. [online] Available at: https://medium.muz.li/how-progress-bars-or-loaders-impacts-the-user-experience-5082370f810b [Accessed 20 Jun. 2019].

[Fra11] Frattesi, T., Griesbach, D., Leith, J., & Shaffer, T. (2011). Replayability of Video Games. https://web.wpi.edu/Pubs/E-project/Available/E-project-051711-130604/unrestricted/Replayability_of_Video_Games_2011.pdf [Accessed 19 Jun. 2019].

[GPS17] GPS.gov. (2017). *GPS Accurancy*. [online] Available at: https://www.gps.gov/systems/gps/performance/accuracy/#how-accurate [Accessed 24 Jun. 2019].

[Abr04] Abras, C., Maloney-Krichmar, D., & Preece, J. (2004). User-centered design. *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, *37*(4), 445-456.

[Sau11] Sauro, J. (2011). *Measuring Usability with the System Usability Scale (SUS)*. [online] MeasuringU. Available at: https://measuringu.com/sus/ [Accessed 26 Jun. 2019].

Appendix

Usability Tests Questionnaires

“Rapinas AR” Indicators Test Questionnaire

Teste Rapinas AR
Responda às questões que se seguem assinalando a opção que achar mais adequada.

1. **Idade**

2. **Quão frequentemente faz uso de aplicações móveis por dia?**
   Marcar apenas uma oval.

   - ◯ Nunca
   - ◯ Menos de 1 vez por dia
   - ◯ Entre 1 a 5 vezes por dia
   - ◯ Mais de 5 vezes por dia

3. **O jogo respondeu conforme esperado aos controlos.**
   Marcar apenas uma oval.

   - ◯ Discordo plenamente
   - ◯ Discordo
   - ◯ Não tenho opinião
   - ◯ Concordo
   - ◯ Concordo plenamente

4. **Achei o jogo divertido.**
   Marcar apenas uma oval.

   - ◯ Discordo plenamente
   - ◯ Discordo
   - ◯ Não tenho opinião
   - ◯ Concordo
   - ◯ Concordo plenamente

5. **Gostei do aspecto visual do jogo.**
   Marcar apenas uma oval.

   - ◯ Discordo plenamente
   - ◯ Discordo
   - ◯ Não tenho opinião
   - ◯ Concordo
   - ◯ Concordo plenamente

6. **Indique a (s) faixa (s) etária (s) que considera adequada (s) para esta aplicação (Pode escolher mais do que uma opção).**
   Marcar tudo o que for aplicável.

   - ☐ Menos de 18
   - ☐ 18 - 35
   - ☐ 36-50
   - ☐ 51-64
   - ☐ Mais de 64

7. **Comentários/Sugestões:**

Application Map Test Questionnaire

Inquérito - Mapa

*Obrigatório

1. **UserID** *

2. **Idade** *

3. **Género** *
   Marcar apenas uma oval.
   - ◯ Masculino
   - ◯ Feminino
   - ◯ Outra: _____

4. **Eu uso o meu smartphone ...** *
   Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Nunca (não possuo um smartphone)	◯	◯	◯	◯	◯	◯	◯	Várias vezes durante o dia

5. **Estou à vontade com aplicações como o Google maps, Apple maps, etc.** *
   Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Não estou à vontade (não conheço)	◯	◯	◯	◯	◯	◯	◯	Muito à vontade (uso frequentemente)

6. **Foi fácil localizar-me no mapa.** *
   Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

7. **Foi fácil perceber no mapa, para onde estava virado.** *
   Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

8. **Reparei nos icons ...** *

Icon 1

Icon 2

Marcar apenas uma oval.

- ◯ Não reparei.
- ◯ Reparei apenas no icon 1.
- ◯ Reparei apenas no icon 2.
- ◯ Reparei em ambos os icons.

9. **Gostei do aspeto visual da aplicação.** *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

10. **Comentário/Sugestão**

Application Map Test Observer Form

Inquérito - Mapa (Observador)

*Obrigatório

1. **User ID** *

2. **Conseguiu indicar corretamente o ponto de interesse mais perto.** *
   Marcar apenas uma oval.
   - ◯ Sim
   - ◯ Não
   - ◯ Não aplicável

3. **Conseguiu indicar corretamente para onde se tinha de virar de modo a conseguir movimentar-se para o ponto de interesse mais perto.** *
   Marcar apenas uma oval.
   - ◯ Sim
   - ◯ Não
   - ◯ Não aplicável

4. **Conseguiu indicar corretamente para que serve o tracejado.** *
   Marcar apenas uma oval.
   - ◯ Sim
   - ◯ Não
   - ◯ Não aplicável

5. **Outras notas**

“Vida no Muro” Aligners Test Questionnaire

Inquérito - Vida no Muro

*Obrigatório

1. **UserID** *

2. **Idade** *

3. **Género** *
   Marcar apenas uma oval.
   - ◯ Masculino
   - ◯ Feminino
   - ◯ Outra: _____

4. **Eu uso o meu smartphone ...** *
   Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Nunca (não possuo um smartphone)	◯	◯	◯	◯	◯	◯	◯	Várias vezes durante o dia

5. **Estou à vontade com aplicações de Realidade Aumentada.** *
   Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Não estou à vontade (não conheço)	◯	◯	◯	◯	◯	◯	◯	Muito à vontade (uso frequentemente)

6. **Consegui fazer o scan do muro corretamente.** *
   Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

7. **Foi fácil perceber que tinha de alinhar o topo e o fundo do indicador com o topo e o fundo do muro.** *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

8. **Comentário/Sugestão**

“Vida no Muro” Aligners Test Observer Form

Inquérito - Vida no Muro (Observador)

*Obrigatório

1. **User ID** *

2. **Tipo de Scan** *
   Marcar apenas uma oval.
   - ◯ Normal (COM texto indicativo no topo e em baixo)
   - ◯ Normal Alternativo (SEM texto indicativo)
   - ◯ Simular QR Code scanner comum (escuro à volta)

3. **Conseguiu iniciar corretamente o scan sem mais instruções.** *
   Marcar apenas uma oval.
   - ◯ Sim
   - ◯ Não
   - ◯ Não aplicável

4. **Conseguiu fazer o scan corretamente.** *
   Marcar apenas uma oval.
   - ◯ Sim
   - ◯ Não
   - ◯ Não aplicável

5. **Outras notas**

Test in the park Questionnaire

Inquérito - App PBG-AR

*Obrigatório

1. **Idade** *

2. **Género** *
Marcar apenas uma oval.
- Masculino
- Feminino
- Outra: _____

3. **Eu uso o meu smartphone ...** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Nunca (não possuo um smartphone)								Várias vezes durante o dia

4. **A aplicação funcionou como esperava.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente								Concordo totalmente

5. **Senti necessidade de um tutorial para utilizar a aplicação ?**
Marcar apenas uma oval.
- Sim, na tarefa: _____
- Não

6. **O mapa é útil.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente								Concordo totalmente

7. **O mapa é fácil de usar.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente								Concordo totalmente

8. **O tracejado no mapa ajuda-me a perceber por onde já passei.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

9. **A atividade "Vida No Muro" ajudou-me a perceber que espécies residem no muro.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

10. **O mini-jogo "Rapinas AR" levou-me a associar as silhuetas dos pássaros com os seus respetivos nomes.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

11. **O uso de Realidade Aumentada tornou a experiência mais memorável.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

12. **A notificação no ícone dos colecionáveis chamou-me à atenção para interagir com o respetivo botão.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

13. **Ter espécies para colecionar, alicia-me a experimentar todas as atividades e completar a coleção.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

14. **A informação das espécies foi interessante e educativa.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

15. **A aplicação tem uma componente educativa eficaz.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

16. **16. Achei que o aspeto visual da aplicação era atrativo.** *
Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

SUS

17. **Eu acho que gostaria de usar este sistema com frequência.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

18. **Eu acho a aplicação desnecessariamente complexa.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

19. **Eu achei a que aplicação foi fácil de usar.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

20. **Eu acho que precisaria de ajuda de uma pessoa com conhecimentos técnicos para usar a aplicação.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

21. **Eu acho que as várias funções da aplicação estão muito bem integradas.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

22. **Eu acho que a aplicação é muito inconsistente.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

23. **Eu imagino que as pessoas aprenderão rapidamente a usar esta aplicação.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

24. **Eu achei a aplicação atrapalhada de usar.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

25. **Eu senti-me confiante ao usar a aplicação.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

26. **Eu precisei de aprender várias coisas novas, antes de conseguir usar a aplicação.** *
Marcar apenas uma oval.

	1	2	3	4	5	
Discordo totalmente	◯	◯	◯	◯	◯	Concordo totalmente

27. **Comentários/Sugestões.**

Consent Form

DECLARAÇÃO DE CONSENTIMENTO

(Baseada na declaração de Helsínquia)

No âmbito da realização da tese de Mestrado do Mestrado Integrado de Engenharia Informática e Computação da Faculdade de Engenharia da Universidade do Porto, intitulada Outdoor Park Exploration using Augmented Reality and Mobile Computing realizada pelo estudante Nuno Filipe Sousa e Silva, orientado pelo Prof. Rui Nóbrega e sobre a coorientação do Prof. António Coelho, eu abaixo assinado, declaro que compreendi a explicação que me foi fornecida acerca do estudo no qual irei participar, nomeadamente o carácter voluntário dessa participação, tendo-me sido dada a oportunidade de fazer as perguntas que julguei necessárias.

Tomei conhecimento de que a informação ou explicação que me foi prestada versou os objetivos, os métodos, o eventual desconforto e a ausência de riscos para a minha saúde, e que será assegurada a máxima confidencialidade dos dados.

Explicaram-me, ainda, que poderei abandonar o estudo em qualquer momento, sem que daí advenham quaisquer desvantagens. Por isso, consinto participar no estudo, respondendo a todas as questões propostas.

Porto, __ de _____ de 201_

(Participante ou seu representante)