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RODRIGO FERREIRA DOS SANTOS PERESTRELLO DE ALARCÃO

AUGMENTED REALITY CONCEPT TO IMPROVE PUBLIC AWARENESS AND SAFETY AT THE BEACH

Projeto apresentado ao IADE - Faculdade de Design, Tecnologia e Comunicação da Universidade Europeia, para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Design de Interação realizada sob a orientação científica do Professor Doutor Gabriel César Ferreira Pestana da Universidade Europeia.

Keywords

Beach safety, Rip Currents, Augmented Reality, Gamification, and Interaction Design

Abstract

Rip currents pose a threat to the safety of bathers at most beaches around the world. Risk perception and swimming preference are critical factors for safety at beaches. In general, the inability to detect a rip current and a false sense of security may lead to situations where people are confronted with unforeseen dangers. The presented research intends to contribute to improving beach safety with situational-awareness data to keep bathers informed about undergoing dangers on a selected beach. As such, the need to create a beach-safety culture and a provocative social conscience in adopting safety behaviors at the beach, during leisure time, is a ground-breaking goal. The research presents a study regarding people understanding about rip currents and other (potential) beach dangerous situations and analyze their willingness to integrate a community of users and to collaboratively contribute to improving safety at the beach, in particular for social groups with children, older adults and citizens who would like to improve their beach-safety literacy.

The proposed approach includes the specification of a platform to empower the user in becoming an active beach-safety agent. For this strategic objective, a service design approach was implemented to conceptualize a solution for collecting data about potential hazards, including information on the status of active rip currents. The innovation is settled over the combination of immersive technologies (e.g., Augmented Reality) with visual data analytics and Artificial Intelligence (AI), in particular Deep Learning algorithms for image processing. Mobile Augmented Reality mixed with a gamification strategy are two other technologies considered in the architectural design of an interactive and gamified environment in promoting a beach-safety behavior. Such a mobile tool also addresses a strategy to create a social movement challenging citizens to integrate and benefit from the services and informational artifacts provided by the Beach Safety Community (BSC).

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1. Introduction

Rip currents pose a threat to the safety of bathers at most beaches around the world. The number of rip drownings worldwide is unknown due to the lack of a standard method in collecting and analyzing the data (Fletemeyer. and Stephen, 2010). According to Drozdzewski (2012), the number of drowning deaths caused by rip currents exceeds 1000 per year. Additionally, statistics from the U.S. Lifesaving Association (USLA, 2010) indicate that 80% of all lifeguard rescues are related to rip currents. There is similar data in Australia, where rip currents have been responsible for 23% of drowning deaths since 2004 (Brighton et al., 2013) and responsible for 89% of the 25,000 annual rescues conducted by lifeguards. According to Brighton, rip currents are also a major beach threat in Brazil, in the United Kingdom, and Colombia.

The inability to detect a rip current and the false sense of security may lead to a dangerous situation (Caldwell et at., 2013). For this reason, bathers should be aware of beach-safety and well-informed about possible dangers at beaches of their preference. A survey performed in Australia (Brander et al., 2011) concluded that the risk perception increases when visual insight about beach-safety is provided to the public, in particular with information addressing the risks caused by rip currents.

The standard approach explaining how to escape from a rip current is by fixing warning signs in specific locations at the beach. However, such informational artifacts are useless if bathers are not able to identify a rip current at the surf zone, and if they have no knowledge about the dynamics of rip currents. Acquiring such knowledge might be a tool to help decrease the number of people trapped in rip currents, decreasing the total number of rescues performed by lifeguards due to impulsive behaviors. The research explores the synergies derived from a community of users committed to beach-safety. Gamification techniques will be used to engage users to play an active role in monitoring hazards, thereby contributing to a living environment where each member within the community has an important role.

1.1. Rip Currents' Overview

Rip currents are strong, narrow seaward flows of water in the surf zone (Sinnett and Feddersen, 2014). Due to their dependence on wave breaking, rips can be developed in any beach environment. Rip current formations are mainly driven by wave breakage and water levels in the surf zone, which in turn are controlled by near-shore and coastal morphology, wave characteristics (height, period, and direction), and wind. Additional aspects favoring the formations of rip currents are tides and the morphology of the underwater soil (Loureiro et al., 2012). However, a rip current is also foreseen as a natural phenomenon important for the transportation of heat, pollutants, nutrients, and biological species.

From a beach-safety viewpoint, **the most significant threat that rips currents represent is the danger to bathers, in particular those not aware of the life-threatening risk associated with rips in the surf zone.** It represents a real risk of dragging distracted/uninformed bathers to areas (and situations) likely to cause drowning. The magnitude of the risk is determined by a combination of the rip current flow speed and circulation patterns (Scott et al., 2014).

Nowadays, a global debate within the scientific community discusses ways to keep citizens informed and aware of the dangers rip currents represent, in particular to children, older adults, or any imprudent bather not aware of the precaution to take before entering into the sea. Figure 1 outlines two of the techniques that can be applied to avoid being dragged by a rip current: (a) "Swim parallel" and (b) "Stay afloat" escape strategies under different flow conditions. Green arrows represent successful escape strategies and the red ones unsuccessful escape strategies. The gray dashed arrows represent the underlying field flow.

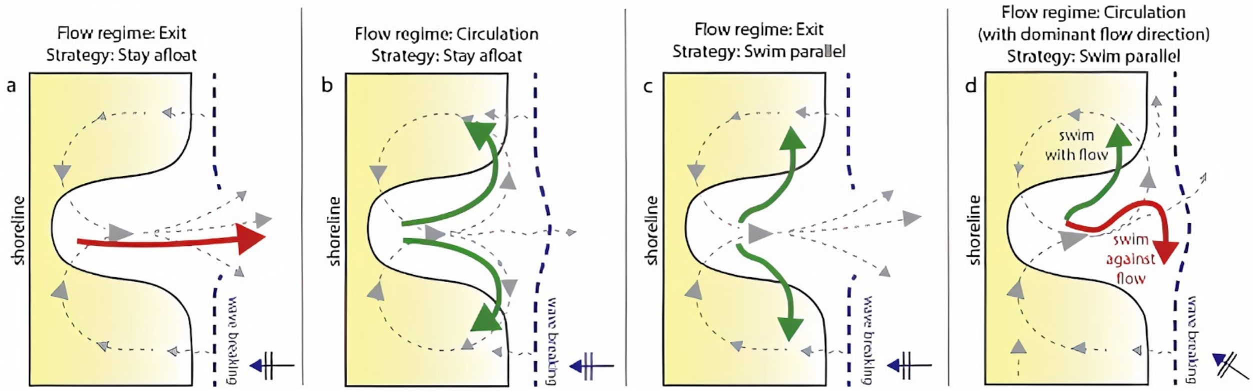


Figure 1: Rip Current Escape Strategies, Source: B. Castelle et al., 2016[1]

[1] Rip current types, circulation and hazard

According to Miloshis (2011), the "swim parallel" recommendation does not consider the likelihood of a current longshore happening at the same time as a rip current. If so, the subject could be swept back into the rip by swimming against the longshore current. The bather will, therefore, not be able to return to the shore, resulting in fatigue and anxiety, two factors that can lead to drowning. **The highly variable nature of rips and beach morphology suggests that these strategies are not universally applicable to all circumstances.**

Figure 2 provides a conceptual framework for rip current hazards, known as the 'Temporal Risk Signature' (THS), which defines the main rip hazard over a range of time scales. The annual long-term characteristic types of beach, controlled by environmental conditions, are linked to rip current activities (Scott et al., 2014). High energy beaches with sandbar systems usually present the highest rip currents hazards. Tides and wave conditions, together with sandbar morphology, influence rip current dynamics. Finally, prevailing rip dynamics and hazards may vary depending on the variability in tide levels, swell, and wind conditions.

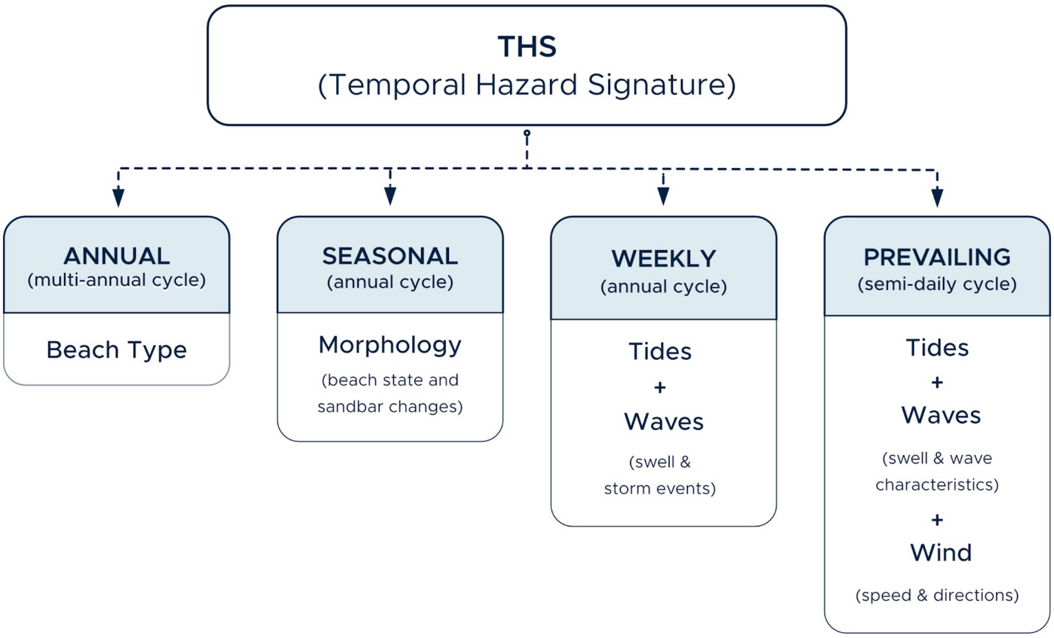


Figure 2**:** Rip current 'Temporal Hazard Signature' (THS), Source: adapted from Scott et al., 2014[2]

Rip currents can emerge in gaps between sandbars, piers, or parts of the reef. Such underwater obstacles obstruct water from flowing back to the sea. The mass of water from breaking waves, known as the feeder currents, flows along the shore until it finds a path around the obstacle. The stream of water, now a rip current, flows to the gap. The diagram presented in Figure 3 outlines the movement of water driven onshore by breaking waves, that can be either **recirculated by rip currents within the surf zone or carried seaward through a narrow rip neck where it dissipates in an expanding rip head.**

[2] Controls on macrotidal rip current circulation and hazard

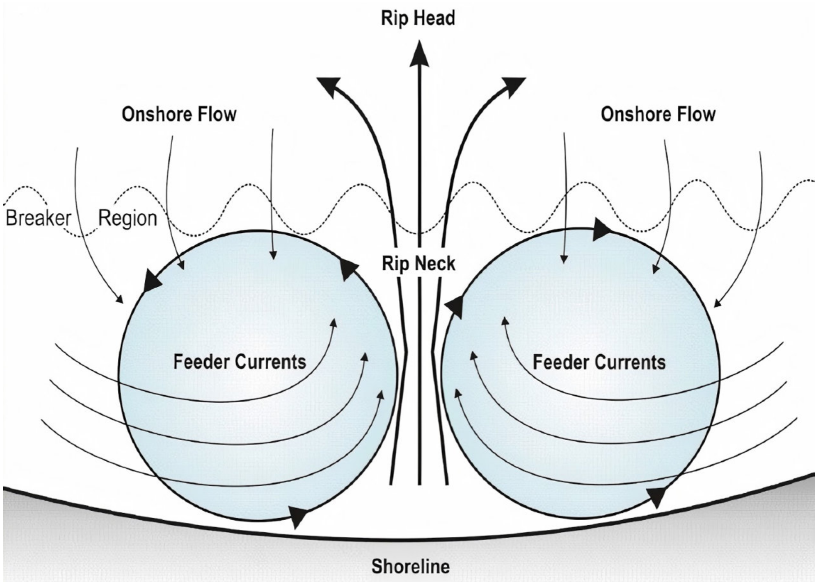


Figure 3**:** Water Flow in a Rip Current, Source: Drozdowski et al., 2012 [3]

Rip current flows are faster than the water on either side of the beach, which sometimes makes rip currents easy to spot as dark or muddy lines running from the sand to the ocean (Rutledge et al., 2011)**.** Rip currents are typically more calm-looking than the surrounding water. Once past the obstacle (between sandbars or piers), a rip current loses its strength and stops flowing. Annex 1 presents a set of rip current examples demonstrating the visual characteristics of these hazards.

1.2. Problem Identification

Portugal has a diverse coastal landscape of more than 850 km, where swells, waves, tides, and different beach morphologies produce a range of hazards, including rip currents. Our research shows that the portuguese population's knowledge regarding beach safety and safe practice is limited (for more information, see in Chapter 3). Results of the survey conducted in this research indicate that **only 40% of the population knows what a rip current is, and 61% do not know where a rip current is likely to appear, suggesting that the population does not have a clear understanding of the dynamics of the beach.**

In addition to the lack of knowledge held by the population, the current responses to beach safety in Portugal are also limited. Existing safety strategies do not promote an active beach-safety culture. Despite lifeguard coverage during the bathing season (May 15 to September 15), there are people who prefer to go to non supervised beaches, which may increase the risk of being caught in a rip current without even knowing or getting a professional (lifeguard) rescue.

[3] Surveying rip current survivors: preliminary insights into the experiences of being caught in rip currents

In Portugal, each year, a significant number of beach incidents involving bathers is reported. Most of these incidents could be avoided by improving the existing social knowledge about beach risks, including information about the risk of rip currents.

The creation of a user community committed with the promotion of a social beach-safety culture within the Portuguese society might contribute to mitigate the identified problem, with benefits regarding bathers' beach-safety literacy and improving social conscience, thus making the Portuguese beaches a safer and more enjoyable destination.

1.3. Research Questions

The research challenges endorse the understanding of rip currents directly and engagingly, contributing simultaneously to promote a beach-safety culture in Portugal. The creation of the Beach Safety Community intends to contribute to increasing beach-safety awareness, with a special focus on the rip currents threats. Therefore, the following research questions were formulated to drive the research work in conceptualizing a solution that could contribute to mitigating the identified problem:

- **RQ1. How to improve the beach-safety strategy to keep bathers aware of beach hazards?**

  1.1. Identify the type of beach safety policy that exists in Portugal;
  1.2. Evaluate current methods in communicating active beach risks to bathers;
  1.3. Identify the safety measures for the most dangerous threats in Portuguese beaches.

- **RQ2. Can a user community help to promote beach-safety and context-awareness?**

  2.1. Identify the profile of bathers, their interests and motivation to integrate a beach-safety community;
  2.2. Understand the population's level of knowledge regarding risks at the beach;
  2.3. Assess if a user community is willing to use a digital tool to visualize hazards at the beach.

- **RQ3. Can digital reality improve safety at the beach?**

  3.1. Analyze if AR is foreseen as a good approach to enhance understanding of beach' dynamics;
  3.2. Validate if a gamified approach would engage a community member to monitor hazard information proactively;
  3.3. Identify the motivations of different user groups regarding a gamified strategy.

1.4. Thesis Structure

This section describes the structure of the document as well as the methods used throughout the development of the research, and how they complement each other. Introduction, the first chapter of this document, describes and contextualizes the phenomenon of rip currents, their natural dynamics and how they pose a threat to some bathers. This chapter also addresses the research questions that were formulated to guide the research work in conceptualizing the proposed solution.

The second chapter of the document, Literature Review, provides an overview of previous studies regarding beach safety, discusses the concept of Augmented Reality and how it can be used to overcome the problem, how gamification can promote user engagement and how interaction design methodologies can be used to design a solution focused on a consumer-centered approach.

The Methodology chapter presents the methodologies used throughout the development of the research. The first section of chapter 3 describes the Systematic Literature Review used to select scientific evidence for problem identification. The second section on chapter 3 presents the methodology used to understand user needs, beach professional needs and requirements for conceptualization of the proposed solution. The research outcomes are presented in the third section of the chapter.

The Proposed Solution chapter outlines the concept of the project, explains which stakeholders should be involved and its roles, and also outlines the gamification strategy. Furthermore, this chapter also describes the design methodologies used in the design process, including Journey Mapping, Architecture Information, Wireframes, Prototype and Usability Tests implemented during the project development. The last chapter of the document summarizes the research outcomes, addresses usability tests results and describes the future work to be done to execute the project.

Figure 4: A Schema of the Document Structure

2. Literature Review

2.1. Beach Types and the Risk of Rip Currents

In general, those who practice water activities (e.g., surfers, life-guards) regularly have a good notion of the risks on the beach and in the sea. In this thesis, we refer to them as professional bathers. Professional bathers are able to identify rip currents and are even able to use rip currents to their advantage. However, **the majority of bathers are not aware of the risks associated with rip currents**; in some situations, they adopt unconscious risk behaviours, which (in the specific case of rip currents) is particularly critical when bathers do not have good swimming skills.

Sherker et al. (2010) performed a survey in Australia, where they found that 36% of a sample of 300 people were unable to identify a rip current, and 51% of those who rarely visited the beach could not identify a threat when entering the sea. As a result, **beaches prone to the formation of dynamic rip currents are particularly dangerous for occasional and careless bathers.** Knowing the beach characteristics and the potential hazards around each beach might be a piece of useful information addressing beach-safety. Such information might also develop new approaches to education and awareness procedures, creating a social commitment with a beach-safety culture.

Beach Types

Beaches are wave-deposited sediment accumulations on the coast, where ocean waves are generated by shoaling, breaking and smashing against the shore. By doing so, wave activities influence the seafloor and determine the morphology of the beach, a process known as beach morphodynamics (Short & Woodroffe 2009). Figure 5 represents a cross-section of a beach where zones are defined on the basis of geomorphological features.

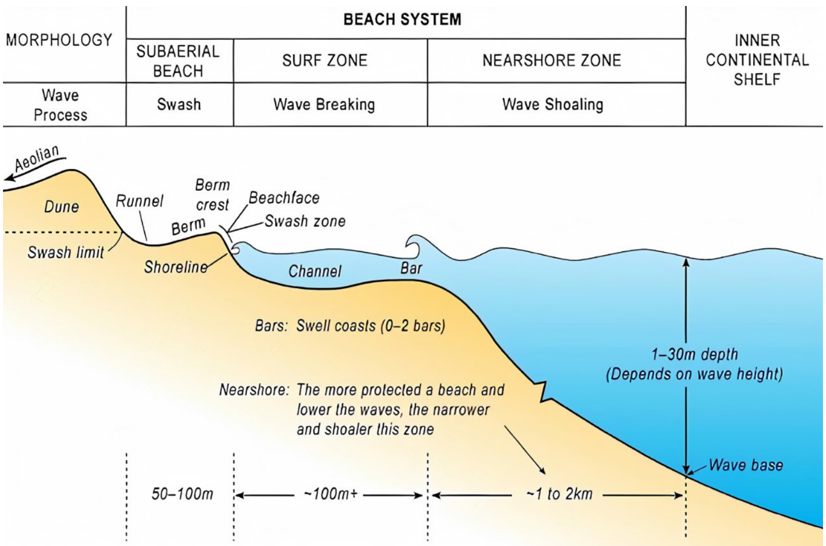


Figure 5: Cross-Section of a Beach System, Source: Short & Woodroffe, 2009[4]

[4] Sediment dynamics of a temperate water carbonate system of the midwestern Australian coast

Waves and tide predominantly influence the beach morphology (Davies and Hayes, 1984). According to Short (2006) beaches morphology can be grouped into three generic groups. Such types of beaches include six **wave-dominated types** defined by Wright and Short (1984), three **tide-modified types** identified by Masselink and Short (1994), four **tide-dominated types** plus two **types in which rock flats or coral reefs dominate the subtidal zone** listed by Short (2006):

Wave-dominated beaches	• **Dissipative beaches**, which are the most energetic of the wave-dominated beach spectrum; • **Intermediate beaches** with four states; • **Reflective beaches**, which are at the low energy end of the wave-dominated beach spectrum (see Annex 2).
Tide-modified beaches	Occur in areas of high tide range and usually have lower waves. They consist of three types of beaches: • **Reflective and Low Tide Terrace;** • **Reflective and Bar and Rip;** • **Ultra-Dissipative.** Obs.: These beach states are characterized by being sheltered from ocean swell and to receive low to moderate wave height and short-period wind waves, with RTR (Relative Tide Range) range of between 3 to 15 (see Annex 2).
Tide-dominated beaches	Occur in areas with higher tide range and low wave height, with a lower RTR boundary of nearly 10 and an upper boundary of nearly 50 (see Annex 2).

Waves and tides are also used as variables for classifying beaches according to these 15 beach types. The classification criteria are based on four variables: breaking wave height (Hb), wave period (T), sediment fall velocity (Ws) and the tide range (TR). Two parameters are used to quantify each of the four variables: the dimensionless fall velocity $\Omega = Hb/WsT$ used by Wright and Short (1984) and the relative tide range $RTR = TR/Hb$ used by Masselink and Short (1993). The value of the dimensionless fall velocity indicates whether reflective, intermediate, or dissipative surf zone conditions will prevail. The Relative Tide Range (RTR) is given by the ratio of tide range to breaker height, where large values of RTR indicate tide-dominance and small values express wave-dominance beach types (for more detail, see Annex 2). According to Benedet et al. (2006), the topography of the beach (types of sand bars and rip canals), the beach substratum (sand and gravel size), the wave energy and tidal range are used in Australia and Florida east coast to classify the beaches according to their morphological expression.

Beaches exposed to strong weather phenomena can produce the most dangerous rip currents. For instance, a hurricane on the high sea can create powerful waves that break into the shore with massive forces. Such waves can develop sandbars and create inshore holes. **Big waves, deep inshore holes, and sandbars can lead to powerful rip currents** (Rutledge et al., 2011). Heavy rip currents are one of the first signs of an incoming hurricane in areas like Western Australia and the U.S. state of Florida.

Beach morphology is responsible for the formation of two main types of rip currents known as **beach rip currents** (or dynamic rips) and **topographic rip currents** (or fixed rips). Beach rips are described as rip currents associated with sandy beaches, while topographic rips are associated with fixed topographic boundaries, such as headlands, cliffs, reefs, and groins, which redirect the rip current towards the sea. **Beach rips are driven by the surf zone morphodynamics and, since they are driven by prevailing wave conditions, beach rip currents are susceptible to change in size and position.** Fixed rips, on the other hand, can always be observed on the same spot, near rocks or beach infrastructures that facilitate the formation of rip currents (Short 1985).

The morphodynamics of the surf zone changes in a predictable way between each beach state, generating a predictable change in the type, location, and intensity of the hazards. Within the context of beach morphodynamic, the variables considered to be potential hazards are: **the water depth variability, the size of the break waves, the prevalence and strength of the rip currents, the presence of longshore currents, and high energy beach states.**

The types of beaches studied (by Short, 2006) for the Australian coast are also observed around the world. This methodology provides a framework for the categorization of the type and state of the world's beaches. **Rip currents are characteristic of all intermediate wave-dominated beaches as well as tide-modified beaches.**

2.2. Risk Assessment in a Beach Context

From a beach-safety perspective, knowing the location of dynamic rip currents might be a key information not only for professional bathers but also for any bather to be aware and conscious of the prevailing hazards. Figure 6 presents a flowchart of the variables for risk assessment at the beach, and how they complement each other to estimate the Beach-Safety Rating. According to Short and Hogan (1994), beach-safety can be classified on a scale of 1 (most safe) to 10 (least safe). This classification is associated with beach hazards based on the depth of water, waves, and wind. Annex 3 provides information on how the wave size affects the rating of the beach-safety.

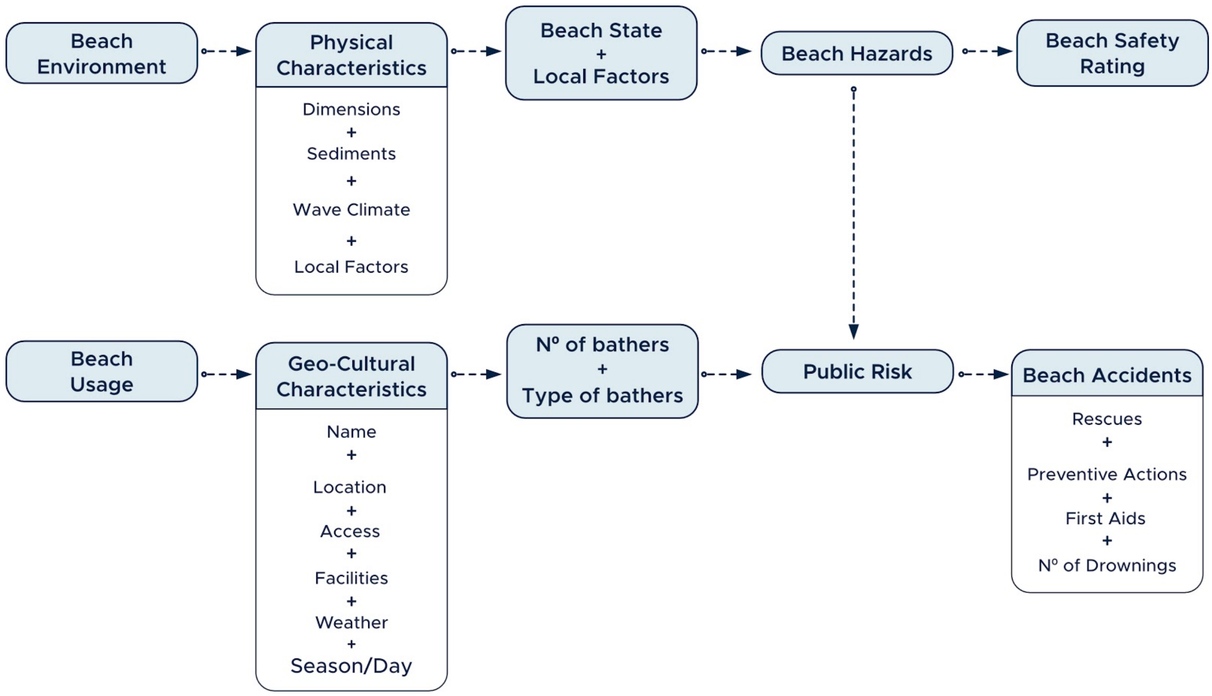


Figure 6: Flowchart for Beach Risk Assessment

In this framework, local factors such as headlands, cliffs, coral reefs, inlets, structures (groins, seawalls) can also be integrated to evaluate the risk of a specific beach and may increase the classification by 1 or 2 points. In this framework, beaches with 1-3 points are considered to be the least hazardous, 4-6 points are considered to be mildly hazardous, 7-8 points are considered to be moderately hazardous, and 9-10 points are considered to be extremely hazardous. It is important to know both the type and level of hazards on an average and prevailing basis to provide reliable information about the beach risk.

Hazard Communication

To ensure the adoption of a beach-safety culture, the communication to bathers of the active localization of rip currents (and/or other beach hazards, such as submerged rocks, slippery areas or sudden drops) is an essential information in addition to the corresponding risk level. The lack of such information-awareness combined with the inability to detect a rip current can lead to dangerous situations. The research community agrees that bathers need to get committed to a beach-safety culture and get trained in how to identify a rip current (Sherker et. al. 2010). Studying how beach users perceive beach-safety is a step towards developing a viable educational tool to improve safety at the beach (Williamson et al. 2012).

Warning signs are intended to warn people and encourage them to engage in behaviours that reduce the risk of injury. The National Rip Current Task Force[5] designed a rip-current warning sign, presented in Figure 7 (on the left side), to inform people of possible rip currents. This sign was used worldwide, including Portugal (Figure 7, on the right side), as a model for the development of similar rip current

[5] Rip current warning sign developed by the United States Rip Current Task Force

warning messages. However, Brannstrom's survey (2015) indicates that the rip current sign illustration may recommend bathers to swim parallel to the shore but does not help to identify rip currents. It is useful to explain what to do when caught in a rip current; however the sign only suggests swimming parallel to the shore, whereas as explained in chapter 1, this escape strategy is not suitable to all types of rip currents scenarios.

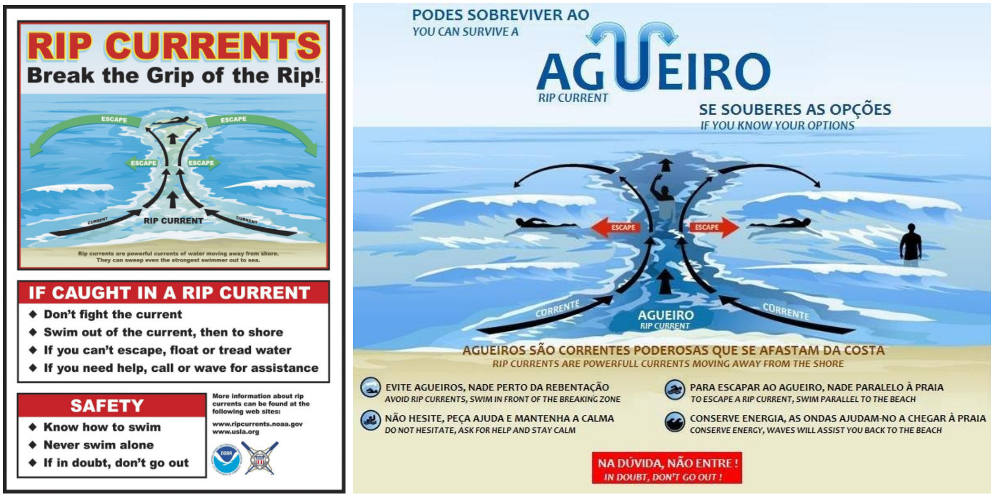


Figure 7: Rip Current Warning Signs

- **Left:** original rip current warning sign developed by The National Rip Current Task Force
- **Right:** Portuguese version of the same warning message

The communication of beach hazards using physical signs at the beach is not efficient enough. The study performed by Matthews (2014) suggested that physical signage is less effective than could be imagined. In this study, less than half of the beachgoers did not notice any signage. However, when warning signs are presented, they are more likely to be noticed (96.4%) than other awareness signs, providing support for evidence that **warning signs are more effective than other types of messages.**

White and Hyde (2010) argued that beach signage, in addition to the existing flag system, should motivate safe attitudes such as swimming between the flags. Ballantyne (2005) suggests that educational materials should point out that the risk is substantial (e.g. using rescue and fatality statistics to illustrate the extent of the problem), that everyone is vulnerable and the threat can be significantly reduced by swimming in patrolled areas. An useful rip current warning strategy should include an accurate and comprehensive message that attracts the attention of beach users and is also simple enough to be quickly absorbed.

To sensibilise bathers, the Surf Life Saving Australia (SLSA) has performed a public experiment to alert the bathers community for the risk of rip currents by dropping an innocuous purple dye into 32 rip currents along every surfing beach in Sydney, Australia (Brender et al, 2011). The experiment provided a visual notion of the speed and direction of the rip current flow (see Figure 8), contributing to the public to get a situational awareness about the rip currents risk.

Figure 8: Purple Dye Showing a Rip Current Plume. Source: Brender et al, 2011[6]

The outcomes of this initiative indicate that **visual approaches are particularly effective as an educational tool for promoting awareness and understanding of rip currents.** As the SLSA initiative points out, a visual approach is more successful than traditional warning signs, and people need more resources to overcome their lack of knowledge and concern about beach hazards.

Within the scope of this thesis, the project will explore the use of digital technologies to increase public awareness and understanding of the dynamics of rip currents in the local environment. To this end, the proposed solution will use Augmented Reality and Artificial Intelligence to help people identify rip currents and to engage beachgoers to become more conscious about beach hazards. Gamification strategies will also be used to encourage users to play an active role in the detection of risks, thus contributing to the effectiveness of the system.

2.3. Digital Reality - The New Paradigm

Introduction to Augmented Reality

Digital reality is a technology driven from Augmented Reality (AR), where a 360° imagery can provide a full spectrum of the beach environment, including aspects related to the identification of rip currents. Figure 9 represents the outlining formation of the rip using a virtual plume to show the rip formation and its shape on the water.

[6] "Dye in the Water": A Visual Approach to Communicating the Rip Current Hazard

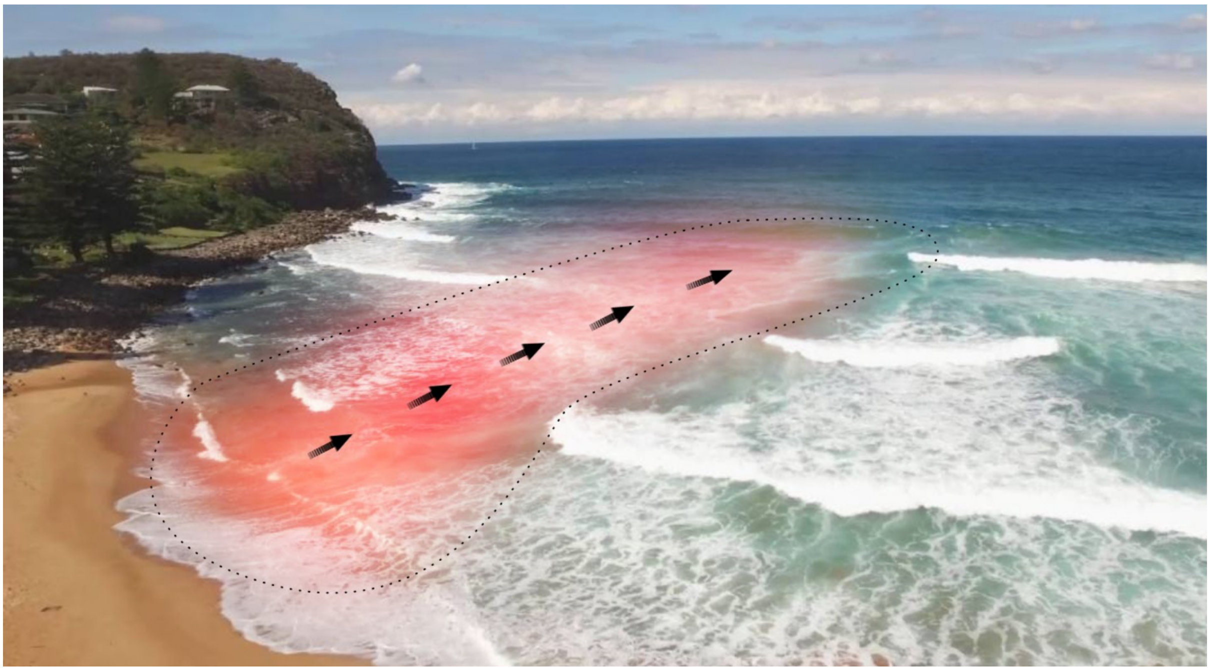


Figure 9: Digital Representation of a Rip Current Plume

Digital reality enables the use of digital information to make real-time decisions. According to Deloitte (2018), "Digital Reality" can be used to engage and to drive attention to specific phenomena. Digital reality is defined by three key elements that must be combined to enable the user to assemble and understand the message that is transmitted using AR:

1. **Source of data:** there is a need to access digital information about the environment in real-time from different sources and to communicate that information so that it can be processed, analyzed, and acted upon.

2. **Method of presentation**: digital content should be easy to understand and contextualized so that users can comprehend it effortlessly.

3. **Interaction with and use of data to drive action:** digital reality enables not only the display of digital information but also the control of it, as it can be manipulated in order to be always well contextualized in the environment.

As computers become more powerful and smaller, new mobile, wearable and mainstream computing devices become available, allowing people to access online resources anywhere and at any time. Technological evolution makes it possible for new types of applications to take advantage of people's surroundings. **Augmented Reality (AR) provides a user interface (UI) for context-aware environments by integrating digital data into the physical environment of an individual.** AR seeks to complement the real world rather than construct an entirely artificial environment.

Mobile Augmented Reality

For the context of this research, the definitions of Azuma et al. (2001) were adopted, which define an **AR system as one that integrates computer-generated data in a real environment, interactively and in real-time, and aligns virtual objects with physical ones.** Mobile Augmented Reality (MAR) extends the concept of AR to mobile applications, away from research laboratories and special-purpose areas of work.

In order to implement MAR, it is necessary to combine a variety of technologies to make it possible (Höllerer and Feiner, 2004). The first essential component for the design of MAR experiences is a computer system capable of generating and handling virtual data to be layered over the real environment, process information and control a display. This computer system can be a cloud computer. Next, there is a need for a display to present the virtual content in the context of the physical world (a mobile handheld display or display integrated into the physical world can be used to fulfill this purpose). Visual registration (the alignment of the digital components with the physical objects) can be achieved by tracking the position and orientation of the user and/or by making the device "see" and "interpret" the real environment using cameras and computer vision technology. Wireless networking is also necessary to connect to servers and cloud computers while the application runs. The following diagram (see Figure 10) shows two possible alternatives for process architecture for implementing a MAR experience.

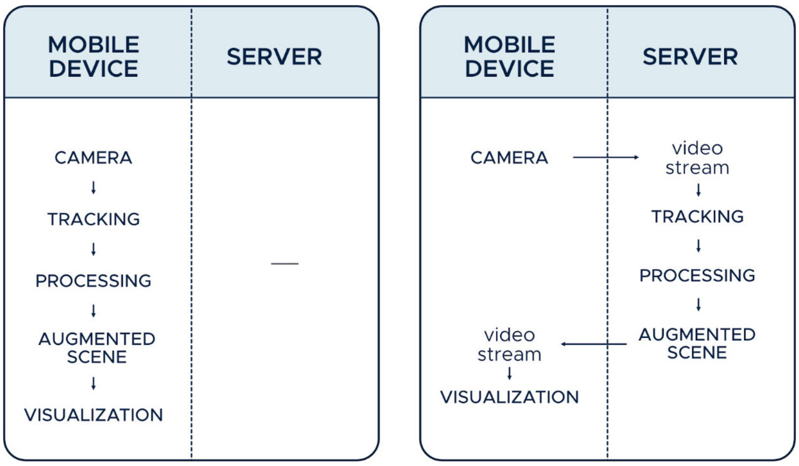


Figure 10: Client-Server Architecture for an AR System. Source: adapted from - Izkara et al, 2018[7]

- The left side of the image represents the process architecture where a MAR experience is processed on the device itself.
- The right diagram represents the process architecture where a MAR experience is processed in a server and displayed in the device.

[7] Architectures Of Mobile Augmented Reality

In the context of rip current surveillance using a mobile device, the MAR technology needs to be supported by information artifacts that report the right position of what is being collected by camera sensors. The Global Positioning System (GPS) and the Differential Global Positioning System (DGPS) are both satellite-based navigation systems that are already implemented on most smartphones. The fundamental distinction between GPS and DGPS is that GPS's instrument range is global and the DGPS range is local (B.GPS, 2017). While the GPS is a system that can have an accuracy of 15 meters, DGPS can provide an accuracy of around 10 cm, by using fixed ground-based reference stations to transmit the difference between the GPS coordinates and the fixed location from the base station. **With the use of the current technology, digital information can be provided at a threshold of only 10 cm, which is appropriate in the beach scenario to mark the position of a hazard on the map.**

The current smartphone market provides a range of devices which are already equipped to deliver MAR experiences. High definition cameras, powerful chips, fast internet connection, GPS and DGPS technologies, and vibrant displays are already built into smartphones to enable the user to have a stable Augmented Reality experience. Figure 11 provides an example of what can be achieved with Augmented Reality regardless of context-awareness. In the Google Maps App, the Augmented Reality feature demonstrates how GPS, DGPS and computer vision work together and successfully layer digital information over the real-world environment in real-time, introducing a new way of delivering directions that will affect human computer interaction.

Figure 11: Augmented Reality in Google Maps App

Within the scope of this thesis, Augmented Reality can be useful in helping bathers to visualize and understand the nature of beach hazards, particularly rip currents. **AR warning signage at the beach will help bathers make safe decisions by helping them to see where the active threats lie.** Furthermore, given that visual strategies are effective educational tools to encourage awareness and understanding of rip currents, **a digital presentation of the dynamics of the danger**, which can be seen with a smartphone, **might improve risk perception, leading to the adoption of a safer behaviour.**

2.4. Gamification

Introduction to Gamification

Gamification is characterized as the use of game design elements in non-gaming contexts, to increase engagement and enjoyment between users and the product. Research indicates that when people find something enjoyable, they are more likely to remain involved in activities for longer periods of time (Looyestyn et al, 2017). Since video games are developed for the purpose of entertainment and can motivate users to engage with them with incredible intensity and duration, game elements should also be able to make other non-game products and services more enjoyable and engaging (Flatla et al., 2011). Two widely accepted definitions of gamification are:

1. **"The process of game-thinking and game mechanics to engage users and solve problems"** (Zichermann, 2011);

2. **"The use of game design elements in non-game contexts"** (Deterding et al, 2011).

Gamification aims to have a positive effect on user motivation, which in turn stimulates the user experience. **It can be used as a tool to improve people's engagement and enthusiasm in performing tasks and activities that could not normally be attractive.** The implementation of gamification techniques is not limited to any specific area and has been used in diverse contexts such as education, development of social behaviour, and well-being improvement for elderly people (Aparicio et al, 2002).

FourSquare is a good example of a game-like service that allows users to check in to food services using their smartphones. It encourages users to revisit locations such as restaurants or pubs and become loyal customers through the use of gamification features (e.g., points, badges, levels, and leaderboards), which can be used to exchange virtual rewards into real products (eg. change a badge for a free coffee). Foursquare app has shown how game mechanics can trigger user behavior by having 10 million users on their platform. Figure 12 shows how game mechanics (challenges and badges) operate in this platform to motivate users to continue using the service.

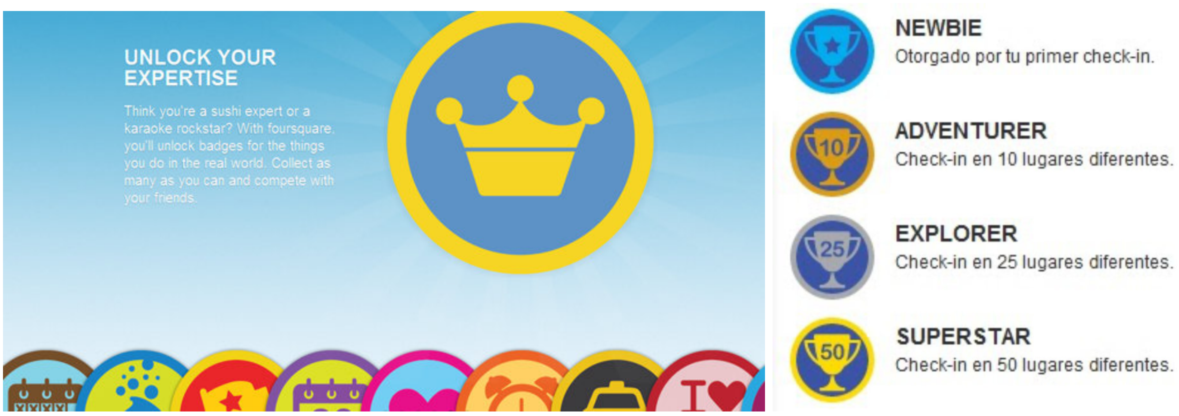


Figure 12: Foursquare's gamification examples, Source: Foursquare (2009)

Nike+ App, a competitive running game-like software, is another well known example of how gamification can be used to inspire users to compete and develop their fitness, with the aim of addressing the main problem of fitness programs: lack of motivation (see figure 13). Nike+ allows users to easily upload their training data to the app in order to challenge themselves and their friends.

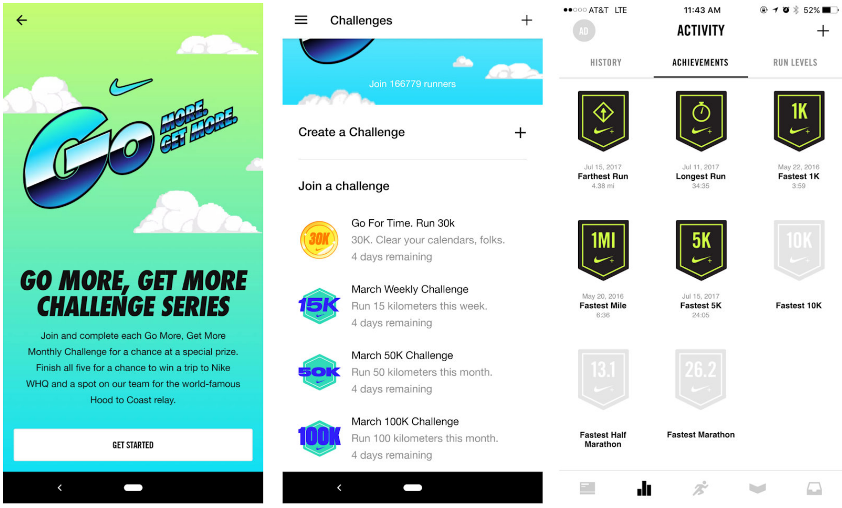


Figure 13: Nike+ App Gamification Example

The gamification approach encourages users to complete challenges through community involvement and achievement. Users can choose to complete a challenge and track their progress against friends and other competitors. Milestone 's achievements encourage users to take an extra mile to win virtual rewards such as badges, which contribute to the development of personal satisfaction.

Game Mechanics

Metrics such as points, badges, and levels are key game elements for building a successful gamified user engagement. Such metrics allow the user to measure where he is and how far he has come in the game journey. However, these mechanics don't make sense as a stand-alone system without the underlying learning process to keep the user engaged - "a good game takes the player on a journey toward mastery" (Kim, 2014). Amy Jo Kim introduced the concept of "Smart Gamification" which focuses on the design of **an effective "player journey" with intrinsic values strategy rather than using just extrinsic rewards.** Kim argues that the idea of progression from "newbie" to "enthusiast" (see Figure 14) is the core of the player's journey framework, which is based around the design of three main phases of the user experience:

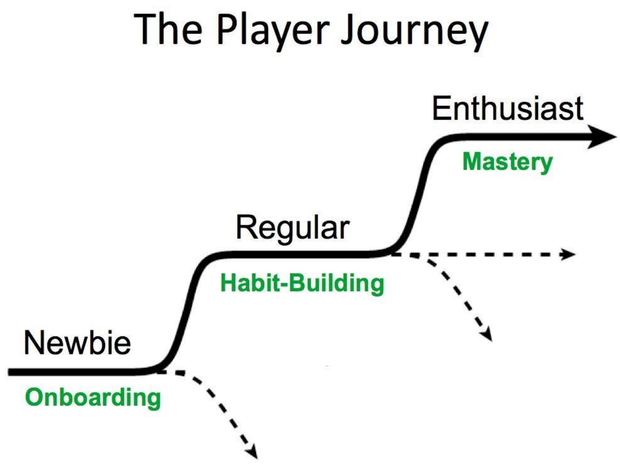


Figure 14: The Player Journey, Source: Amy Jo Kim Kim, 2014[8]

- **Onboarding:** The initial Newbie experience that teaches basics and sets expectations for what is to come.
- **Habit-building:** Triggers, activity loops, and feedback systems that turn Newbies into Regulars.
- **Mastery:** Game elements that open up to Enthusiasts who've mastered the system and want to go deeper.

Intrinsic activities are those that an individual finds interesting and performs without any kind of pressure, only by the enjoyment of doing so. In order to maintain the inner motivation of individuals, game mechanics can be used in activities to satisfy psychological and social needs of motivation by meeting psychological and social needs such as **autonomy**, **competence,** and **relatedness** (Ryan, 2002).

- **Autonomy:** refers to psychological freedom and the desire to fulfill a certain task. Autonomy refers to both experienced freedom of choice, which means being able to choose between multiple courses of action, and experienced meaningfulness of the task, which implies that the action to take is consistent with one's own objectives and attitudes.
- **Competence:** the need to participate in challenges and feel competent and efficient. The factors that improve the experience of competence, such as the opportunities for acquiring new knowledge or skills, be optimally challenged or receive positive feedback, improve the perceived level of competition, and therefore also improve intrinsic motivation.
- **Relatedness:** Relatedness is experienced when a person feels connected to others. Intrinsic motivation will be strengthened in relations that convey the security, making this type of motivation appear more frequently and in a more robust way. It represents the basic desire of the individual for coherent integration with a given social environment.

[8] The Player's Journey

These three intrinsic psychological needs can be used as motivational resources that can be developed by influencing the environment. Therefore **motivational behavior can be improved by deliberately addressing the human need for competence, autonomy, and social relatedness** (Vansteenkiste et al., 2010).

Game Elements

Game design elements are the building blocks of gamification applications (Deterding, Dixon, et al., 2011). There are several game design elements that can be used in a gamified application, but the choice of which game design elements to use is subjective to the nature of the project (Sailer et al, 2017). This study will explore the effects of a selection of specific game design elements, a selection that is not exhaustive, but that represents some of the game design elements most often discussed, such as **points and levels, achievements and badges, and performance graphs:**

- **Points and levels:** Points are the basic elements of games and gamified applications (Zichermann & Cunningham, 2011). They are rewarded for the successful accomplishment of specified activities within the gamified environment, and they numerically represent a player's progress. One of the most important purposes of points is to provide feedback. Points serve as continuous and immediate feedback and as a reward (Sailer, 2012).

- **Achievements and Badges**: Badges are visual representations of achievements. They confirm the players' achievements, symbolize their merits (Anderson et al, 2013), and visibly show their accomplishment of levels or goals (Antin & Churchill, 2011). Earning a badge can depend on a specific amount of points or on particular activities. Badges may serve as goals if the prerequisites for winning them are known to the player or as virtual status symbols. In general, badges usually have no narrative meaning. However, badges can influence players' behavior, leading them to select certain challenges in order to earn badges that are associated with them (Wang & Sun, 2011). Additionally, as badges symbolize one's membership in a group of those who own this particular badge, they also can exert social influences on players and co-players, particularly if they are rare or hard to earn.

- **Performance Graphs**: Performance graphs provide information about the players' performance during a game (Sailer et al., 2012). Performance graphs do not compare the player's performance to other players, but instead, evaluate the player's own performance over time. By graphically displaying the player's performance over a fixed period, they focus on improvements. Motivation theory postulates that this fosters mastery orientation, which is particularly beneficial to learning (Sailer et al., 2013).

The goal of implementing gamification in interaction design is to influence user behavior. Gamification extrinsic rewards such as points and badges may be effective in user engagement, although they may lose interest after a certain period of time. **The underlying learning strategy to keep the user engaged will be focused on the idea that the user will become a master of beach**

safety. The intrinsic value of safety can be enhanced by promoting the ability to identify active hazards (autonomy and competence) and by being able to communicate hazards with other swimmers (relatedness). Within the scope of this thesis, the application of a gamified strategy is crucial to the adoption and development of a beach safety culture.

2.5. Interaction Design

Interaction Design Overview

Interaction Design is the area of research that focuses on making the connection between a device, its interface and the user. Whenever a choice is made on a device, it is an interaction design that responds. Figure 15 demonstrates the context of the interaction design within the scope of this project. Interaction research will be at the center of the proposed solution, with close attention to the user experience. In addition, this project will incorporate gamification strategies to promote user engagement and augmented reality to improve safety at the beach, by contextualizing safety information in the user environment.

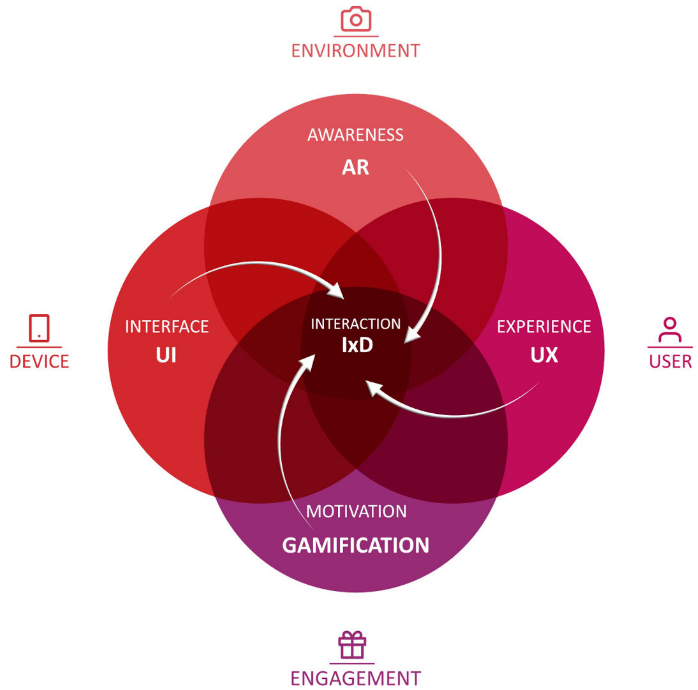


Figure 15: Context of Interaction Design within the scope of the project

Design includes a combination of analytical and creative skills, yet interaction design also requires the ability to understand and empathize with people, as well as to express complex design ideas to a target audience. Good practice of interaction design includes **skills that allow the designer to understand what people want to accomplish, identify the tools by which digital systems communicate with people and how people interact with digital systems** (Interaction Design Foundation, 2018). An interaction designer must first understand the users at a level that he can determine what they want and expect, and then determine how to fulfill those needs within the technological limitations of a system.

Interactions are the core of all user experiences. The cyclical relationship between making a decision, performing an action, and observing the reaction establishes a feedback loop of action-reaction (Preece et al., 2002). Users come to the last part of the loop cycle, where the reaction must first be clearly understood in order to make an informed decision. This process of action-reaction is at the core of all interactions, and only when all three components are accomplished (decision, action, and reaction) does the interaction work properly.

Interaction design focuses on a consumer-centered approach and is driven by user needs, rather than technical problems. To this end, the four activities of an interaction designer are (1) **identifying user requirements**, (2) **developing design solutions** and (3) **evaluating and test designs** (Preece et al, 2002). In order to design something to support people, designers need to know who the target audiences are and what kind of support an interactive product can provide. This practice is the key to a user-centered approach. The following diagram (see Figure 16) shows the context for the use of the User-Centered Design process in the creation of a project.

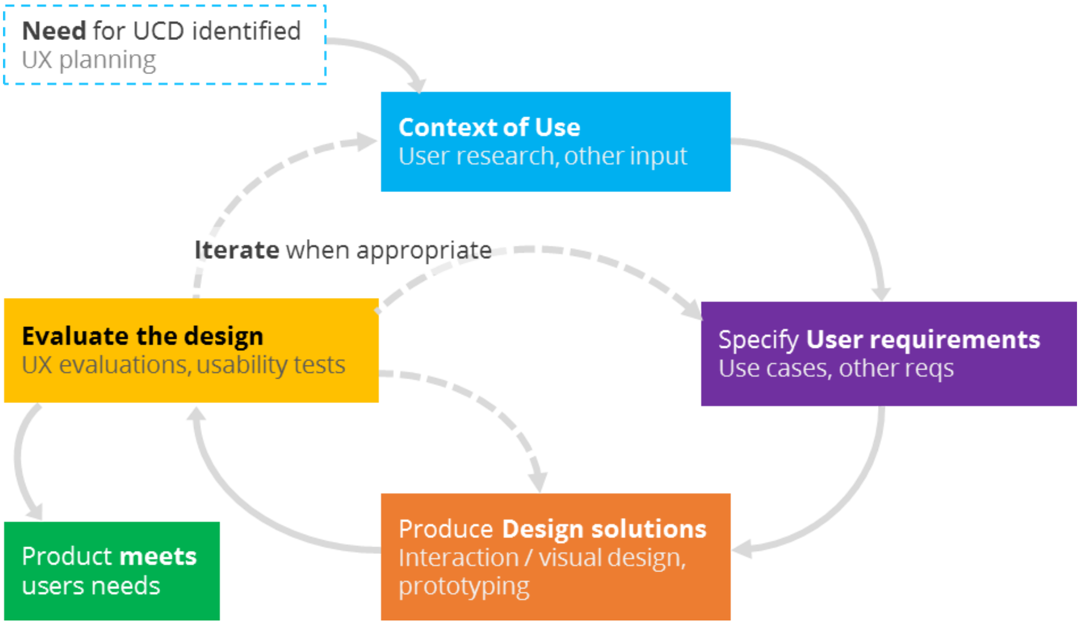


Figure 16: User-Centered Design process. Source: ISO (International Organization for Standardization (1997) [9]

After all the requirements are established and documented, a designer starts to explore different possibilities that fulfill all the requirements identified. This activity can be divided into two sub-activities: User Experience design (UX) and User Interface design (UI). Figure 17 highlights the distinctions between UX and UI practices and contextualizes the importance these two design fields have on the creation of a project.

[9] User-Centered Design process according to the ISO 9241-210 standard

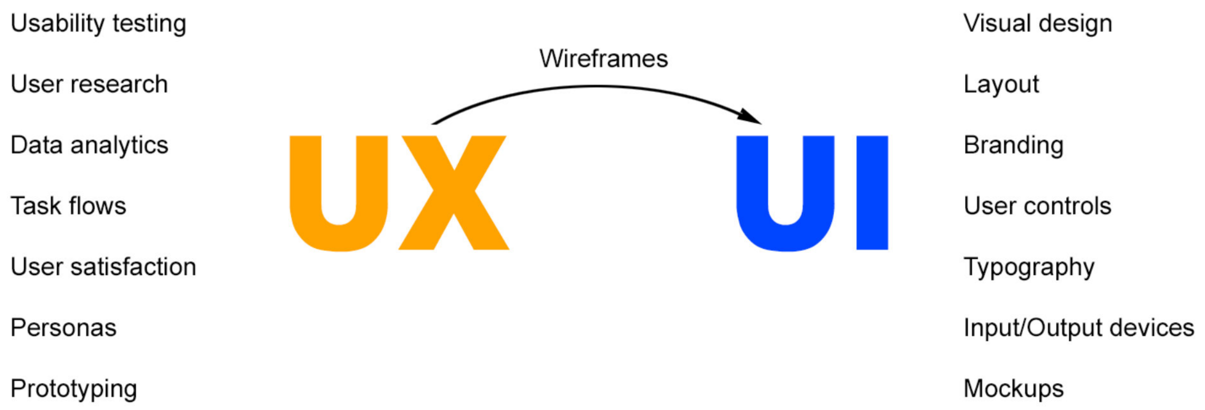


Figure 17: Differences Between UX and UI Design, Source: adapted from: Ajay Mittal, 2018 [10]

UX design is a multidisciplinary field, drawing upon elements of cognitive science and psychology, computer science, communication design and usability engineering. It focuses on user research, research analysis, the development of a conceptual model for the product and specifies what the product should do, how it should feel and behave. UI design is a different but complementary design activity that takes into account the product's graphic details including interface design, design specifications and final product execution. Both design activities are key for the development of a well designed product.

In addition to the development of product interfaces, interaction design also involves the creation of interactive prototypes, as interacting with a prototype is the most viable way for users to evaluate potential solutions. The evaluation process is the method of measuring the usability and acceptability of a product or design, and it can be expressed in terms of a variety of variables (e.g. the number of errors that users make, how appealing it is, and how well it meets the requirements). The three key elements of the interaction design process to mitigate the risk of usability flaws are (1) User Focus (2) Requirements and (3) Iteration (Preece et al, 2002).

1. **User Focus:** while a process cannot guarantee that development will involve users, it can encourage focus on such issues and provide opportunities for evaluation and user feedback.
2. **Requirements:** should be defined, documented, and debated at the start of the project. The requirements documentation is vital for designers to evaluate different design versions of the product, review the progress of the project, and choose the best design alternative.
3. **Iteration** enables projects to be optimized on the basis of feedback. As users and designers connect with the system and start to discuss requirements, needs, hopes, and aspirations, different perspectives can emerge into what's needed and what's possible.

[10] UX Vs. UI — Similarity & Differences

No matter how good the designers are and how straightforward the users can transmit their vision of a particular product, it will be necessary to review ideas. In order to improve people's experiences, it is necessary to identify needs and establish requirements. However, people don't necessarily know what they want and what is feasible to do. As a result, **designers need to approach users by understanding their characteristics and capabilities, what they are trying to achieve, how they are already doing it, and whether they would achieve their goals more efficiently if they were guided differently.** It is, therefore, important that representative users of the target population are consulted during the development of the product.

Design Operations

Interaction Design is a scientific area that incorporates distinct but complementary disciplines that, when used together, provide a framework for the creation of a well designed product. Design experts have tried to understand how design can be converted into the center of methodologies such as Design Thinking, Lean UX, Agile in a meaningful way. As companies begin to see value in a design-driven strategy that can enable businesses to be more efficient and effective in delivering value to consumers. This way of thinking known as "DesOps" (Design Operations) focuses on how to integrate different work processes so the organization's product management, design, engineering, and marketing teams can work together in an efficient way.

At the fundamental level, DesOps is not about introducing new models or processes into the industry; rather, it is about orchestrating the best practices of Design Thinking, Lean Methodologies, User-Centered Design practices with modern technologies to identify, develop and deliver value. Figure 18 illustrates how DesOps can be applied by combining Design Thinking, Lean UX, Agile, and Optimisation phases throughout the project.

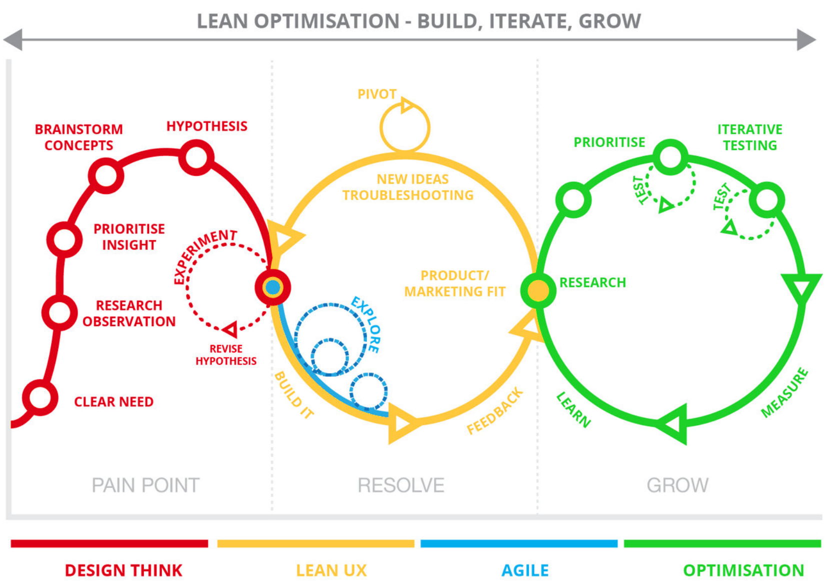


Figure 18: DesOps framework. Source: Pinterest [11]

[11] From DesignThinking to GrowthHacking, through LeanUX & Agile

Usability and Utility Concepts

The process of writing structured, verifiable, and observable usability requirements is a key feature of an interaction design strategy known as usability engineering. Usability engineering includes identifying quantifiable product performance measures, documenting them in the usability specification, and evaluating the product against them. One way to use this approach is to make changes to the system based on feedback from documented test results from earlier versions.

Usability is the extent to which a system, product or service can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use (ISO 9241-210:2019[12]). Usability criteria can be used to assess aspects of user experience is a quality feature that measures how simple user interfaces are to use. The term "usability" also refers to tools for enhancing the ease of use during the design process. Jakob Nielsen (2012), a specialist in usability engineering, claims that usability can be defined by 5 quality components represented in Figure 19.

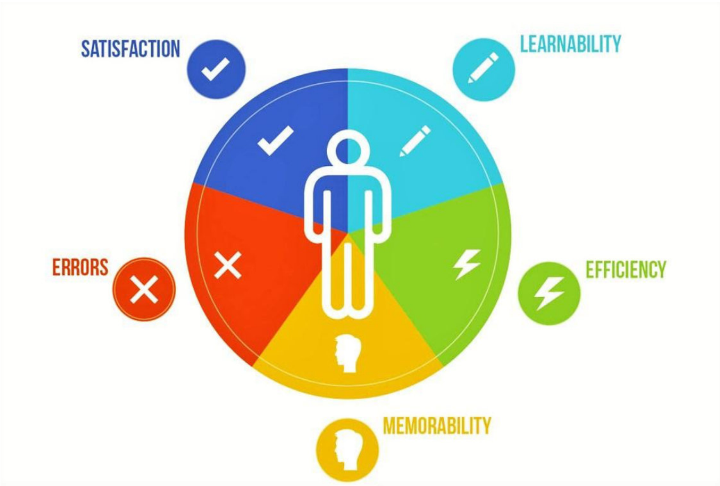


Figure 19: The 5 Components of Usability, Source: nngroup.com[13]

1. **Learnability:** How easy is it for users to accomplish basic tasks the first time they interact with the design?
2. **Efficiency:** Once users have learned the design, how quickly can they perform tasks?
3. **Memorability:** When users return to the design after a period of not using it, how easily can they resume proficiency?
4. **Errors:** How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
5. **Satisfaction:** How pleasant is it to use the design?

[12] ISO 9241-210:2019 Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems (www.iso.org/standard/77520.html)

[13] Usability 101: Introduction to Usability

Utility is another important attribute of an interactive product. It relates to the design functionality and checks whether the product meets the user needs. Usability and utility are equally important, as both evaluate whether something is useful. It doesn't matter that something is easy if the user doesn't need or want it. On the other hand, it doesn't matter either if the device can do what the user wants, but the user can't do it because the UI is too complicated. For this reason, Nielsen claims that **the principles of engineering usability should extend to digital design for improved functionality.** He proposes incorporating user evaluation into the design process, first through heuristic analysis, followed by usability testing with a product redesign after each evaluation phase (Nielsen, 1994).

Gestalt Theory for Efficient UX

The human brain is wired to see structure, logic, and patterns. In the 1920s a group of German psychologists developed theories around how people perceive the world around them, called Gestalt principles. Gestalt is the term that comes from the German word Gestalt [ɡəˈʃtalt] meaning "shape, form". It is used primarily in cognitive psychology for the field exploring the laws of meaningful perception of the data which people constantly get from the world (Studio T, 2017.). When people perceive complex objects consisting of many elements, they apply conscious or subconscious methods of arranging the parts into a whole organized system.

Understanding the ways how people perceive and use information is essential for building good navigation, digestible copy, and effective color choice. The fundamental law that governs a Gestalt principle is that we tend to *order* our experience in a manner that's regular, orderly, and recognizable. Having a solid understanding of how these principles work will help to:

1. **Determine which design elements are most effective in a given situation.** For example, when to use visual hierarchy, background shading, gradients, and how to group similar items and distinguish different ones.
2. Influence visual perception, which allows designers to **direct users attention to specific points of focus, get users to take specific actions, and create behavioral change.**
3. Design products that solve the customer's problem or meet the user's need in a way that's **aesthetically appealing, pleasing, and intuitive to use.**

Knowing the factors that influence visual perception makes the process of UX design more proficient, by giving higher rates of successful interactions and lowering the level of users' misunderstandings. Gestalt principles are based on the idea that people arrange what they see along with some patterns organized into five global categories:

1. **Proximity:** When objects are placed together, the eye perceives them as a group.
2. **Similarity:** When objects look similar to one another, the eye perceives them as a group or pattern.
3. **Continuity:** The eye is compelled to move from one object *through* another.

4. **Closure:** When an object is incomplete or not completely enclosed.

5. **Connectedness:** When the eye differentiates an object from its surrounding area.

The principles of the Gestalt theory were considered in the wireframes process in order to make the UX design process more effective and to prevent usability flaws.

Heuristic Evaluation Methodology

Heuristic evaluation is an usability engineering methodology in which a selected group of experts examine a user interface, looking for design problems by judging its compliance with a set of usability principles. Nielsen developed a set of ten heuristics that are represented in Figure 20.

Figure 20: The Ten UX Heuristics, Source: webkeyz, 2016 [14]

1. **Visibility of system status:** The system should always keep users informed about what is going on, through appropriate feedback within a reasonable time.

2. **Match between system and the real world:** The system should speak the user's language, with words, phrases, and concepts familiar to the user rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

3. **User control and freedom:** Users often choose functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue.

4. **Consistency and standards:** Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

5. **Error prevention:** Even better than good error messages is a careful design that prevents problems from occurring in the first place.

[14] Nielsen's 10 Usability Heuristics

6. **Recognition rather than recall:** Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

7. **Flexibility and efficiency of use:** Accelerators, unseen by the novice user, may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

8. **Aesthetic and minimalist design:** Dialogues should not contain information that is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

9. **Help users recognize, diagnose, and recover from errors:** Error messages should be expressed in plain language (no codes), precisely indicate the problems, and constructively suggest a solution.

10. **Help and documentation:** Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and should not be too large.

After researching the use of individual reviewers as well as groups of varying sizes, Nielsen and Molich proposed the use of three to five experts for heuristic assessment (Nielsen and Molich, 1990). Multiple experts will catch more flaws than a single expert, but using more than five experts will not provide additional results.

Usability Testing Methodology

Usability testing is an empirical method of design development in which participants are practical users of the product or service being tested and are asked to perform specific tasks using a prototype, while their response and reactions to the product are observed and recorded by a moderator. Figure 21 shows the core elements in most usability tests: **the facilitator/moderator**, **the tasks**, **and the participant/user**.

Figure 21: Core Elements of Usability Testing, Source: nngroup.com[15]

[15] Elements of Usability Testing

Usability tests are practical activities that a user might perform in real life. The language used to communicate the task with the participant is critical for usability testing, as small errors in the task description can cause the participants to misinterpret what they are expected to do, or may impact how the participants perform the task. Task requests can be delivered orally to the participant or written on task sheets. Asking the participant to read the tasks' instructions out loud helps ensure that the participant reads the instructions entirely and allows the moderator to take notes of which activities the participant is executing. The objectives of the usability tests, as described in Figure 22, are to uncover the usability problems of the product, to discover opportunities to improve the design, and to learn about the behavior and preferences of the target users.

Figure 22: Usability Testing Goals, Source: nngroup.com[16]

In comparison, the heuristic evaluation uncovers more of the minor problems while usability testing reveals more major global problems (Jeffries et al., 1991). Since each approach reveals specific usability problems, it is recommended that both methods are used complementarity, in particular with an iterative design exchange between heuristic evaluation and usability testing.

Quantitative and Qualitative Usability Testing

Usability research can be qualitative or quantitative (Ralica, 2017). Qualitative usability research centers on collecting insights, findings, and information that identify if the design is easy or hard to use, and it is appropriate for the detection of user experience issues. Quantitative analysis, on the other hand, focuses on gathering metrics that represent user experience and allows designers to assign a number to a redesign and compare how much the new version of a product improved over the old one.

Task efficiency and effectiveness are two of the metrics that can be used in quantitative usability studies. Efficiency can be measured in terms of task time (in seconds and/or minutes) and the number of successfully completed tasks, as shown in the equation below:

[16] Usability Testing 101

$$Time\ Based\ Efficiency = \frac{\sum_{j=1}^{R}\sum_{i=1}^{N}\frac{n_{ij}}{t_{ij}}}{NR}$$

- N = The total number of tasks (goals)
- R = The number of users
- nij = The result of task i by user j; if the user successfully completes the task, then Nij = 1, if not, then Nij = 0
- tij = The time spent by user j to complete task i. If the task is not successfully completed, then time is measured till the moment the user quits the task

Effectiveness can be calculated by measuring the completion rate. Referred to as the fundamental usability metric, the completion rate is calculated by assigning a binary value of '1' if the test participant manages to complete a task and '0' if he/she does not. Effectiveness can thus be represented as a percentage by using this simple equation:

$$Effectiveness = \frac{\text{Number of tasks completed successfully}}{\text{Total number of tasks undertaken}} \times 100\%$$

Both qualitative and quantitative evaluations are necessary for the iterative design cycle and should be used for product development. Figure 23 indicates when these tests should be performed during the development of the project.

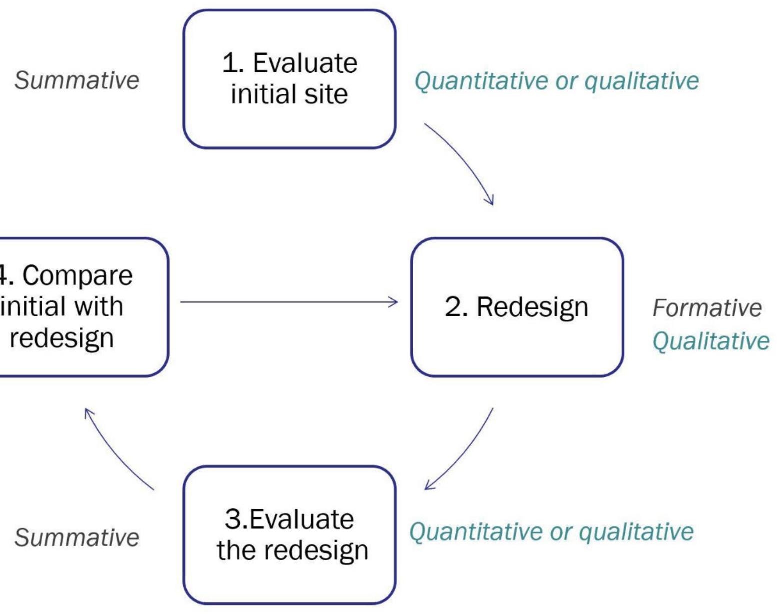


Figure 23: Usability Testing Goals, Source: nngroup.com[17]

[17] The Iterative Design Cycle: Goals for Qual vs. Quant

Remote Usability Testing

Remote usability tests are common as they require less time and money than in-person research. Remote usability testing can be done in two different ways: moderated or unmoderated (Schade, 2013). Remote moderated usability tests work fairly close to in-person research, as the mediator interacts with the participant and asks him to perform the tasks, however the facilitator and the participant are in different physical locations.

Remote unmoderated usability tests do not have the same facilitator-participant interaction as in-person or moderated tests do. In a remote unmoderated test, the moderator uses a dedicated online testing software to set up tasks for the participant and the participant performs the tasks alone at his own time. In this framework, the testing tool delivers instructions on the task and any follow-up questions. After the participant finishes the test, the moderator receives a recording of the session, along with metrics.

Within the framework of this study, the conceptualization of the proposed solution was conducted following the Interaction Design methodology performed on following the three main phases:

1. **Requirements analysis -** Done on the basis of a literature review focused on beach safety, to understand the complexity and extension of the subject. In addition, an online survey and user interviews were conducted to determine Portuguese beachgoers' type of behavior and level of knowledge. Stakeholder interviews were also performed to assess the scenario of beach safety in Portugal. (see chapter 3, User Research Methodology and Research Outcomes)
2. **Design exploration** - Performed in several phases, including personas building, task analysis, journey mapping, wireframing, high fidelity mock-up and interactive prototyping (see chapter 4).
3. **User testing** - Accomplished through heuristic evaluation complemented with moderated usability tests (see chapter 4, Usability tests).

3. Methodology

3.1. Systematic Literature Review

The design of this research study was based on two types of research: **Systematic Literature Review (SLR) followed by the User-experience Research Methodology** (see Section 3.2)**.** A Systematic Literature Review was conducted to identify the relevant literature related to beach safety and beach hazards, with particular attention to rip currents. This research process was essential to understand the components and nature of the subject, to understand how beach hazards affect beachgoers, how hazards are communicated to bathers and how safety measures are perceived by beach users. The purpose of conducting a SLR was to manage literature data and to draw up a shortlist of papers to get a deep understanding of the identified problem.

Guidelines for the selection were that it should enable the identification, analysis, and synthesis of data into a comprehensive understanding focused on the topics of the research questions. The SLR methodology differs from more general literature reviews (Cooper et al, 2018) in terms of comprehensiveness (ensuring that all relevant material is included), specificity (identifying key points by research questions), and clarity (adding validity to findings).

The research was conducted in two repositories Google Scholar and b-on databases. The first step was to compare the results in both databases limited to the years 2000-2019 and in English. Search strings were composed of primary keywords such as *beach safety*, *rip currents*, *risk perception,* and *knowledge*, with boolean operations applied as shown in Table 1. The Google Scholar platform has a limited search engine compared to the b-on platform. The first search strings used on the b-on platform were the same as those used in Google Scholar.

Table 1: SLR Research Results

Operations	**Search Strings:**	**Google Scholar**	**b-on**
All in title	allintitle: beach safety	155	201
	allintitle: rip currents	261	495
	allintitle: augmented reality beach safety	0	0
	allintitle: augmented reality rip currents	0	0
	allintitle: "rip currents" AND "beach safety"	7	15
	allintitle: “rip currents” AND “behavior”	1	1
	allintitle: rip current perceptions	3	3
Anywhere in the article	"rip currents" AND "beach safety" AND "knowledge"	399	199
	"rip currents" AND "beach safety" AND "augmented reality"	2	6
	"rip currents" AND "perceptions" AND "augmented reality"	1	12

	"beach safety" AND "perceptions" AND "rip currents"	121	83
	"beach safety" AND "behavior" AND "knowledge"	460	341
	"beach safety" AND "behavior" AND "rip currents" AND "knowledge"	220	125
Total		**1630**	**1481**

After comparing the results of the primary search on both databases, it was concluded that the findings on both platforms were relatively similar. Strict selection criteria were applied to the initial search pool on the b-on platform in order to refine the results of the research into a more manageable number. The final search in the b-on database resulted of 58 articles using the following string:

- (TI): **"beach safety" OR "rip currents"**
- AND (AB): **"beach safety" OR "rip currents" AND "risk perception" OR "knowledge"**
- OR (TX): **"beach safety" AND "rip currents" AND "risk perception" AND "knowledge"**

Only "Academic Magazines" and "Specialty Publications" were taken into account at this point, with the final result of 27 articles. In order to sort out the findings made on Google Scholar, the number of quotations was the prerequisite to choose the articles. After reading the introductions and conclusions of the articles with a higher number of citations for each search string, a shortlist of 30 papers was created. A final review size of 37 articles was given after the removal of the papers that were paid, out of scope and duplicated on both repositories.

3.2. User Research

Online Survey

A Questionnaire Survey Instrument (QSI) was designed to address the clarification regarding **RQ2 - Can a user community help to promote safety and awareness in the beach context?** The survey was conceived using the Google Forms platform and shared through Facebook, Instagram and WhatsApp chat groups. The survey was available from 25 February until 30 June. In total, the study evaluated **2167 survey responses**, a sample of **46.7% of young adults** (age 18 to 35), **49.3% of adults** (age 36 to 55) and **4% of seniors** (age > 55). All the participants were portuguese. The QSI consisted of twenty-nine questions, both closed and open, for the gathering of quantitative (statistic) and qualitative (short-answer) data, organized by the following sections:

- **Section 1 - Bathers' Profiles**, aims to identify different bather profiles. Questions were designed to obtain information on demographics, types of beach participants are likely to go, safety behaviour and types of sea based activities.

- **Section 2 - Bathers Consumer Behaviors, Amenities and Beach Details**, aims to support data hierarchization and develop the gamification strategy for the proposed solution.
- **Section 3 - Bathers' awareness and perceptions of rip-currents,** aims to evaluate bathers' awareness and perception of rip-currents. Within this section, questions were designed to understand the population level of awareness, understanding of rip currents' dynamics, as well as the capability of recognizing hazardous areas in a surf zone.
- **Section 4 - Bathers' predisposition to use a smartphone on the beach**, aims to assess whether the public knows what AR is and validate if the population is willing to use smartphones as a digital tool to spot and report hazards.

The online survey tool provided simple frequency data (percentages only). In order to filter responses from different profiles, answers were analyzed using Microsoft EXCEL, which was useful to **compare participants' responses, discover behaviour patterns**, **establish project requirements** and **design the gamification strategy** to implement the proposed solution. For more detailed information on the QSI, see the copy of the survey in Annex 4.

Survey Results Analysis

Section 1 - Bathers' Profiles

Participants (sample of 2167, see table 2) were divided into three different categories, such as **frequent beachgoers -** participants who are likely to go to the beach out of bathing season **(24 %)**, **regular beachgoers -** participants who go regularly to the beach only during bathing season **(67%)** and **sporadic beachgoers -** participants who rarely go to the beach **(9%)**, suggesting that a **beach surveillance solution should be implemented in beaches where frequent beachgoers are likely to go out of bathing season**.

Table 2: Bathers Profiles

Bathers Profiles		**Type of Beachgoer** (sample 2167)			
		Total	**Frequent (24%)**	**Regular (67%)**	**Sporadic (9%)**
Demographics	Young Adults	47%	24%	66%	10%
	Adults	49%	23%	69%	8%
	Seniors	4%	22%	65%	13%
Beach risk level	Small size wave beaches	39%	30%	42%	39%
	Medium size waves beaches	48%	51%	46%	49%
	Big size waves beaches	13%	19%	11%	12%
Safety behaviour	Only go to life-guarded beaches	72%	57%	77%	73%
	Also go to non life-guarded beaches	25%	40%	21%	24%
	Don't consider beach survilace a relevant factor	3%	3%	2%	3%
	Know what a red and yellow flag represents	27%	36%	25%	12%
	Don't know what a red and yellow flag represents	73%	64%	75%	88%
	Allways comply with safety signage	74%	67%	75%	80%
	Take in consideration the safety signage	24%	30%	23%	18%
	Don't comply with safety signage	2%	3%	2%	2%
Swimming skills	Poor swimming skills	24%	18%	24%	36%
	Average swimming skills	67%	68%	68%	56%
	Excellent swimming skills	9%	14%	9%	8%
Sea activities	Not likely to go to the sea	11%	13%	9%	22%
	Like to bath in the smashing area	76%	80%	78%	68%
	Like to swim in the sea	49%	55%	49%	39%
	Practice sea base sports (surf, bodyboard , paddle surf)	4%	10%	2%	0%

Beach morphology and dynamics determine the danger level of a beach, in particular wave activity, which is one of the main factors for rip currents formations. Results indicate that 39% of the studied population goes to small wave beaches, suggesting that **61% of the population is likely to go to beaches where rip currents are likely to prevail.**

Beach surveillance is crucial to the safety of the bathers, particularly in scenarios where rip currents are likely to prevail. Our survey results indicate that 72% of the population goes to lifeguarded beaches and 25% is likely to go to non lifeguarded beaches. However, looking into the three groups, it is noticed that **21% of regular beachgoers said they were also going to non-life-guarded beaches, suggesting that beach surveillance should be extended to more beaches.**

Beach signage is key to bathers' situational awareness. However, data show that **73% of the population doesn't know what a red and yellow flag means** (area under the control of lifeguards), which poses a **weakness in the general understanding of safety at the beach.** On the other hand, 74% of the population claims to comply with safety signs, indicating that **bathers usually value the safety signage of the beach but lack knowledge of safety communication.**

Swimming in the sea (49%) and bathing in the surf zone (76%) are activities that can be affected by rip currents, particularly in beaches where medium to large wave activity prevails (61%). Our research revealed that 9% of the participants believe they are excellent swimmers, 67% claim to have average swimming skills, and 24% self-evaluated as poor swimmers. Beside the evaluation of swimming skills of the participants, **28% of beachgoers will still enter the sea on non-lifeguarded beaches or even out of the bathing season.**

Section 2: Bathers Consumer Behaviors, Amenities and Beach Details

The second section of the survey focused on gathering data to **determine system requirements** and **plan the gamification strategy** for the proposed solution. To this end, questions were designed to understand bathers' consumer behaviors, identify widely used beach facilities by the sample population and useful beach information to support users in their beach decision process. Research findings show that 70% of the sample population buy food from food vendors and 49% go to beach restaurants and bars, indicating that **gamification incentives could be based on food and beverage products sponsored by brands and local services** (see figure 24).

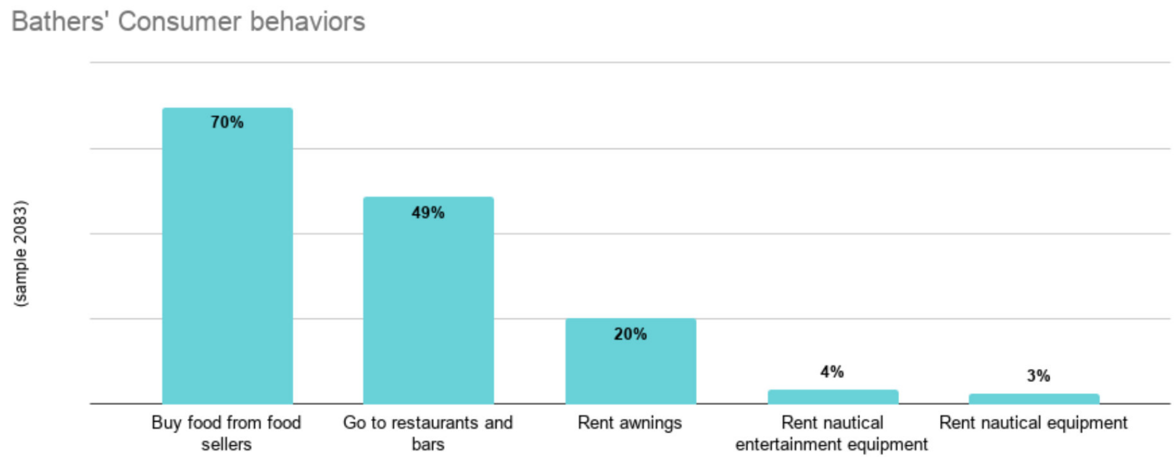


Figure 24: Bathers' Consumer Behaviours

Beach decision is the first interaction that bathers who use weather forecast digital platforms do before they decide on the beach they pretend to go. To understand what information is relevant to the beach decision process, participants were asked what they want to know about a beach before choosing where to go. Survey results show that **beach distance (72%)** is the most relevant information to search for, followed by sea **water quality (50%)**, **swell (41%)**, sea **water temperature (39%)**, **wind (34%)** and **air temperature (28%)**, as shown in Figure 25.

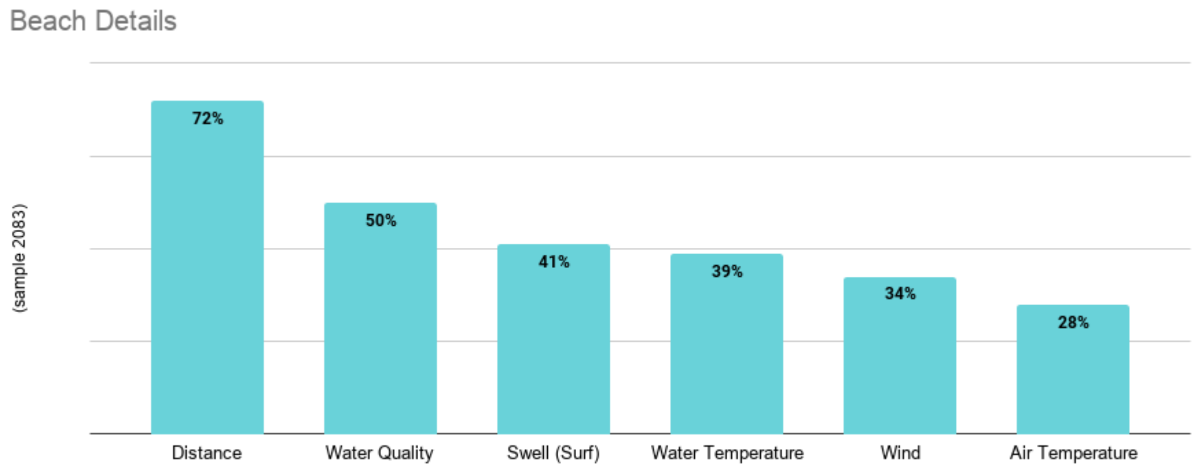


Figure 25: Critical beach details for beach decision process

Additionally, participants were asked about not critical but **relevant information** they would like to know about a beach. **Parking spots were the most requested information (64%)**, followed by **WC or toilet availability (52%)**, **restaurants and bars (17%)**, **access forms (12%)**, **showers (2%)** and **Wifi (1%)**, as shown in figure 26.

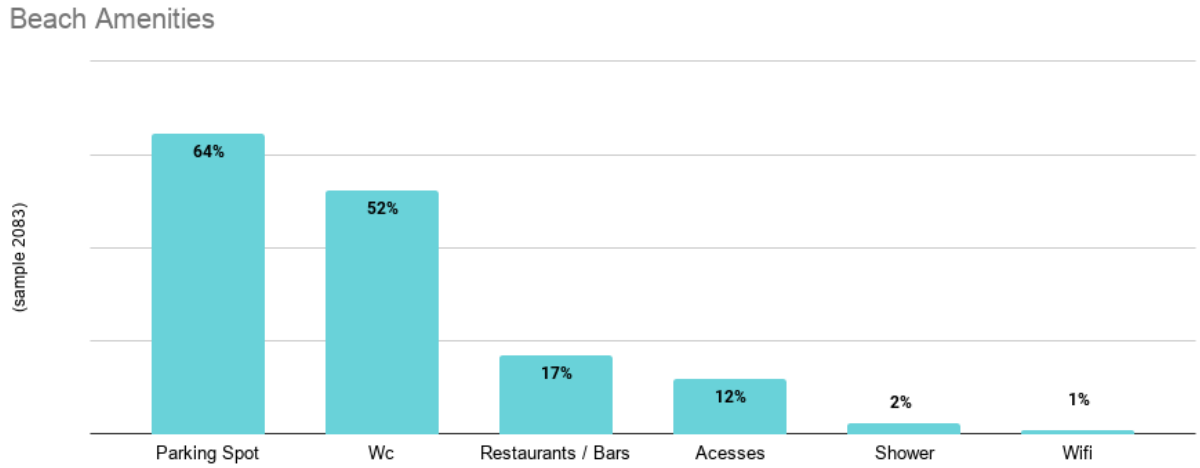


Figure 26: Relevant beach information

Section 3: Bathers' awareness and perceptions of rip-currents

Rip current perception is critical for bathers' situation awareness, particularly in non-lifeguarded or out of season beach scenarios. The inability to detect a rip current and a false sense of security in a personal capacity may lead to a dangerous situation. For this reason, the third section of the survey **focused on the assessment of bathers' understanding and knowledge of rip-currents**. Topics within this segment were designed to assess the sample population's knowledge and understanding of rip currents' dynamics, as well as the ability to identify dangerous areas in the surf zone. The following table shows the results of the study.

Table 3: Bathers' Rip Currents Knowledge

Rip Current Knowledge	**Level of Knowledge** (sample 2167)			
	Total	**Poor (46%)**	**Medium (50%)**	**Good (4%)**
Don't know what a rip current is	31%	64%	2%	0%
Flaw rip currents knowledge	29%	19%	39%	25%
Know what a rip current is	40%	17%	59%	75%
Know visual characteristics of a rip current	39%	17%	58%	63%
Don't know visual characteristics of a rip current	61%	83%	42%	37%
Didn't recognize a rip current on a picture	60%	72%	49%	42%
Recognized a rip current on a picture	40%	28%	51%	58%
Don't know where a rip can appear	61%	81%	44%	34%
Know where a rip can appear	39%	19%	56%	66%
Know how to escape from a rip current	63%	33%	88%	96%
Don't know how to escape from a rip current	37%	67%	12%	4%
Don't recognize safety messages about rip currents	64%	80%	11%	5%
Recognize safety messages about rip currents	36%	20%	89%	95%
Didn´t remember hearing information regarding rip currents	40%	70%	14%	5%
Heard info. regarding rip currents on Media (TV / Radio / Print)	25%	12%	37%	34%
Heard info. regarding rip currents from family and friends	24%	9%	36%	44%
Saw rip currents signage at the beach	14%	5%	22%	26%
Heard info. regarding rip currents at School	4%	2%	5%	13%

A rip current is a powerful, seaward water flow in the surf zone. It is vital for personal safety to be aware of hazards such as rip currents, therefore participants were asked to self-evaluate their knowledge of rip currents. Participants were divided into three categories, according to the expertise they believe to have on rip currents. Results show that **46% believe they have a poor knowledge** (group 1) of the subject, **50% believe that they know something** (group 2), and only **4% self-assessed as rip currents experts** (group 3). However, when confronted with choosing the correct description of the rip current, 17% of group 1 responded correctly, 39% of group 2 selected an untrue description of the rip current, and 75% of group 3 selected the correct rip current description. **Research suggests that only 40 % of the population knows what a rip current is, and 29% have a flaw in their knowledge.**

Participants were asked to select the visual characteristics of the rip currents in a multiple choice question. Evidence shows that 61% correctly recognized the visual characteristics of a rip current, but **83% from group 1 did not respond correctly**. In addition, participants were asked to select the most dangerous part to bathe in a beach picture. Only 40% of the population chose the rip current zone as the least safe zone to bathe, suggesting that **60% of the participants considered the rip current as a safe zone to enter the water.**

Rip currents usually appear between sandbars. Participants were asked to choose the correct description of where a rip current is likely to occur. Analysis shows that **61% doesn't know where a rip current is likely to appear, indicating that the population does not have a clear understanding of the dynamics of the beach.** Despite bathers may not be capable of detecting a rip current, it is relevant to know how to react in hazardous situations. Participants were asked to choose from multiple escape strategies descriptions, the ones that should be performed in case of being caught on a rip current. Results show that 63% would respond to the situation correctly. On the other hand, evidence suggests that **67% out of group 1 would not escape a rip current, which could lead to a deadly situation.**

The last question within this section was focused on understanding where bathers are learning information about rip currents. Results indicate that **40% of the sample population does not remember hearing any information about rip currents**, 25% heard from media platforms such as TV , radio and print formats, 24% heard information from friends and family, 14% from beach signage, and 4% learned information about rip currents at school. **Evidence suggests that the population does not have a strong perception of rip currents, and 86% of bathers never saw rip current safety messages on the beach.** Beach safety culture should be stronger in a country where 91% of the population likes to go to the beach.

Section 4: Bathers' predisposition to use a smartphone on the beach

The last section of the survey focused on the predisposition of bathers to use a smartphone on the beach, assess whether the public knows what AR is, and validate whether the public is willing to use smartphones as a digital tool to visualize and report beach hazards. Participants were asked to self-assess their smartphone usage at the beach. Results indicate that 13% of the participants have a low smartphone usage, **60% has a medium smartphone usage, and 26% of the population have a high**

smartphone usage at the beach (table 4). As far as smartphone features used at the beach, **80% of the participants said they use the smartphone camera,** 55% consult social media and 43% go to the internet, suggesting that **beachgoers are used to interacting with their smartphone at the beach.**

Table 4: Bathers' Rip Currents Knowledge

Smartphone usage at the beach	**Level of Usage** (sample 2166)			
	Total	**High** (26%)	**Medium** (60%)	**Low** (13%)
Camera	80%	85%	80%	70%
Social Media	55%	79%	54%	10%
Internet	43%	68%	41%	8%

Augmented reality was considered to be used in the proposed solution, thus it was necessary to understand the level of AR knowledge of the population. Results indicate that only 5,5% of participants believe they have a good understanding of AR, 40,5% are familiar with the concept but don't have much experience using AR and 54% said they don't know what AR is, suggesting that the population is not used to the AR technology (Figure 27).

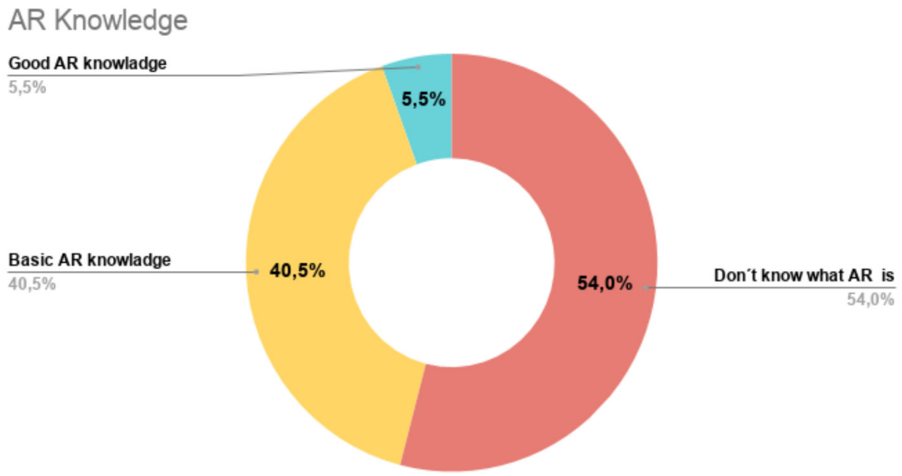


Figure 27: AR acceptability

Nevertheless, participants were also asked if they were willing to use the smartphone on the beach as a safety tool to see hazards in AR. Our research indicates that **85% of participants would use a smartphone to visualize hazards at the beach, 66% would report new hazards and 61% would update hazards** (figure 28).

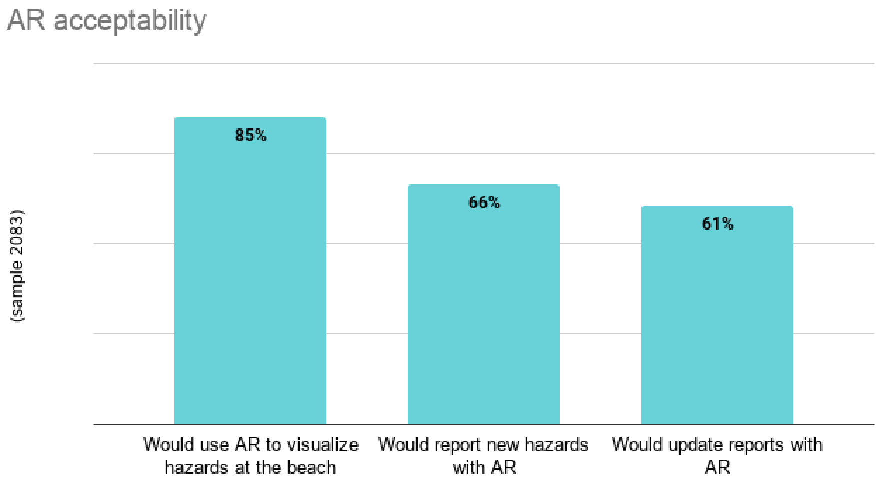


Figure 28: AR acceptability

Our survey research indicates that besides the lack of beach safety knowledge, poor rip currents detection skills, and lack of knowledge of AR technology, **participants are willing to use their smartphone as a safety tool to see and report beach hazards in a beach context.**

Bathers' Interviews

The bathers' interviews were designed to approach the clarification regarding **RQ2 - Can a user community help to promote protection and awareness in the beach context?** - and **RQ3 - Can digital reality improve safety on the beach?** to obtain feedback from the interviewed population. RQ1 was not considered because it addresses the beach professionals' opinion and knowledge. Therefore, **twenty-one interviews** were made via smartphone and recorded with the consent of the participants. The interviews were structured in 4 sections, the two first sections focused on RQ2 and the other two sections focused on RQ3. Each section was composed of open questions to assess qualitative data from different target profiles, organized by the following topics:

- **Section 1 - Beach Safety Knowledge and Behaviour**, aimed to identify different bather's behaviour profiles and understand how bather react when exposed to hazardous situations;
- **Section 2 - Beach Decision Process**, aimed to understand the type of bather profile and to determine what is the most useful information about the beach preference for the user;
- **Section 3 - AR Acceptability,** aimed to assess if a user is willing to use an AR tool to visualize hazards at the beach;

Data from interviews required to be backed up in order to be able to assess without bias what each participant expressed and how they answered throughout the interviews. A software tool named Evolve was used to analyze interview data. Evolve is a collaborative note-taking software that focuses on managing user research data, helping to create digital affinity maps and discovering findings using a three-step methodology:

1. **Extract data from each interview in a Kanban Style List.** This process allowed each section of the interview to be analysed separately about what each participant said, and the raw data to be arranged in a manageable way.

2. **Synthesize the insights of each segment of the interviews and compare what different participants said in the same interview section.** The Evolve software approach allows one to keep track of where the notes came from, allowing traceability at any point of the investigation. It was important to keep all data organized properly since design research is an iterative process and it is helpful to compare different interview outcomes at different phases of the research. This step helped to understand the level of expertise and perception detained by the participants, assess key variables for beach decision-making, understand how people react in hazardous situations, understand participants feelings regarding using AR technology in a beach context.

3. **Turn synthesis into findings,** define different users' target profiles and outline requirements to the development of the proposed solution.

Bathers' Interviews - Results and Findings

The sample population was composed of 60% female and 40% male participants, with 60% of young adults participants, 19% adults and 21% seniors (table 5). The majority of the participants have strong beach background experience (95%) but **75% confess to have basic swimming skills.** As far as risk awareness, 52% identify themselves as being very conscious of beach safety, always check the colour of the beach flag and prefer to go to lifeguarded beaches.

Table 5: Participants Profiles

Bathers Interviews		(sample 21)
Gender	Female	60%
	Male	40%
Age	Young Adults	60%
	Adults	19%
	Seniors	21%
Beach Experience	High	95%
	Medium	5%
Swimming Skills	Basic	76%
	Strong	24%
Risk Awareness	Strong	52%
	Medium	24%
	Low	24%
Rip Current Knowledge	Strong	29%
	Basic	33%
	None	24%
	Flaw	14%
AR Experience	High	5%
	Medium	19%
	Basic	67%
	None	9%
Motivations	Intrisc	67%
	Extrinsic	33%

On the other hand, 24% said that they also go to non lifeguarded beaches and do not consider lifeguards presence as a critical factor to choose the beach, but are extra careful when visiting unpatrolled beaches. There were **24% respondents who seemed to have too much confidence in their ability to identify and avoid hazards**, by claiming that they don't think the beaches they go to are dangerous, and yet beach professionals confirm that those beaches can be dangerous.

When asked to identify beach hazards, **sunburns, strong currents, heavy waves, submerged rocks and wild animals** (sharks, jellyfishes and weevers) were the types of hazards mentioned by the participants. Beside 54% of participants claimed to be aware of beach hazards, **only 29% showed a good understanding of rip currents** (mostly participants with surf experience), 33% had a basic idea but were not confident in their knowledge, 14% showed a wrong perception of what a rip current is and 24% didn't know what a rip current is. **Most of the participants said that they respect the sea but do not feel confident with their beach safety knowledge, and don't know how to interpret the sea to identify hazards.** Beginner surfers are one of the more exposed groups to the danger of rip currents as they show a lack of understanding of beach dynamics, and yet they enter the sea without safety consciousness. Participants who do not surf admit not taking risks when waves are strong, and their level of awareness is influenced by the colour of the safety flag.

When asked what the participants' response would be if they saw someone struggling on a rip current, they said their first instinct would be to look for a lifeguard. However, when confronted with the same event but on an unpatrolled beach, **participants claim that they would call for the responsible entity, but no one specifies which entity they would call for.**

Participants were asked about their decision process before deciding which beach to go, in order to identify information they think is relevant to have about a beach and which platforms they use, if any. Identifying valuable beach information and understanding which platforms users are using is key to understand how beach goers think. Table 6 shows the valuable beach information results.

Table 6: Valuable Beach Details

Valuable Beach Details	(sample 21)
Wind	100%
Crowd level	90%
Safety	62%
Landscape	57%
Habit	52%
Pollution	52%
Sun (air Temperature)	48%
Swell (waves)	48%
Beach Morphology	43%
Water Quality	33%
Water Temperature	29%
ETA	24%
Beach Infrastractures	24%

Wind (100%) is the main variable for beach decision, followed by **crowd level (90%)**, **beach safety (62%)**, **beach landscape** - beauty and nature - **(57%)**, **habit** - beaches users are used to visit - **and pollution (52%)**, **air temperature and swell (48%)**, **beach morphology (43%)**. **water quality (33%)**, **water temperature (29%)**, **ETA and beach infrastructures (24%)** are the least important variables, according to this research.

The most common platforms used by participants are **Windguru** (62%) and **BeachCam** (43%),see Table 7. The Windguru platform is mostly used to check information on wind and swell. BeachCam is a platform that gives access to livestream videos of the beach that users consult to assess wind, swell and crowd conditions. 19% of participants claimed not to use any forecast platform before going to the beach, and usually decide which beach to go based on friends' feedback.

Table7: Forecast Platforms Used by Participants

Forecast Platforms	(sample 21)
Windguru	62%
BeachCam	43%
Friends Feedback	19%
None	19%
Praia em Directo	10%
AccuWeather	10%
Magic Sea Weed	5%
Info Praia	5%
Weather & Radar	5%

Only 5% of the participants said they are experienced AR users, 19% said they have had a few AR experiences, 67% said to have very basic AR experiences and only 9% said that they had never heard about AR before. Furthermore, despite the lack of clear AR awareness among the majority of participants, **67% confirm they would be active users in the community and would report and update beach hazards driven by intrinsic values.** 33% of participants said that they would not actively participate unless there were incentives (extrinsic values). In that case, they would consider collecting data and sharing it with the community

Beach Experts Interviews - Results and Findings

Beach experts interviews were designed to approach the clarification regarding **RQ1 - Is the current beach safety strategy capable of protecting bathers from beach hazards?** Within the scope of the research, beach experts were considered people who have a strong knowledge of the beach dynamics and beach safety strategies such as **a Navy Military Advisor, a Professional Swimmer and Surf Expert, a Surf Teacher, a Hydrographic Engineer and a Lifeguard Coordinator**. Table 8 presents the beach experts who were consulted during the study.

Table 8: Beach Experts Interviewed.

Participants	Expertise	Age	Gender
P1	Navy Military advisor to the Portuguese Ambassador to NATO , responsible for the areas of Maritime Strategy, and all maritime issues.	Senior	Male
P2	Former Olympic athlete, one of the most award-winning Portuguese athletes ever, representing Portugal in various modalities, having reached the highest level in Swimming in Spearfishing.	Senior	Male
P3	Surf Teacher	Young Adult	Male
P4	Hydrographer Engineer	Adult	Male
P5	Lifeguard Coordinator	Adult	Male

Interviews with beach experts were also organized into four sections. Each section consisted of open questions to assess qualitative data from target profiles. Results from the interviews are summarized as follows:

- **Section 1 - Safety practices**
  - **Description:** The first section was focused on understanding safety practices adopted at the beaches in Portugal, such as beach safety classification process, safety tools there are available and what types of hazards may prevail at the beach.
  - **Research Findings:**
    - The characterization of **the Portuguese coast as a dangerous and treacherous landscape was unanimously considered by beach experts.** The Atlantic coast is irregular, exposed to strong wind and sea action and has both rocky and sandy beaches, thus **beach hazards including both forms of rip currents** (fixed and dynamic) **are common in Portuguese beaches.**
    - In order to mitigate the risk of beach hazards in Portugal, the **IH** (Instituto Hidrográfico da Marinha) **has studied the morphology of the coastline to understand what types of hazards** are likely to be present at different locations and **manage safety strategies** accordingly.
    - **There is a safety program that monitors non-lifeguard beaches with military officers - SEAWATCH.** Non-lifeguard beaches do not have a lifeguard professional on the beach to look out and assist swimmers, instead, there are **groups of military patrols** that monitor the coastline and are **ready to intervene if necessary.**
    - The **surfer community has an important role in safety at the beach**. Evidence suggests that **there are fewer accidents today compared to 20 years ago because there are more experienced surfers who help rescue swimmers from risky situations** when there is no lifeguard, or when the lifeguard doesn't notice the situation.

    - **Underwater rocks, unstable cliffs, slippery rocks, sand depressions** (sudden drop), **dangerous animals** (jellyfish, weavers and sharks), **rip currents, strong currents, heavy waves, sun** and **wind** are beach features that can pose a danger to beachgoers.

- **Section 2 - Rip Current Formations in Portuguese Beaches**
  - **Description:** The section was focused on understanding the frequency of rip currents in the Portuguese coastal landscape, addressing the types of beach affected by this phenomena and what safety measures are in place to mitigate this risk.
  - **Research Findings:**
    - **Beach experts unanimously reported that rip currents are common in Portuguese beaches** and can be dangerous **when there is strong sea activity**. "Costa da Caparica," "Meco" and "Fonte da Telha" are examples of popular beaches that are dangerous when strong wind and swell conditions prevail.
    - **Rip current monitoring is critical for beach protection**. Beach experts confirmed that rip currents are detected by beach professionals who are qualified to understand the dynamics of the beach.
    - **Rip currents can have strong underwater power that isn't noticeable from outside.** The strength of a rip current can be strong enough to **scare swimmers and cause them to panic**, which can end up in **deadly situations** in non-surveilled beaches.

- **Section 3 - Bathers behaviour:**
  - **Description:** The third section focused on understanding how bathers' behaviour affects the safety of the beach, if beach communities acknowledge and respect beach safety signage and the overall level of beach community awareness.
  - **Research Findings:**
    - **There are swimmers who do not follow the safety guidelines at the beach nor value lifeguards and beach signage**. These groups of swimmers **were reported as the most dangerous problem for themselves and others.**
    - **Most common rescues are due to accidents with people who did not comply with warning signs** or didn't follow lifeguard's instructions.
    - In general, **bathers do not understand the basic principles of beach safety and are not aware of the types of hazards that may occur in the beach environment.**

- **Section 4 - Improving beach safety with digital reality:**
    - **Description:** The fourth section focused on understanding where beach safety could be improved, how digital signage could change beach safety strategies and how AR could have a positive effect on beach safety culture.
    - **Research Findings:**
        - Experts agree that **beach surveillance should be available all year round in beaches with dangerous morphology profiles and high popularity.** Existing safety procedures do not operate all year round since, without digital technology, it would not be feasible to hire lifeguards to work every day of the year. **Digital signage makes it possible to map and communicate hazardous areas through a digital platform, providing bathers with vital warning information so that they can enjoy the beach being aware of the hazards.**
        - **Local hazards** (e.g., submerging rocks, sand drops and strong currents) **are not easily detectable by outsiders** (eg., tourists and non local beachgoers). Such hazards should also be communicated through AR so that **bathers and beach professionals who visit a beach for the first time can be aware of the local hazards.**
        - Beach experts suggested that **the definition of different beach areas for specific purposes is necessary** and, therefore it should be designed for safety purposes. Popular beaches should have **areas dedicated to different types of activities** such as swimming, surfing and kitesurfing. **Digital signage could help to delimit those areas and communicate it to bathers and beach experts.**
        - **Digital beach signage should be flexible and adjustable based on prevailing beach conditions**, as beach hazards can be unpredictable and occur in areas classified as safe, which can lead to dangerous situations.

3.3. Research Outcomes

Our research confirms the need to conceptualize a new digital beach safety approach, supported by a community of users, able to contextualize beach data with the surroundings of bathers in real time, and to communicate beach safety literacy in order to foster a safer beach culture. Research findings and guidelines for conceptualizing the proposed approach are as follows:

- The portuguese coast landscape is dangerous and treacherous. Beach experts confirm that underwater rocks, unstable cliffs, slippery rocks, sand depressions (sudden drop), dangerous animals (jellyfish, weavers and sharks), rip currents (fixed and dynamic), strong currents, heavy waves, high levels of UV (sun) and strong wind are beach features that can pose danger to beachgoers.

- Rip current flow is mainly driven by wave breakage and water levels in the surf zone, which in turn are determined by beach morphology, swell (wave conditions) and tidal levels. There are two main types of rip current known as beach rip currents (dynamic rips) and topographic rip currents (fixed rips). Beach rip currents are driven by the morphodynamics of the surf zone and are susceptible to change in size, strength and position. Topographic rip currents can always be observed at the same spot.

- Risk perception and swimming preference are key factors for safety at the beach. Our research suggests that 74% of the population claims to comply with safety signs, but 73% of the population does not know what a red and yellow flag means, suggesting that the beach safety communication system is not correctly perceived by bathers. For this reason, bathers should be provided with more beach safety literacy.

- Beach experts agree that beach surveillance should be available throughout the year in beaches with dangerous morphologies and high popularity. Moreover, popular beaches should have areas dedicated to different types of activities such as surfing, surfing schools, and swimming. Augmented Reality could be used to display digital signage at the beach and help delimit and communicate such areas to bathers and beach experts.

- Visual representation of the dynamics of hazards can have a positive impact on the promotion of the rip current safety messages and, as a consequence, on bathers' behavior. Local hazards (e.g. submerging rocks, sand drops and strong currents) are not easily identified by outsiders (e.g. tourists and non-local beachgoers). Such hazards can be communicated through AR so that bathers who visit the beach for the first time can be aware of them.

- Digital beach signage should be flexible and adjustable on the basis of prevailing beach conditions, as beach hazards, such as rip currents, can be unpredictable and appear in undesirable areas (e.g., surf schools).

4. Proposed Solution

4.1. Project Concept

The Portuguese coast is dangerous and treacherous, exposed to strong winds and swells. Beach hazards including both forms of rip currents (fixed and dynamic) are common in Portuguese beaches. For that reason, rip currents detection and communication is critical for beach safety, as they present a major threat to bathers who are not aware of them.

Safety beach culture combined with effective beach signage are key factors for bathers' situational awareness. In our research achievements we have concluded that only 40% of the Portuguese population is familiar with rip current phenomena and only 27% knows what a red and yellow flag means, revealing a lack of understanding of beach safety communication. Beach experts consider swimmers who do not follow the safety guidelines and don't respect beach signage to be the most dangerous problem for themselves and others; our research also indicates that Portuguese bathers don't have a strong beach-safety culture and that beach hazard communication should be improved. Moreover, the research community agrees that bathers need to get committed with a beach-safety culture and should know how to identify a rip current.

This project aims to contribute to improve beach safety with situational-awareness data to keep bathers informed about prevailing hazards at the beach. A service design approach was designed to conceptualize a solution for collecting data about potential hazards, including information on the status of active rip currents. The proposed approach consists of a platform to empower the user in becoming an active beach-safety agent and also to create a user community engaged in the promotion of a social beach-safety culture. The goal of the project is to mitigate the number of rescues and deadly incidents at the beach, with additional benefits regarding bathers beach-safety literacy and social conscience, thus making the Portuguese beaches a safer and more enjoyable destination.

The architectural design of the platform consists of the combination of immersive technologies including Augmented Reality (AR), Artificial Intelligence (AI) and Gamification. Augmented Reality will be used to display a digital presentation of the prevailing hazards, which can be seen with a smartphone, helping bathers to make conscious and safe bath decisions. Artificial Intelligence, in particular Deep Learning algorithms, will be used for image processing and hazard detection. AI allows the detection of hazards without the presence of a lifeguard, helping to improve beach safety communication without bathing season and lifeguard covering constraints. Gamification is a key element considered to be included in the experience strategy. The design of an interactive and gamified environment promoting a beach-safety behaviour will encourage bathers to be aware of beach hazards, detect and communicate them with the community and improve the beach-safety culture in Portuguese beaches.

4.2. System Contextual Diagram

A context diagram represents the direct environment of the proposed solution and the communication flows from and to it. It contextualizes the System of Interest (SoI), associations between the different stakeholders and the SoI, and associations between other enabling systems with which it has direct information flows. The following diagram illustrates all the stakeholders involved in the architecture design to support platform development, how each entity is related to the SoI, what information flows from each entity to the SoI and vice versa.

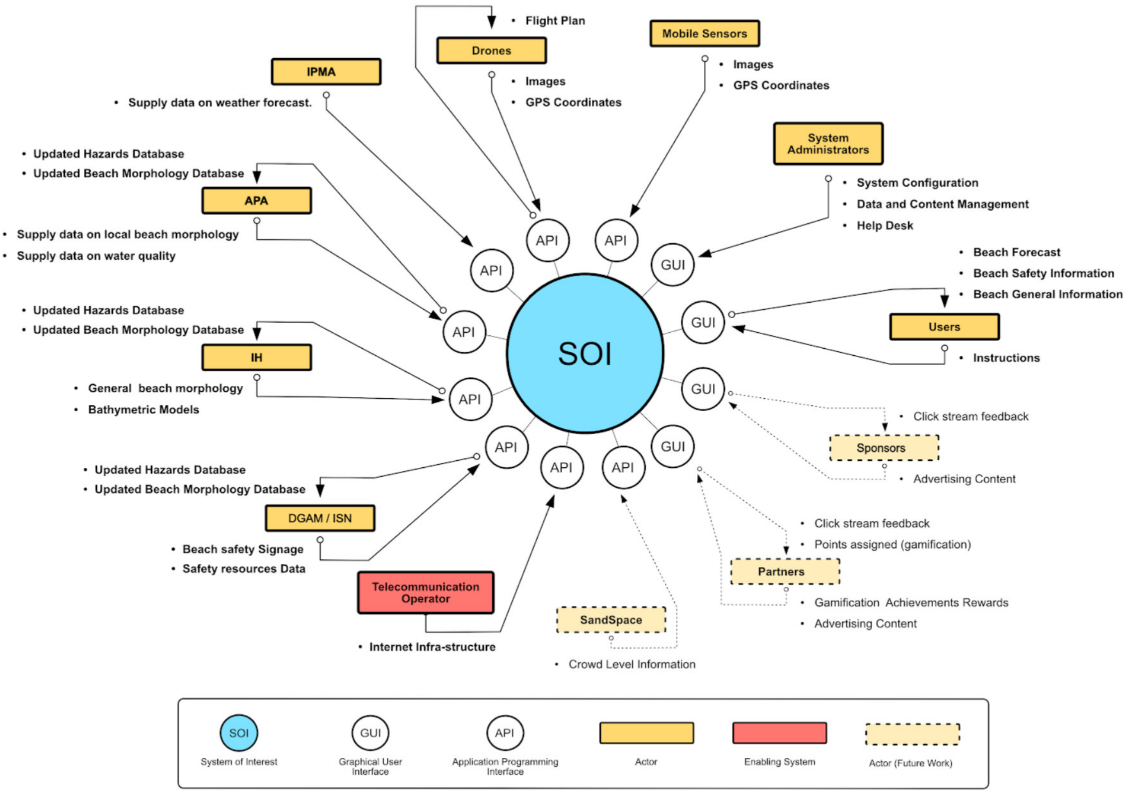


Figure 29: System Context Diagram

The proposed solution will combine data from different strategic stakeholders. **System Administrators** and **Users** are system actors who will interact with SoI through Graphic User Interfaces (GUIs). **IH** (Instituto Hidrográfico da Marinha), **APA** (Agência Portuguesa do Ambiente) **DGAM/ISN** (Direcção Geral de Autoridade Marítima e Instituto de Socorros a Náufragos), **IPMA** Instituto Português do Mar e da Atmosfera), **Drones** and **Mobile Sensors** are also system actors that communicate with the SoI, but instead of GUIs, they will use Application Programming Interfaces (APIs) to directly integrate data into the platform. The solution must include an enabling system, the **Telecommunications Operator**, which will facilitate the communication infrastructure to allow data to flow between system actors and the SoI. In addition, the SoI will be able to integrate future actors, such as **SandSpace**, **Partners** and **Sponsors**, which are for now, outside the scope of this project (for more details, see Future Work Section). Table 9 summarizes the descriptions and roles of stakeholders in the project.

Table 9: Description of The Stakeholder Role

Stakeholders	Type / Role Description
System Administrators	• Type: Actor • Responsible for System Configuration. • Secure Data and Content management. • Help Desk.
Users*	• Type: Actor • Access to beach forecasts, safety and general data regarding beach culture. • Send specific instructions to the SOI (based on the gamification interactions).
Drones	• Type: Actor • Receive flight plans. • Capture pictures of the surf zone and GPS data .
Mobile Sensors	• Type: Actor • Send pictures of the surf zones. • Send GPS data.
IH	• Type: Actor • Provide generic data about beach morphology (i.e., high level view) and bathymetric models. • Access to prevailing hazards database. • Access to information for developing new safety strategies.
APA	• Type: Actor • Provide data about beach morphology (i.e., local view) and water quality, namely by integrating results from the project COMOS • Access to prevailing hazards database.
IPMA	• Type: Actor • Provide data on weather forecast by using an API to connect to their website (https://www.ipma.pt/en/)
DGAM/ISN	• Type: Actor • Support compliance with Digital Signage standardization (AMN) • Access to prevailing hazards database. • Access to relevant information for developing new safety strategies.
SandSpace	• Type: Actor (Future Work) • Provide beach crowd data.(SandSpace).
Partners	• Type: Actor (Future Work) • Sponsor Gamification Achievements Rewards. • Give advertisement content. • Gamification points feedback (feedback of users engagement). • Access to clickstream feedback.
Sponsors	• Type: Actor (Future Work) • Give advertisement content. • Access to clickstream feedback.
Telecommunication Operator	• Type: Enabling System • Facilitate the communication and data flow between system actors and SOI.

**Users:* The gamification strategy was designed to increase user engagement and enjoyment when interacting with the system. Users will be invited to complete achievements and engage with the community by completing the objectives while providing safety information on the state of the beach (see section 4.4). The more advanced the user is on his journey, the more effective his ability to detect rips will be, contributing to a higher reliability of the platform. Thus, the user level will be taken into account when data is submitted to the system.

4.3. Introduction to the System Architecture

The system architecture defines a schema based on principles, concepts and properties that are related with each other (Faisandier Alan and Roedler Garry, 2020). This section presents an overview of the system architecture and describes how the system components are integrated to address the project requirements. Figure 30 provides the block diagram of the proposed solution, without considering the details of implementation. Three high-level blocks are presented in the diagram: the ***Presentation Layer**,* the ***Business Logic Layer**,* and ***External Systems***. Within the scope of this thesis (Interaction Design), the ***Presentation Layer*** will be described in more detail, as it is the component that connects the user to the system and will define the design strategy for the user experience.

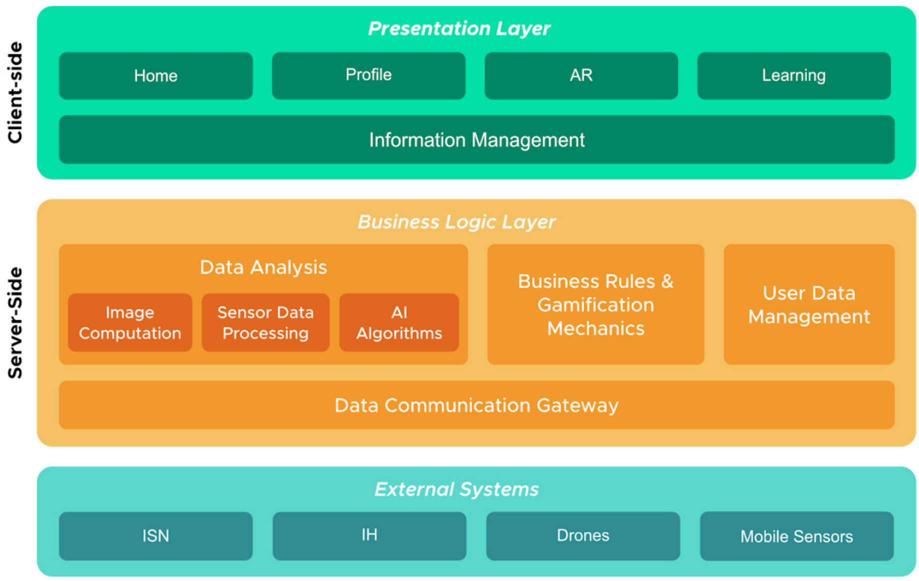


Figure 30: Block Diagram of the SOI

Client-side: Presentation Layer

The ***Presentation Layer*** represents the **Client Side**, which was divided into five different sections: **Home, Profile, AR, Learning** and **Information Management.** The description of the Information Architecture (IA), designed to organize information and help to clarify where users are, what they will find, and what they can expect when they interact with the product, is given in Annex 5.

The **Home** area focuses on the experience of exploring different beach details and access to safety information, including beach risk level, number of prevailing hazards and presence of lifeguards, so to inform users of the safety conditions before they consider where to go. The home page will be the first interaction with the system, thus it has to respond to user expectations regarding beach decision interactions, it has to be useful, enjoyable and easy to use (see Annex 7, section 9 and 10).

The **Profile** screen will be used as a "dashboard" designed to promote user's commitment and enthusiasm towards becoming a master of beach safety. Gamification elements such as progress bar, user level, badges and activity will be displayed in this section to allow the user to measure where he is and what he has already accomplished. Users will be encouraged to complete different challenges for each level and explore rewards that will motivate them to actively collect and share data on new hazards, and to update information on already identified hazards (see Annex 7, section 13).

The **AR** section will be the main screen with which the user will interact at the beach. Safe areas supervised by lifeguards, prevailing hazards (such as rip currents and sudden drops), lifeguards' position and beach facilities are some examples of what will be displayed in AR (see Figure 31). Digital representation of safety information that can be easily accessed from a smartphone may have a positive effect on bathers' situational awareness, as it allows people to see where dangers lie, contributing to a more conscious beach culture. Beach professionals will also use AR as a tool to manage safety strategies and promote the safe use of the beach (see Annex 7, section 7, 11 and 12).

Figure 31: Example of Digital Signage in AR

The **Learning** section will focus on beach safety literacy and will be a tool for bathers to learn about beach safety, develop rip detection skills and strengthen the Portuguese beach safety culture. This section will provide beach literacy on categories such as *Rip Currents, Lifeguard Tips, Beach Morphology, Weather, Marine Creatures* and *Emergency Contacts*. Users will be able to develop their beach safety culture and learn about the safe use of the beach, what to do in extreme scenarios and how to check for rip currents by watching videos on the subject (e.g., a video demonstrating how to detect a rip current). There will be a Quiz at the end of each section to determine if the user has absorbed all the important information (see Annex 7, section 14).

The **Information Management** module will be responsible for managing the data flow between the user and the server. It verifies user authentication when logging in and manages the appropriate data to be displayed to each user (e.g. user level and XPs, game mechanics, user configurations and notifications).

Server-side: Business Logic Layer

The server side implementation does not fall within the scope of this study, however a contextualization will be given on how the proposed solution could operate. The ***Business Logic Layer*** represents the **Server Side** of the SoI, which consists of four block components: **Data Analysis**, **Business Rules and Gamification Mechanics**, **User Data** and a **Data Communication Gateway**.

The **Data Analysis** block includes three components for processing data from external systems: **Image Computing, Sensor Data Processing** and **AI Algorithms**. These three components will receive data from the Data Communication Gateway, process, validate and detect the presence of rip currents. **AI Algorithms**, in particular Deep Learning algorithms, uses neural-network algorithm layers to interpret information to other layers based on raw input data (Simplilearn, 2020). In the context of the proposed solution, AI algorithms will identify the presence of rip currents, draw the hazard plume in Augmented Reality, and ultimately, predict the evolution of hazards by creating a predictive model. Figure 32 provides an example of a raw image taken by the user (left side), the same picture after being processed by the SoI, with the rip plume detected by the AI (centre), and the representation of the AR warning sign of the detected hazard, which will be seen by every user.

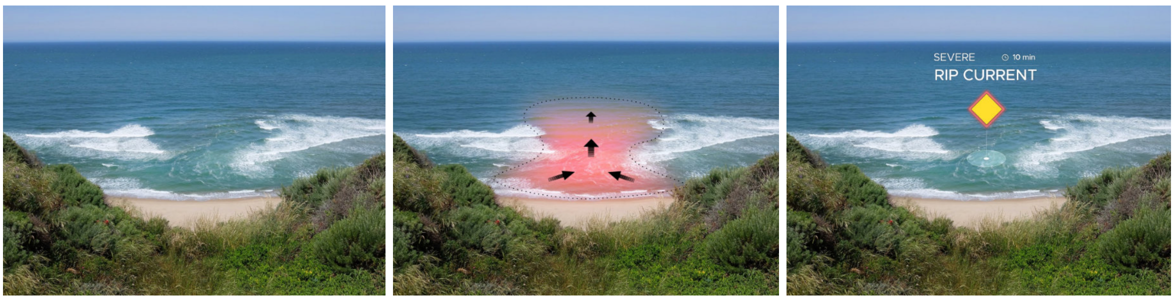


Figure 32: Rip Current Detection and Representation

The presentation of the Digital Signage, which will be perceived through AR, will use a "virtual grid" (not visible to users) as a foundation to display digital data in the user's surrounding environment. The "virtual grid" will be used as a map to contextualize user coordinates (see Figure 33, point A) with hazard positions (see Figure 33, point B). Drones can be used to capture aerial images of the beach and send them to the SoI, that will use Photogrammetry as a way to produce low poly mesh morphology of the beach and use it as a "grid". Once a new rip current is detected, the information is uploaded to the database and every community member on the beach will be notified and able to see the AR Warning Sign, indicating the position of the new rip current as well as the hazard plume.

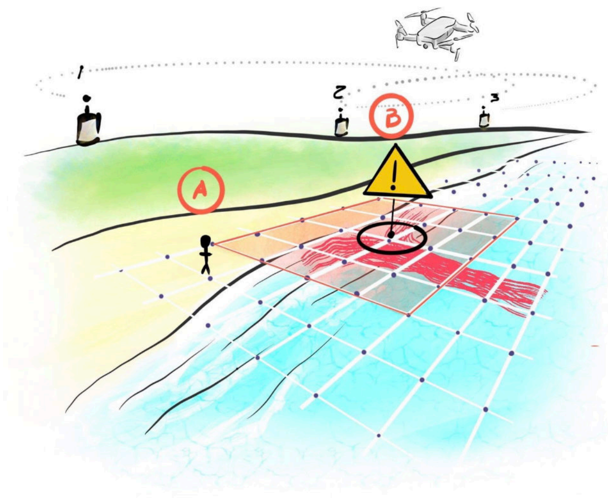


Figure 33: Virtual Grid and the Contextualization of the Position Between User and Hazards

The **Business Rules** will be the component responsible for contextualizing data from **External Systems** with the **Data Analysis** and **User Data**. It will be necessary to manage and contextualize beach morphology data with weather forecast data, identified hazards, user data and gamification rules. Each beach has its own morphology that dictates what kind of hazards might prevail. Weather Forecast data, in addition to being relevant to the user, will also help to predict the severity and behavior of the hazards. User Data will contextualize gamification information (eg. User level XPs, achievements will be addressed to the bather, in accordance with his progress throughout his journey). **Gamification Mechanics** determine how the user will collect and share the hazard data to the system (see Gamification Mechanics section for more detailed information on the gamification strategy).

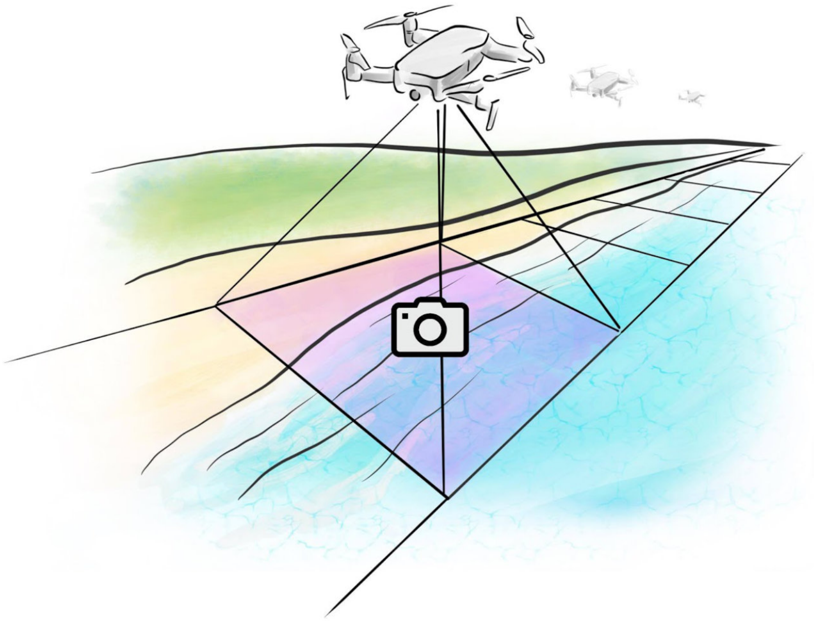
The **User Data Management** will be used for collecting, processing and storing users data securely. The purpose of data management is to optimize the use of data within the regulatory policies. It will manage the operations of users and administrators, the regulatory requirements and the needs of the SoI to extract value from its data. The **Data Communication Gateway** will be the component responsible for connecting external systems to the SoI and managing external data from different sources.

4.3.3. External Systems

External systems are systems or components of systems that fall outside the scope of the SoI and over which the SoI has no direct authority. In this project, external systems will be used to combine already available data from **IH, IPMA** and **DGAM**, as well as data from **Mobile Sensors** and **Drones**. The **IH** and **IPMA** will provide data on weather forecasting, water quality and beach morphology (surf zone). **DGAM** will coordinate **ISN** efforts to manage and track digital signage. Both entities will have access to a hazard database, hazards and beach morphology historical changes, and other relevant information for the development of new safety strategies or studies related to the Portuguese coastal landscape (e.g., demographic studies on high beach use levels in non-lifeguard beaches).

Mobile sensors (e.g. users' smartphones and beach infrastructure sensors) and **Drones** are two other **External Systems** that will be used to send pictures and GPS data to the SoI. The data collected from mobile sensors will be processed in the server and communicated to users through a GUI. In addition, to help create the "virtual grid", **Drones** can also be used to capture pictures of the surf zone, at specific geodesic points, and help detect hazards (see figure 34).

Figure 34: Drone Taking Pictures At Geodesic Points



Aerial hazard monitoring is quite effective as rip currents are easier to spot from above compared to the perspective of bathers standing on the beach. **Drones** are efficient and sustainable vehicles that can be programmed to operate independently and can patrol several beaches in a short period of time. In the future, it would be exciting to have a structure to support and integrate these aircrafts with the system in a feasible and autonomous way.

4.4. Gamification Strategy

Gamification is another key element considered to be included in the proposed approach. The aim of creating a gamified environment to promote beach-safety behavior is to encourage bathers to be aware of, identify and communicate beach hazards to a community, while at the same time, improve the beach-safety culture in portuguese beaches. The underlying learning strategy to keep users involved is based on the idea of motivating users to become beach safety experts and be able to understand beach dynamics, by developing rip current detection skills. The intrinsic value of safety can be developed by promoting the ability to identify rip currents (autonomy and competence) and by being keen to communicate hazards with the community (relatedness).

Gamified Interactions

Users will be able to progress in the game and unlock rewards by interacting with the System and sharing data with the community. The gamified environment will consist of three types of user interaction: **Rip Interactions**, **Simple Interactions** and **Eco Interaction.** Figure 35 presents the game mechanics to be implemented in the proposed approach.

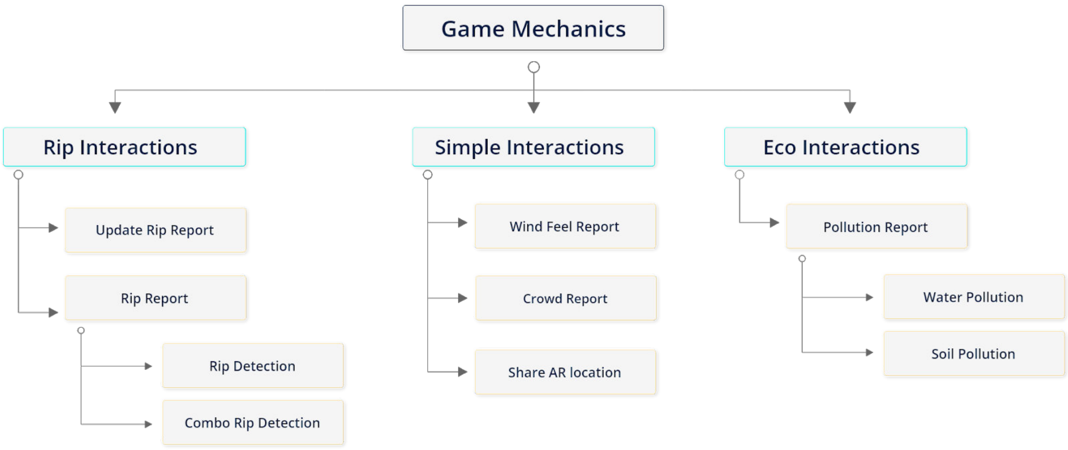


Figure 35: Game Mechanics

Rip Interactions were designed to empower the user to collect data about rip currents and contribute to improve beach safety by keeping the community informed about prevailing hazards at the beach. The user will be able to collect data by taking pictures of the surf zone at specific points on the "virtual grid" known as **Viewpoints** (see Figure 36)**. Viewpoints** are geodisc points that can be seen in AR and will be used to guide the user to a known beach location to take a picture of the surf zone.

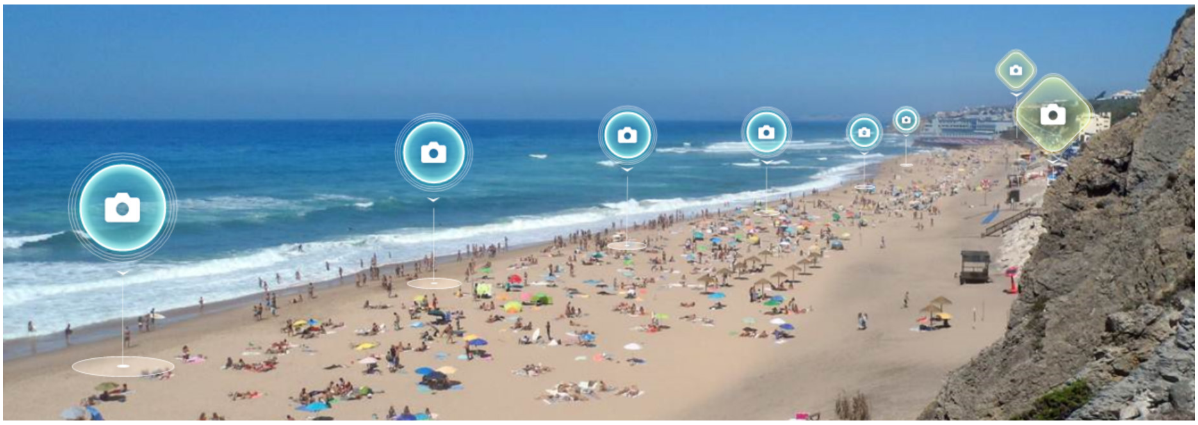


Figure 36: Viewpoints

The user will only be able to take a picture if his location matches the viewpoint location, otherwise it would not be possible to manage the data sent by the users and it would be impossible to determine what part of the surf zone each picture represents. There will be two types of viewpoints: **Standard Viewpoints** and **Golden Viewpoints. Standard Viewpoints** are the blue geodesic locations close to the surf zone, and will be used to assist the user to take a picture of a specific beach area. **Golden Points** are strategically positioned yellow geodesic locations that guide the user to take a picture from a higher perspective, allowing the user to detect more than one rip current with one shot and **achieve a Combo Rip Detection**. Unlike the Standard Viewpoints, which will be available to every user, Golden Viewpoints will only be available to more advanced users who already know what a rip current looks like, to help prevent users from sending useless pictures to the SoI.

Since beach rip currents are susceptible to change in size and location, these types of hazards need to be regularly monitored. Once a dynamic rip current has been reported, the report will indicate the type, the severity and the last time the hazard has been updated. The user will be able to collect XPs by updating an already identified hazard - **Update Rip Report -** or by taking a picture of the Surf Zone - **Rip Report**.

Simple Interactions - Wind Report, Crowd Report and **Share AR Location -** are quick actions designed to promote the use of the platform and encourage the community to share qualitative data on the conditions of the beach. The **Wind Report** is a qualitative evaluation of the feeling of wind that a user will be able to make once he arrives at the beach. The idea of integrating a qualitative evaluation of the wind sensations emerged after the user interviews, as the majority of the participants didn´t know what wind forecast values represent in terms of physical sensation. The **Crowd Report** is a qualitative evaluation of the number of people at the beach. Aside from being one of the requirements detected in user research, this feature will be helpful in preventing users from going to crowded beaches, helping fight the COVID-19 pandemic we are living in. The average evaluations of the reports can be calculated and displayed on the beach detail screen.

Share AR Location is a simple feature which will be used to promote community growth. A Beach can be a crowded environment, with few reference points, which make it difficult to describe a person's position. The SoI will be able to contextualize GPS coordinates between two users and display their relative position in AR. This feature will only be accessible to community members and will be used to attract new community members.

Eco Reports will be interactions aimed at promoting sustainability and helping to keep the Portugal shoreline clean. Users will be able to take pictures of polluted areas (water and soil) and share them with the SoI. The purpose of collecting pollution data is to track pollution on the beaches and to send the information to the authorities responsible for cleaning polluted areas in an efficient manner.

Game Mechanics

The gamified journey will be composed of five levels: ***Beginner, Trainee, Expert, Master*** and ***Guru***. Each level is defined as the total number of XPs and will present different challenges, suited to the users' experience, so to drive them to collect data, while developing their beach-safety and rip detection skills. Users will be able to receive XPs by performing Rip Current Interactions (Update Rip Reports or Rip Reports), Basic Interactions (Crowd Reports, Pollution Reports and Share AR Position) and Pollution Reports. Table 10 presents the levels of the game and their XP goals, as well as the value of the user interactions at the different levels.

Table 10: Gamified Strategy

User's journey to mastery of beache safety						
User Interactions		**Beginner**	**Trainee**	**Expert**	**Master *****	**Guru**
Rip Current Interactions	Update Rip Report	20 XP	50 XP	75 XP	75 XP	75 XP
	Rip Report *	10 XP	5 XP	-	-	-
	New Rip Detected	30 XP	50 XP	150 XP	150 XP	150 XP
	Combo Rip Detected **	-	-	250 XP	250 XP	250 XP
Simple Interactions	Crowd Report	10 XP	20 XP	30 XP	30 XP	30 XP
	Wind Feel Report	10 XP	20 XP	30 XP	30 XP	30 XP
	Share AR location	15 XP	15 XP	15 XP	15 XP	15 XP
Pollution Report		25 XP	25 XP	25 XP	25 XP	25 XP
Level Goal		**250 XP**	**1000 XP**	**2000 XP**	**3500 XP**	**>5000 XP**

* When a user makes a rip report to find a new rip current, he will earn a small amount of XP to stimulate him to look for more rip currents. These participation points are only available on the first two levels (Beginner and Trainee). Once the user reaches the Expert level, he should already understand what the rip current looks like, so he will only earn XP when a new rip current is detected.

** Combo Rip Currents can be achieved when a user identifies more than one rip current in a single report. This is only possible at Golden Viewpoints, which become available at the Expert level.

*** The Master and Guru Levels are designed to motivate frequent bathers to actively collect data all year. These levels might have perks sponsored by partners to reward the most active users in the community with, for example, free parking at a local beach or regular discounts coupons in local services. However, once a user reaches the Master level, he will be penalized if he makes more than three non-confirmed rip reports or if he fails to make a new report during a certain period of time.

Challenges motivate users to perform different interactions and promote the development of the beach-safety culture. Users will be encouraged to follow specific goals to add meaning to their interactions. Each challenge will consist of a set of game interactions which must be completed by the user. After the accomplishment of a challenge, the user will receive an amount of XPs, collect a badge related to the achievement, and potentially unlock an award sponsored by a partner (future work). Every challenge must have a clear objective and must be contextualized with user level. Table 11 provides a set of challenges that are designed to guide the user on his journey.

Table 11: Gamification Challenges

Gamification Challenges			
Incentive	**Achievements**	**Points**	**Badge**
Learn how it works	Complete Toturial	50 XP	Finish Tutorial
Improve bathers safety knowledge	Respond Quiz in Learning Section	50 XP	Conscient Bather
Explore different beaches	Explore 5 different beaches	50 XP	Beach Explorer I
	Explore 10 different beaches	75 XP	Beach Explorer II
	Explore 20 different beaches	100 XP	Beach Explorer III
Promote user engagement in the same beach	Update 10 Rip Reports in the same beach	100XP	Master Beach Name
	Update 15 Rip Reports + Detect 3 New Rips in the same beach	200 XP	Expert Beach Name
	Update 20 Rip Reports + Detect 10 New Rips	300 XP	Guru Beach Name
Promote user engagement in different beaches	Update 10 Rip Reports in 5 different beaches	150 XP	Major Beach Master
	Update 15 Rip Reports + Detect 3 New Rips in 5 different beaches	250 XP	Major Beach Expert
	Update 20 Rip Reports + Detect 10 New Rips in 5 different beaches	350XP	Major Beach Guru
Promote Sustainability	Make 5 Pollution Reports	25 XP	Eco I
	Make 10 Pollution Reports	100 XP	Eco II
	Make 20 Pollution Reports	200 XP	Eco III
Bring new members to the community	Share Location with 5 Friends	50 XP	Socializer I
	Share Location with 10 Friends	100 XP	Socializer II
	Share Location with 20 Friends	200 XP	Socializer III

Badges will be used as a visual representation of achievements and can be collected at the end of each challenge. They can influence users' behaviour, encouraging a bather to accept certain challenges in order to earn a particular badge. Moreover, badges symbolize one's integration in a sub-community of users who own the same badge, while promoting competition between community members.

4.5. Journey Mapping

How do I help my customers achieve their goals on my service while still achieving mine?

A customer journey map is an artifact that describes how a user will move through each phase of interaction and what he will experience at each phase. User Personas and storytelling are essential components of the Journey Map development, as they help focus on users behaviour, expectations and product requirements. Figure 37 presents three personas at different levels of the game, created to represent different types of target users, with different needs, to understand their perspectives as they follow the path of need and fulfillment.

User Personas

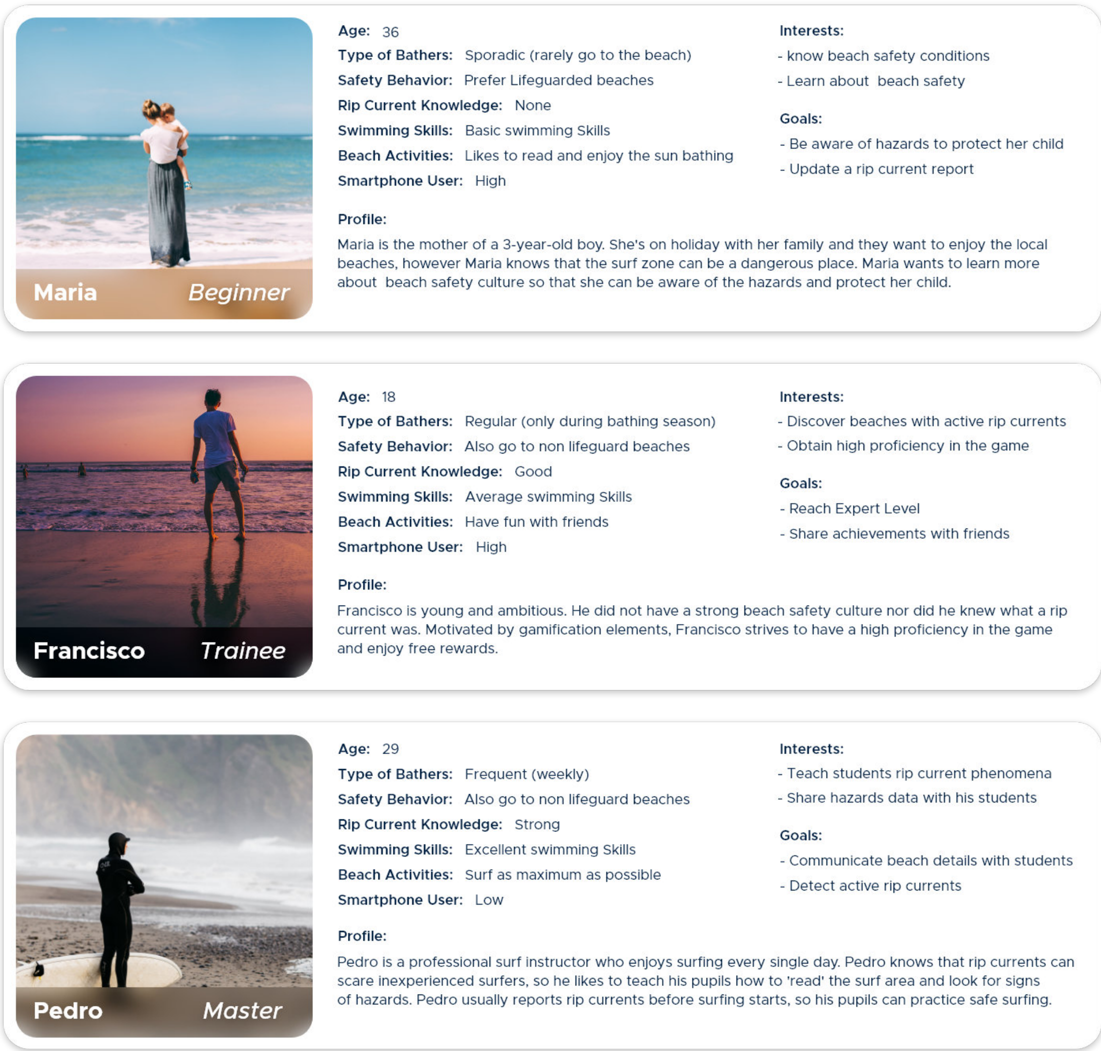


Figure 37: Presentation of User Personas

Maria's Storytelling

Maria is a mother on holiday with her family. She wants to visit the surrounding beaches and enjoy the beauty of the Portuguese coastline. Maria knows the surf zone can be a hazardous place, so she wants to compare differente beach risk levels before she leaves Home.

Scenario 1: Maria wants to know the beach safety conditions to decide which beach to go. After a quick search on Google, she finds a variety of apps that she can use to check the beach forecast, but there's only one that provides information on the predominant hazards. She wants to give it a try.

Scenario 2: Once signed up, Maria notices the gamified environment on the profile screen and is pleased to see the partners involved in the app. Maria doesn't have a strong beach culture, so she doesn't feel confident about her ability to complete the challenges presented on the profile screen. She watches videos from the *Learning* section to learn about beach hazards and strengthen her beach safety knowledge.

Scenario 3: Before leaving the apartment, Maria checks the *Close To You* beach selection, located in the *Home* screen to compare different beach conditions. After choosing the beach, Maria clicks on *Get Directions,* which guides her to the chosen beach.

Scenario 4: Upon arriving at the beach, Maria uses AR for the first time and becomes surprised with the experience of seeing the digital signage. She notices the location of two small rip currents and decides to stay close to the lifeguard position and the swimming area. While her son is playing with other kids, Maria is confident to respond to the quiz related to rip currents. She successfully completes the quiz, becomes knowledgeable about rip currents and confident to start looking for them.

Scenario 5: Maria successfully updates one rip report and feels confident to complete more challenges. Maria is happy to learn about beach safety from a gamified app, which will give her more confidence to protect her child. Moreover, the community gained one more active member who will contribute to the healthy use of the beach.

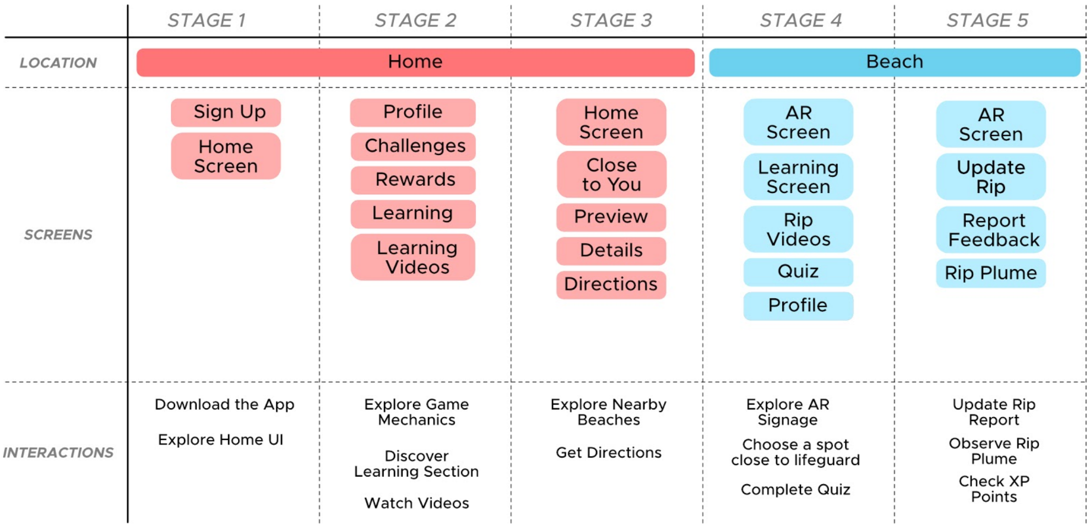


Figure 38: Maria's Storytelling

Francisco's Storytelling

Francisco is a young competitive player. He wants to find one more rip current to complete the challenge he needs to reach the expert level, communicate his accomplishments with his friends and unlock a free reward that he can use in the local beach bar. To achieve this goal, Francisco needs to understand the morph-dynamics of the beach in order to be able to choose the beach that is likely to form rip currents.

Scenario 1: Francisco learns about beach morphology to understand what types of beaches are more likely to form rip currents by watching beach morphology videos in the *Learning* section. After learning what variables influence the formation of rip currents, Francisco looks for a beach which might enable him to complete the challenge and progress to the expert level. He finds the beach he wants to go to and shares the details with his friends, who agree to meet him at the beach.

Scenario 2: When Francisco arrives at the beach, he realizes it's a crowded day, and he shares his location with his friends to facilitate a meeting point that only his friends can see. Francisco wants to have a high proficiency in the game to earn as many XPs as possible, so he does the *Wind* and *Crowd Reports*. There aren't rip current warning signs yet, but Francisco knows the swell will grow and soon rip currents will emerge.

Scenario 3: Francisco looks closely at the submerged rock area, where he believes a rip current might emerge. He decides to make a new *Rip Report*. After waiting a few seconds, Francisco receives a notification of the image already processed by AI and observes the rip current plume on the screen. The digital warning sign appears in the surf zone and every user on the beach is alerted to the new hazard identified.

Scenario 4: Francisco successfully completed his challenge and progressed to Expert level. He shares his success with his friends and unlocks a free beer reward that he can enjoy at the local beach bar.

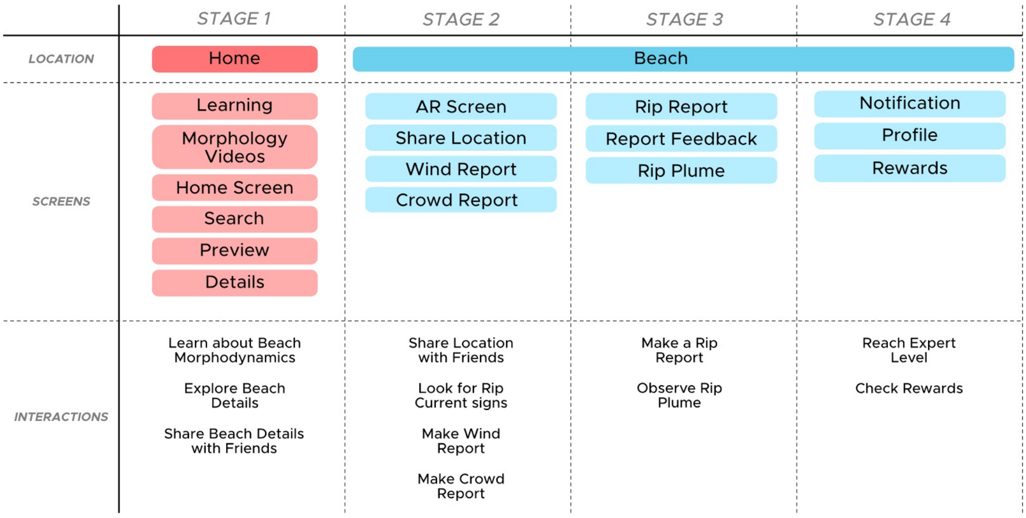


Figure 39: Francisco's Storytelling

Pedro's Storytelling

Pedro is a surf instructor who knows beach dynamics, and has great rip detection skills. He knows the risk that rip currents pose to bathers and inexperienced surfers, so he values being able to identify and communicate the presence of rip currents with his pupils.

Scenario 1: Early in the morning, Pedro checks the beach details and shares it with the surfing class pupils, so that everyone can be prepared for the surf conditions.

Scenario 2: Pedro wants to check the status of a fixed rip current. Before he arrives at the beach, Pedro makes a rip report and walks to the golden viewpoint, at the top of the hill next to the beach. By standing in a Golden Viewpoint position, Pedro is able to successfully detect two rip currents.

Scenario 3: After the surfing class is over, Pedro checks each rip current's last update and evaluates whether an update is needed. Both risks have been updated in less than 15 minutes, so Pedro thinks there's no need to make another update. However, Pedro notices some pollution at the beach, so he decides to report the polluted area to help clean the beach.

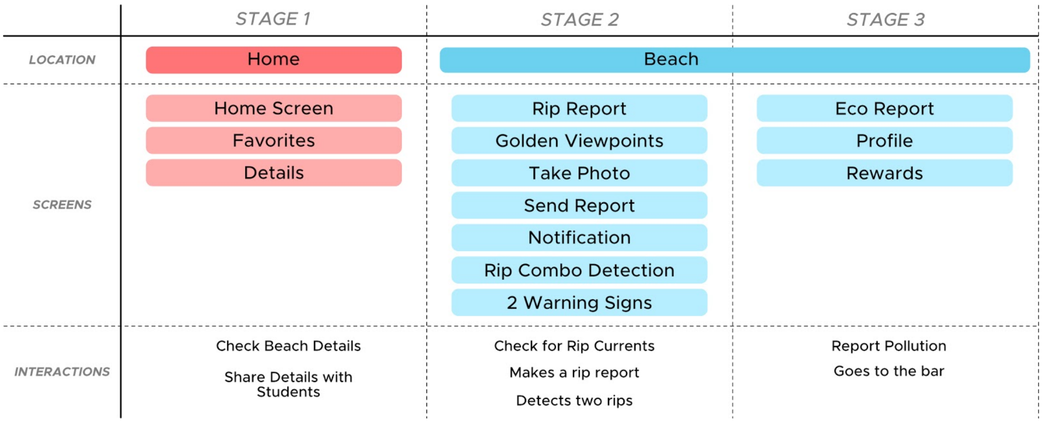


Figure 40: Pedro's Storytelling

4.6. Wireframes

A wireframe is a static, low-fidelity representation of the different layouts that make up the product. It is a graphic illustration of the interface using only simple shapes to explain the **structure** (how components of a page will be placed together), the **content** (what will be presented on the screen) and the **functionality** (how the interface will work). The goal of the wireframes is to create a foundation to start and define a direction for the design of the product. Wireframes provide an opportunity to plan carefully before moving further, thus reducing the risk of going backwards because something was missed, as they also allow designers to easily test their overall design strategy without getting too involved in the details of the visual design.

Through the development of the proposed solution, the wireframes were designed in two different phases: **sketching** and **digital wireframing**. The sketching technique was particularly useful for initial brainstorming sessions to rapidly explore different ideas (e.g. exploring a variety of key screen layouts). The first wireframes were designed on paper, as hand-drawn sketches are quick to create and to iterate on. Figure 41 presents a set of sketches used in the early phase of the project development.

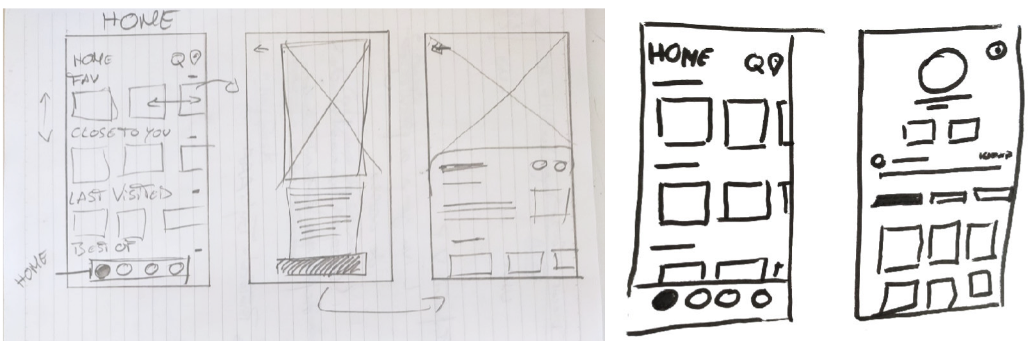


Figure 41: First Sketches for screen layouts

After defining the general layouts of the core screens on paper, the digital wireframes were replicated in the UX design software-Adobe XD. This digital tool allows us to easily iterate the layouts of the screens and evaluate their usability. Figure 42 presents a set of screens designed in Adobe XD and how the screens are connected around each other.

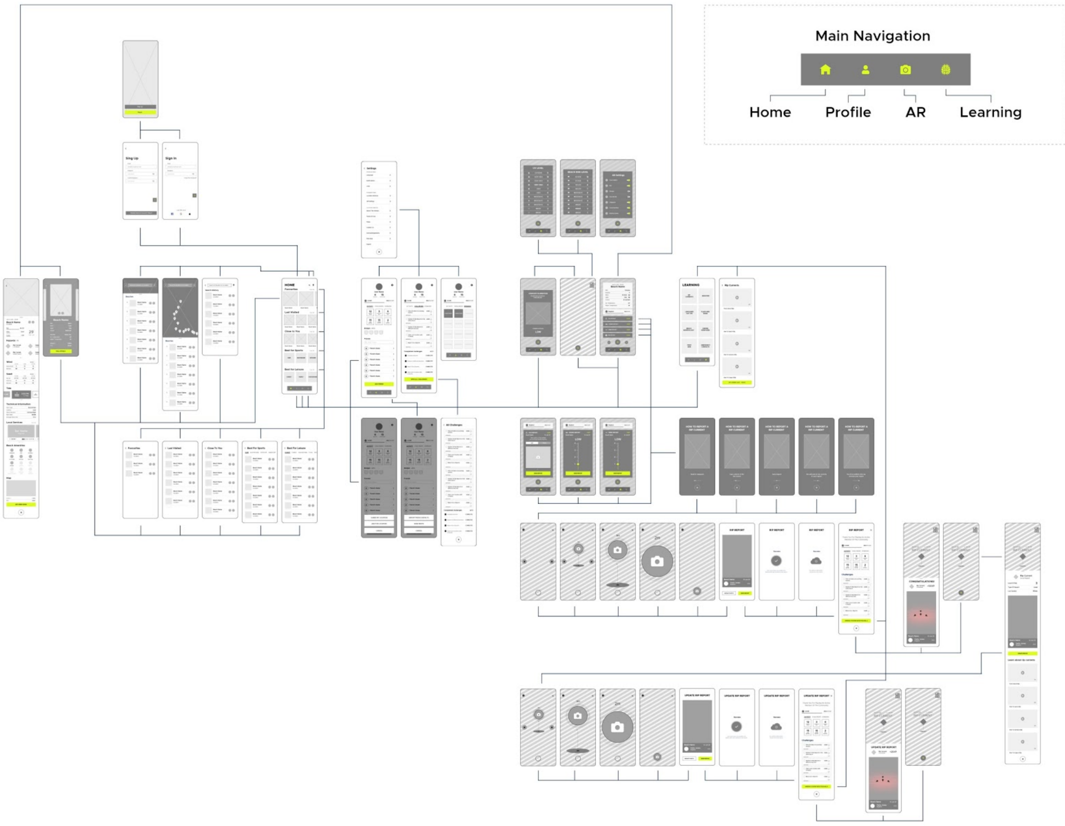


Figure 42: Digital wireframing made in Adobe XD

Generally wireframes are static, which makes it difficult to use them to test the overall user experience. However, the Adobe XD software allows the creation of interactive links between different wireframes, and quickly creates simple interactive prototypes. An interactive digital wireframe was used to gather feedback on the overall structure, content and functionality of the app during the initial phase of the design development.

Mobile Navigation

The principles of good mobile navigation are **clarity** (use familiar navigation patterns and each navigation element leads to the proper destination), **consistency** (global navigation controls always located in the same area) and **visibility** (to navigate successfully, the user should always be able to answer the question "Where am I?"). The proposed approach explores the use of known design elements (e.g, navigation toolbar at the bottom of the screen) and standard mobile interactions (e.g. horizontal and vertical scroll) to help the user to navigate throughout the app and quickly access different areas of the AI (Home, Profile, AR and Learning), as displayed in figure 43.

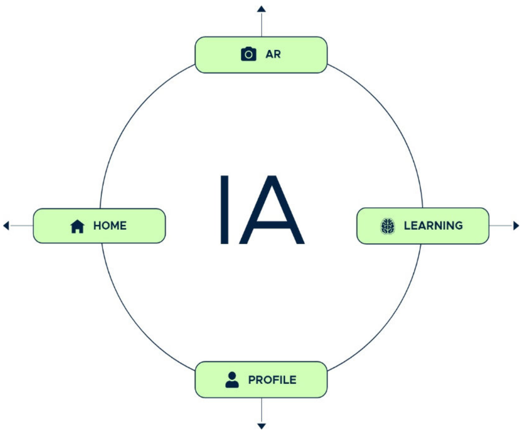


Figure 43: First level of the AI.

The toolbar layout is inherited from the design of the desktop. This design element was chosen because it **communicates clearly the current user location** with visual clues (icons and colors), **offers direct access to other areas of the system**, and **shows all the navigation options on the screen,** so that users have clear visibility and single-click access to all main sections of the app. Figure 44 shows the position of the toolbar menu on the app main screens and how to navigate between sections.

Figure 44: Toolbar Menu Navigation

In addition to the toolbar menu, the use of horizontal and vertical scrolling was another design decision to support the navigation of the app. The use of the scroll technique is almost 100% consistent across all devices, allows space for secondary information and saves vertical screen space. Instead of presenting all content on a very long page at once, horizontal layouts expose users to smaller pieces of information, making the layout more flexible. Figure 45 shows the "Full Beach Detail" screen, the "longest" screen in the app, which incorporates the use of vertical and horizontal scroll techniques to display segmented information related to a chosen beach, without frustrating the user with a never-ending vertical screen.

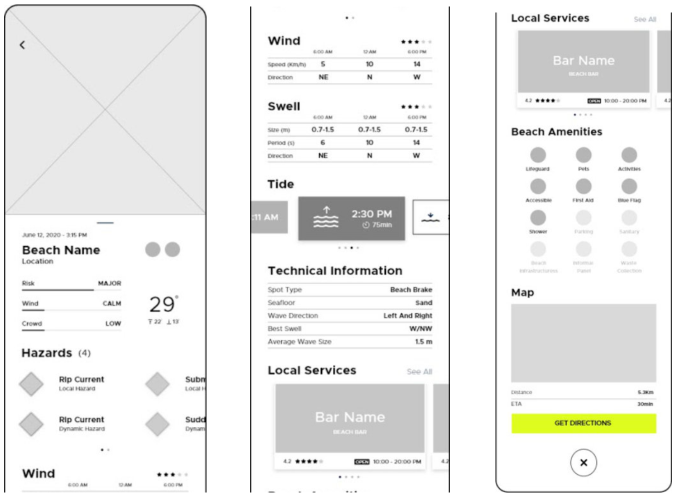


Figure 45: Digital wireframing made in Adobe XD (Home screen navigation)

Horizontal scrolling allows users to see options within a category by swiping to the side, or scrolling down to see different categories (e.g., hazards description, tide information and beach services). The use of two-dimensional scrolling is widely implemented in the proposed solution, as it supports users by showing a variety of options without forcing them to navigate through different screens.

Design controls based on hand position was also a priority when defining the general layout of the screen. Steven Hoober found that 49% of people rely on a single thumb to get things done on their phones (Steven Hoober, 2013). Figure 46 shows the diagram that appears on the mobile phone screens and its estimated range maps, with colors showing which areas the user can easily reach with the thumb to interact with the screen.

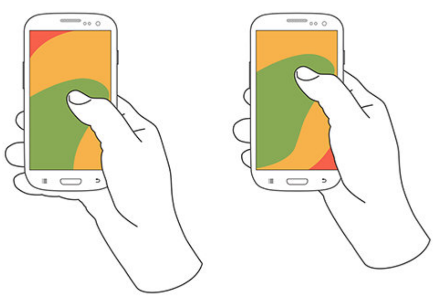


Figure 46: Comfort zones for a person's one-handed reach on a smartphone. Image Source: uxmatters

The green color on the diagram indicates the area a user can reach easily; yellow, an area that requires a stretch; and red, an area that requires users to shift the way in which they're holding a device. The position of the controls on a mobile screen is directly influenced by the position of the hand and the grip of the user. The strategic position of interactive elements (e.g., CTA, links and primary buttons) follow these usability guidelines.

Throughout the wireframing process, the design of the screens was based on the AI (see Annex 5) and applied different UX guidelines to mitigate usability flaws. One UX rule-of-thumb used in the architectural strategy of the proposed solution was the 3-click rule, a persistent unofficial heuristic that says that no page should take more than 3 clicks (or taps on a touchscreen) to access. The 3-click rule assumes that users will become frustrated and will likely give up on tasks that require more than three total clicks to be completed. While this idea is reasonable, pursuing it often requires designers to prioritize broad IAs over deep IAs. Both very broad and very deep IA structures have their own usability problems. Very broad IAs with a large number of categories at the top level are more laborious for users to assess and require a lot of UI space. Very deep structures with few top-level categories and a great number of tiers require either a lot of menu diving (often with frustrating hover-revealed menus or confusing sequential menus), or large time spent waiting for category landing pages to load on the journey to low-level pages.

The design approach for this project was made on the basis of UX concepts such as the 10 Usability Heuristics and the Gestalt Theory (see section 2.4). Annex 6 presents the complete wireframe study designed for the proposed solution.

4.7. Prototype

After conducting a heuristic evaluation on wireframes and presenting it to family and close friends for feedback, the following step was to build the interactive prototype. This prototype is a middle to high-fidelity representation of the final product, which simulates user interface interaction. While the prototype may not have every interaction in place, it showcases the key interactions that will provide a clear understanding of how the final product will behave. In this section, we used two of the user scenarios described previously for each persona (see section 4.5. Journey Mapping) to represent key interactions between the user and the app, highlight relevant features, and show how different users might use the app to achieve different goals. The complete design system and screens used in the latest version of the prototype are presented in annex 7.

Maria’s User Flow 1

In this scenario, as presented in section 4.5, Maria explores the App content and learns more about beach safety culture, so that she can be aware of the hazards and protect her child. The flow diagram outlines the first screens of the App and the interaction path that Maria can perform to achieve her goal.

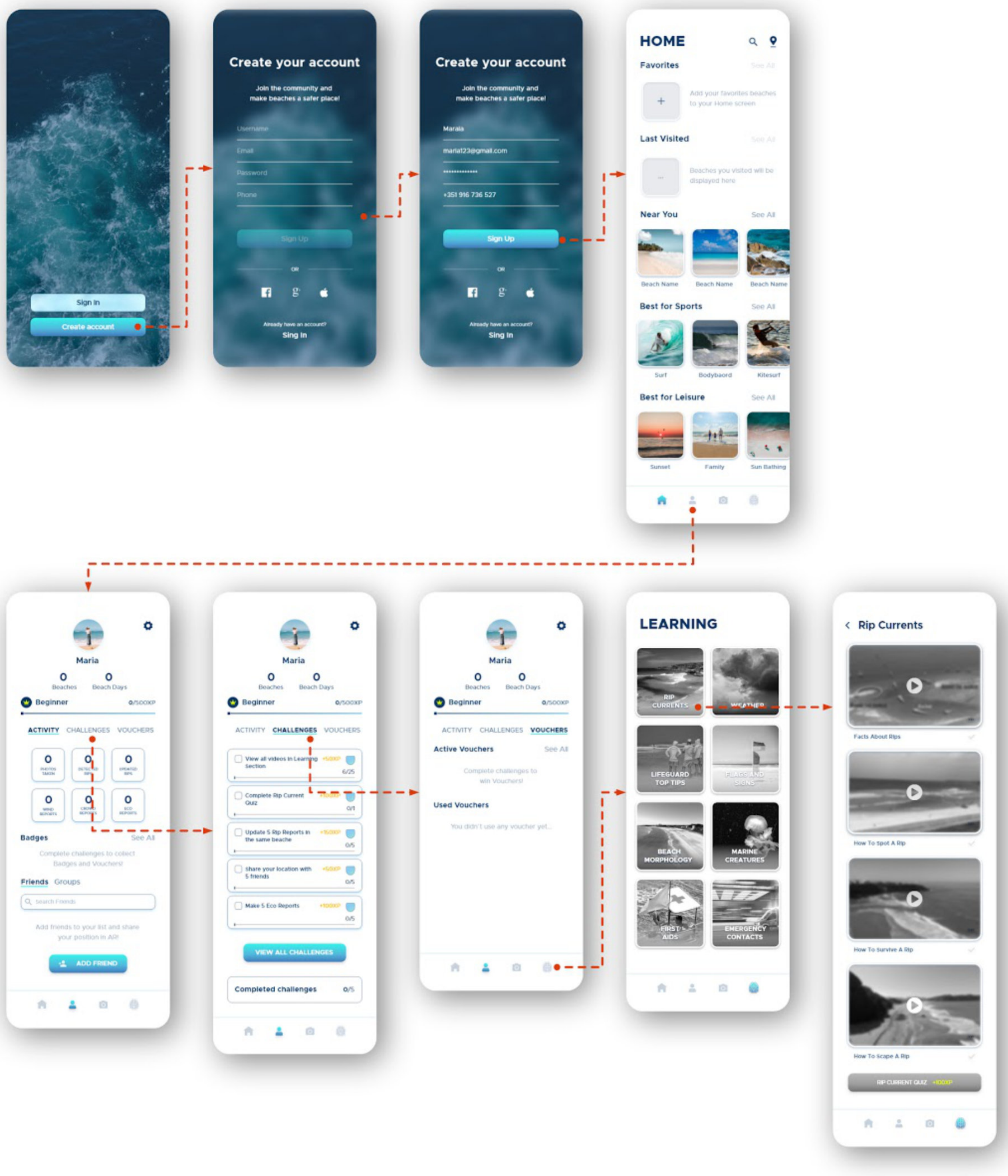


Figure 47: Maria’s Storytelling, Scenario 2, Home, Profile and Learning Section Screens

Maria’s User Flow 2

In this scenario, Maria is updating a rip report using the app. Figure 48 illustrates the interactions Maria has to perform in order to achieve her goal. In this scenario, the user must be at the beach for this specific activity, interact with the digital rip current sign and update the hazard report by taking a new picture of the surfzone and sending it to the cloud services, where the AI algorithms will be housed. If the user updates the hazard report successfully, he'll be compensated with an amount of XP.

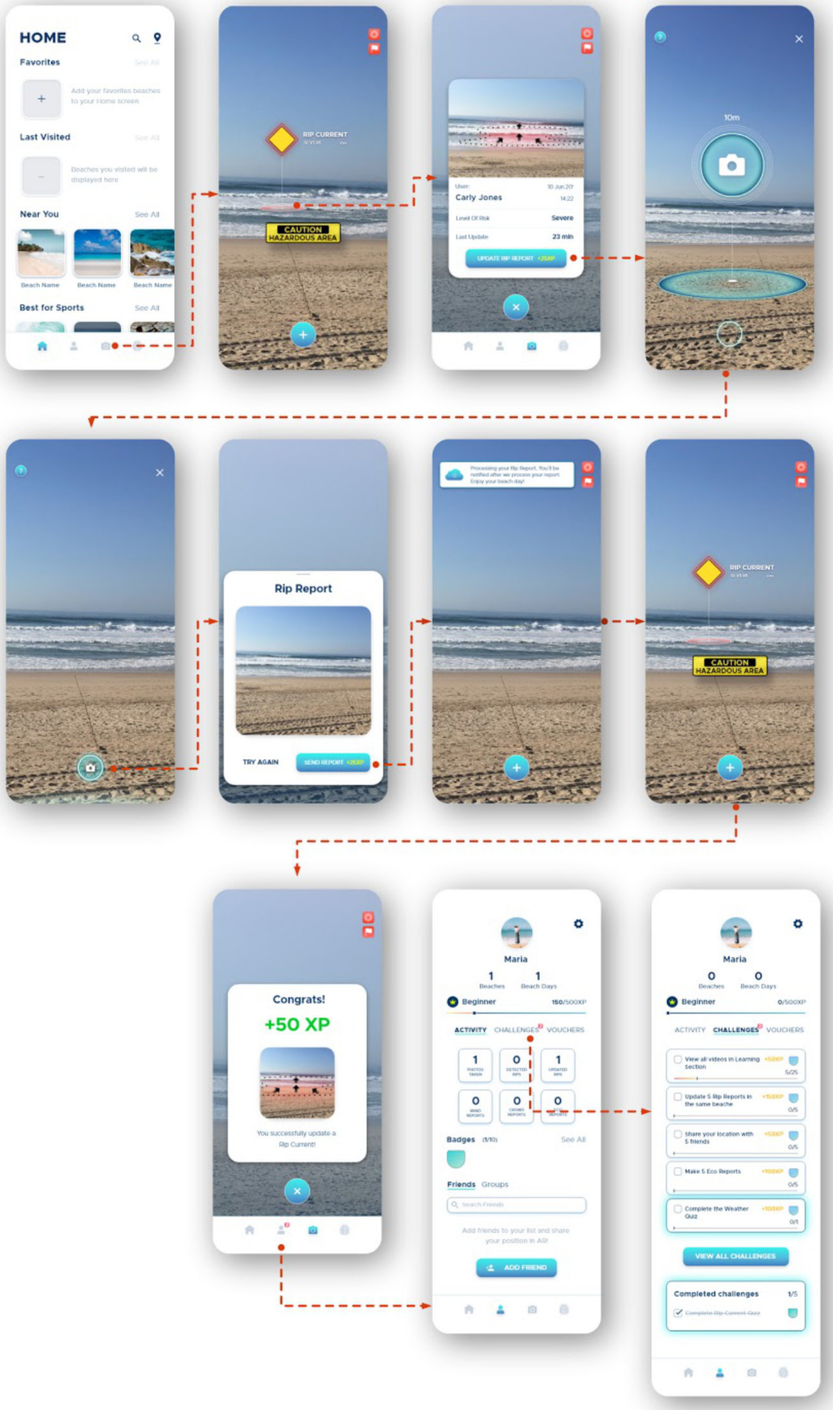


Figure 48: Maria’s Storytelling, Scenario 5 - Update a Rip Report

Francisco's User Flow 1

In this example, Francisco uses the app to share his location with his friends, so that they can see Francisco's real-time position on the beach, in AR. Francisco is a competitive gamer who wants to evolve as quickly as possible along his journey. Figure 49 presents how Francisco can do crowd and wind reports and quickly gain experience points.

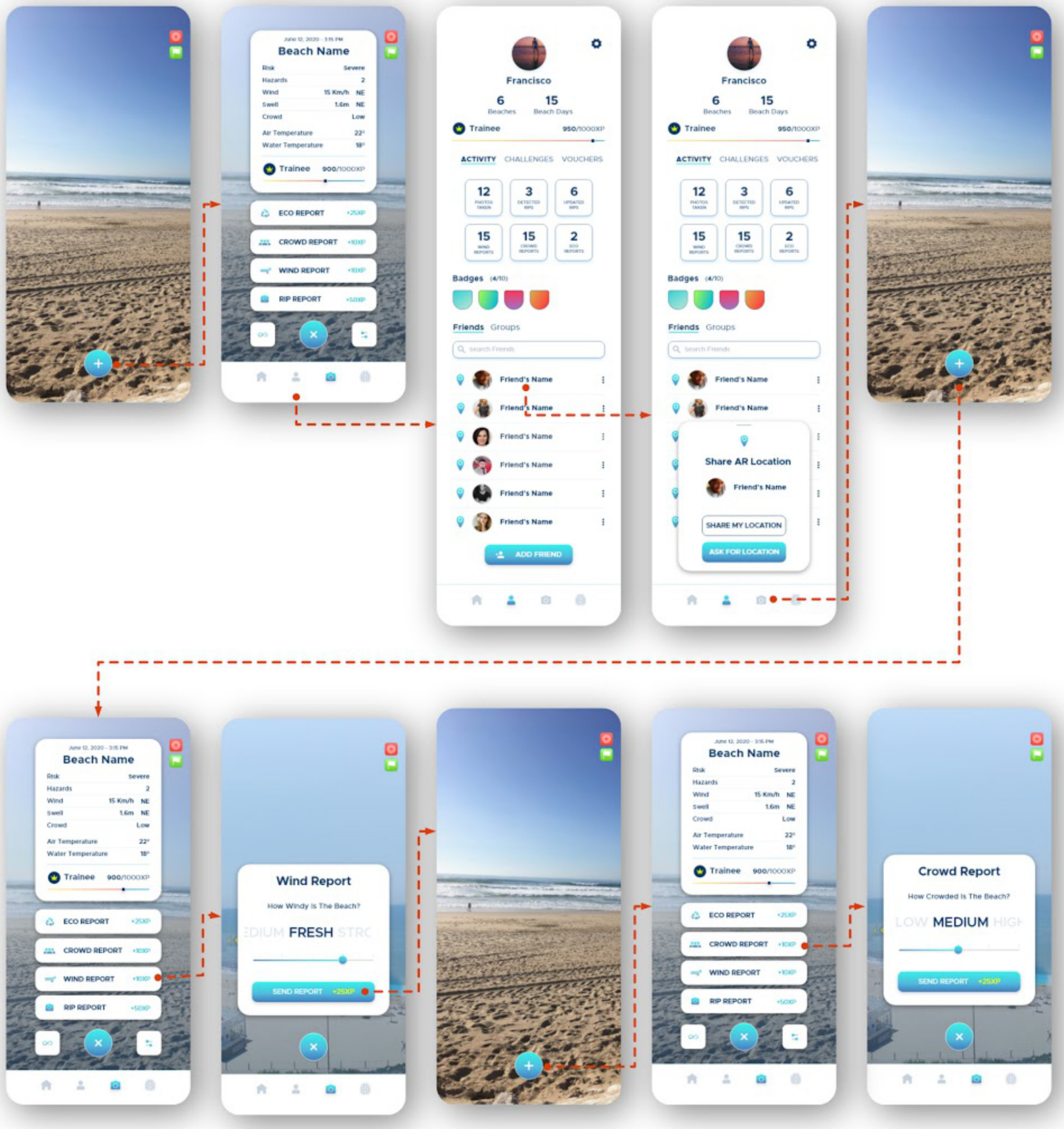


Figure 49: Francisco Storytelling, Scenario 2 - Share Location + Wind and Crowd Reports

Francisco's User Flow 2

In this example, Francisco uses the app to successfully report a new rip current. Francisco completes a challenge by achieving his goal and is rewarded with a voucher, sponsored by a partner stakeholder. Figure 50 illustrates how to report a new rip current, how the digital hazard sign in AR can be presented to bathers, and the feedback messages and UI elements that lead the user to where the new voucher is located.

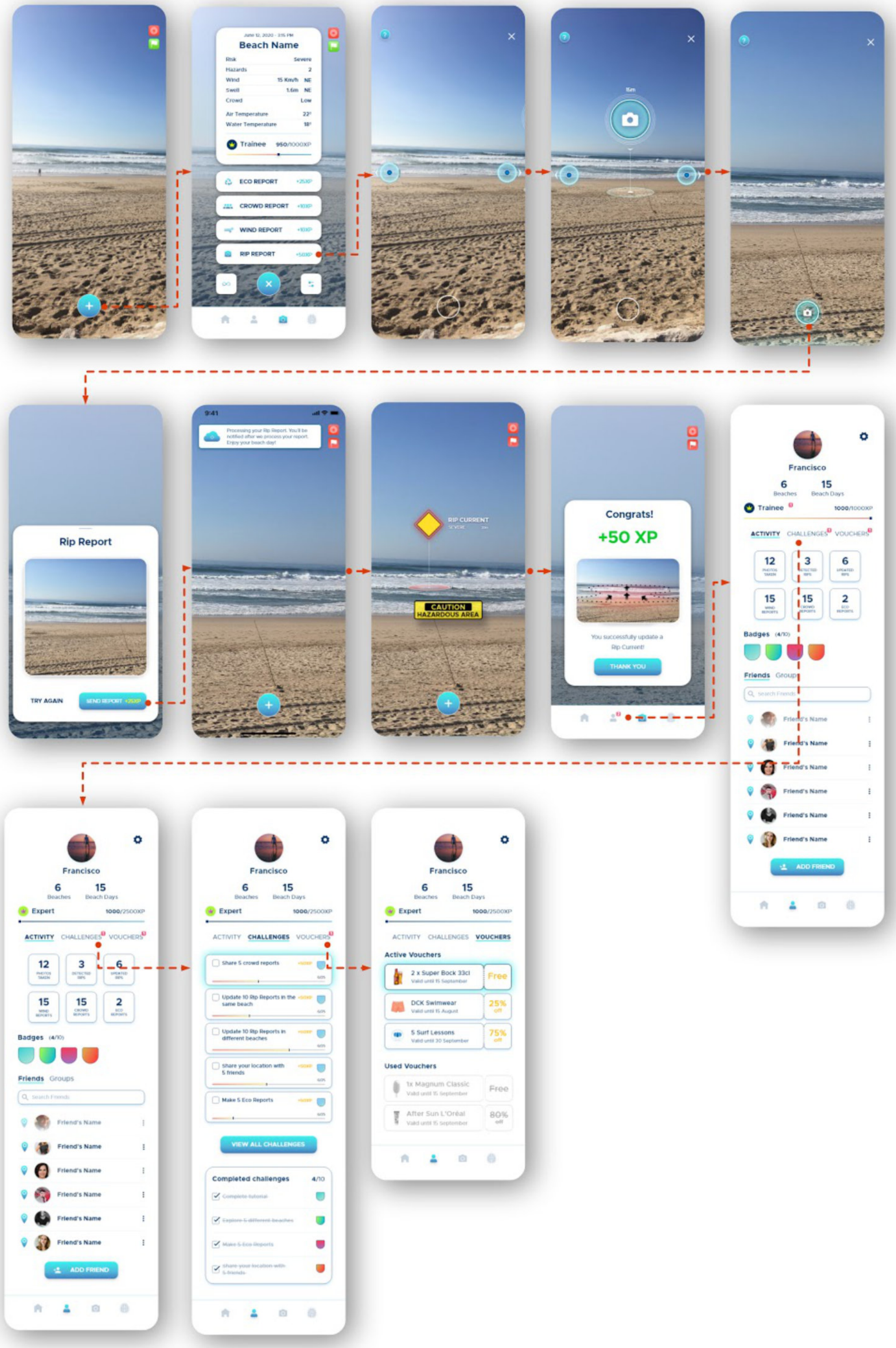


Figure 50: Francisco Storytelling, Scenario 4 - Rip Detection and Rewards Feedback

Pedro's User Flow 1

In this scenario, Pedro uses the app to assess and share with his pupils beach details such as prevailing hazards, weather forecast and swell conditions. Being conscient of beach conditions and prevailing hazards can prevent unnecessary accidents, and promote users to adopt safe behaviour at the beach. Pedro knows how dangerous beach activities can be, so he uses the app to communicate relevant beach details and teach his pupils how they should behave to avoid accidents.

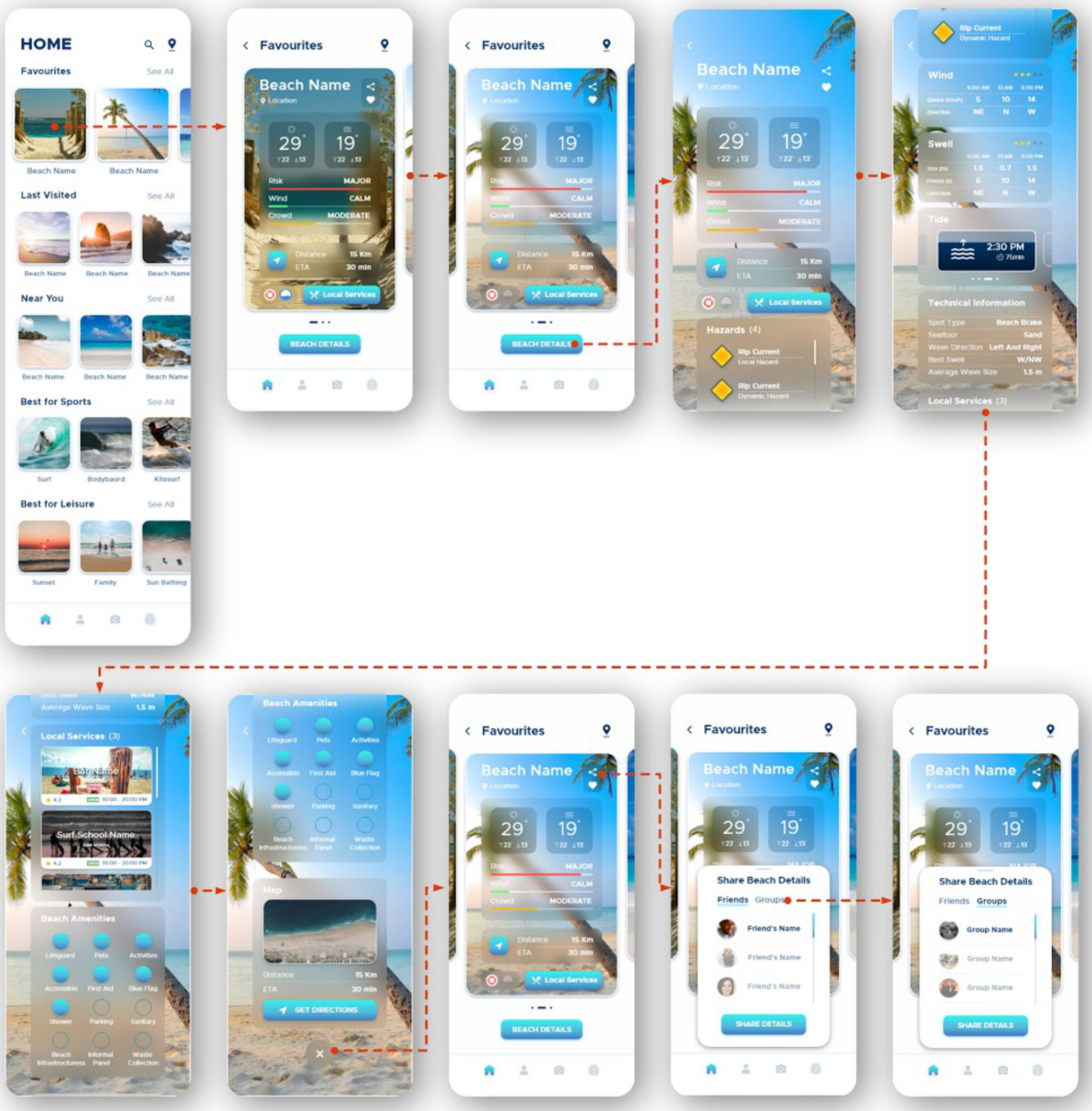


Figure 51: Francisco Storytelling, Scenario 4 - Access and Share Beach Details

Pedro's User Flow 2

In this scenario, Pedro uses the BSC App to check the status of local rip currents. Before he arrives at the beach, Pedro makes a rip report and walks to the golden viewpoint, at the top of the hill next to the beach. By standing in a Golden Viewpoint position, Pedro successfully detects three rip currents and completes a Combo Rip Report.

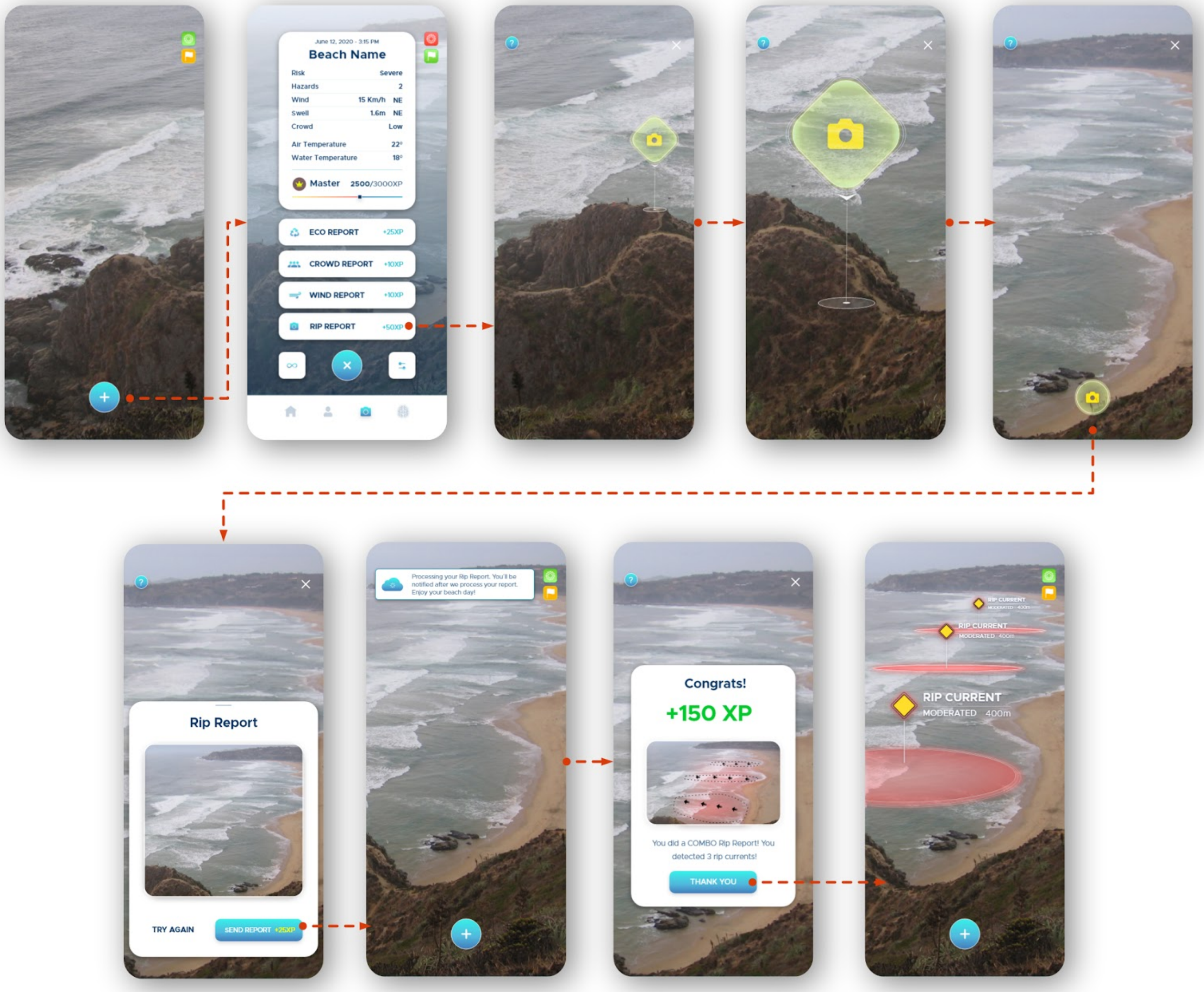


Figure 52: Francisco Storytelling, Scenario 2 - Combo Rip Report Dete

4.8. Usability Tests

Usability testing is the empirical method of design development in which participants are practical users of the product being tested. The proposed solution testing goals were designed to address the clarification regarding **RQ.2.3** - Assess if a user community is willing to use a digital tool to visualize hazards at the beach; and **RQ.3** - Can digital reality improve beach safety?, embedding the following 3 queries:

1. Analyze if AR is foreseen as a good approach to enhance understanding of beach' dynamics;
2. Validate if a gamified approach would engage a community member to monitor hazard information proactively;
3. Identify the motivations of different user groups regarding a gamified strategy.

In addition to responding to the academic research goals, the usability tests were also designed to evaluate the project solution with the target audience by receiving immediate feedback and recognizing participants' needs, exposing friction points and frustrating interactions, and identifying usability problems with the prototype. The ISO 9241 - 11 defines usability as "the extent to which a product can be used by specified users to specific goals with effectiveness, efficiency and satisfaction in a specified context of use." Usability is not a single, one-dimensional attribute, but rather a combination of the factors identified in the definition, which are the metrics used to evaluate the prototype:

- **Efficiency:** accuracy and completeness in which users achieve the specified objectives
- **Effectiveness:** resources spent on the accuracy and completeness with which users achieve the objectives.
- **Satisfaction:** convenience and acceptability of use.

Usability Tests Methodology

In order to test the proposed solution and gather data to conduct qualitative and quantitative analysis of the prototype, we drew up the following usability test protocol. The participants for these usability tests should be chosen from the user interview database (described in chapter 3) as they are already familiar with the concept of the project. The screening requirements for the moderated usability tests should be based on **age, bather type** (beach experience), **rip current knowledge and smartphone usage**. Our usability tests were designed to take approximately 35 minutes to complete, divided into five sections, structured by the following order:

- **Section 1 - Welcome and Introduction** (10 min):
  After welcoming the participant, each interview must begin with a project concept introduction to ensure that the participant understands the concept of Augmented Reality, to clarify how AR can

be used in a beach safety context, what details it can provide and how users can experience digital content through their smartphones. The project introduction step is achieved with the help of an interactive mock-up (see Annex 8), designed to showcase a well-known and dangerous portuguese beach - Praia Grande - with digital layer information at the top. The introduction mock-up is also used to demonstrate how rip detection viewpoints will be presented on the beach, and how the rip current plume will be presented after being processed by the AI.

- **Section 2 - Pre-test Questionnaire** (2 min):
  Pre-test interview questions were structured to evaluate the participant's type of bather, beach experience, assess whether the participant is familiar with the concepts of beach safety and beach hazards, as well as the extent of his smartphone usage. The full questionnaire for the interview is available in annex 9.

- **Section 3 - Test Tasks** (10 min):
  UX design is incomplete without user testing, a critical part of the process. Tasks are activities required to achieve a goal. Test tasks are scenarios of practical use to which participants are exposed, each scenario describing a task to be performed on the system. There are different types of usability tests for uncovering different project insights (e.g. Single Task Test, Multiple Tasks Test, 5 Seconds Test, First Click Testing and Open Analytics Testing). Through the development of the proposed solution, we focus on 3 types of tests: Task Tests, Multiple Task Tests and Open Analytics Testing (see annex 9).

- **Section 4 - System Usability Scale Questionnaire** (3 min):
  The System Usability Scale (SUS) is used to gather statistical data and assign a usability score to the app. SUS measures have become an industry standard, with references in over 1300 articles and publications (Usability.gov, 2013). It consists of a Likert Scale that includes 10 questions (see annex 9) which participants answer after completing the tasks. In this framework, participants rank each question from 1 to 5 based on how much they agree with the statement they are reading (5 - completely agree, 1 - completely disagree).

  After responding to the questionnaire, participant's scores can be translated to a new number for each question, summed together, and then multiplied by 2.5 to convert the original scores from 0-40 to 0 - 100. Although the ratings are 0-100, these are not percentages and should only be perceived as percentile rankings. A SUS performance above 68 will be considered above average, but anything below 68 will be below average (Sauro, J., 2011).

- **Section 5 - Post Test Interview** (10 min):
  Post-test interview is an undertaken process at the end of each test session which involves going through and analyzing the actions performed by the participant, which provided additional insight on why participants performed such actions. While the test session reveals usability issues, the debriefing session provides insight into why those problems happened. Post-test interviews will be recorded with the consent of the participants and include 10 questions (see annex 9).

Usability tests Results

Due to the lack of availability of participants and the lack of equipment resources to strictly follow the methodology outlined in the previous section, the usability tests had to be simplified and focused mostly on qualitative assessment of the concept. Screen recording could not be implemented to measure the time spent on tasks and to verify interaction errors. Nevertheless, we established a score system from 0 to 3 to classify each task usability. Table 11 presents the scores achieved for each task.

Table 12: Usability Tests Tasks Scores

Participant	T. 1	T. 2	T. 3	T. 4	T. 5	T. 6	T. 7	T. 8	T. 9	T. 10
1	3	3	3	3	2	3	3	3	2	3
2	2	3	2	3	1	3	2	3	3	1
3	3	3	2	3	2	2	3	3	3	2
4	2	3	1	3	1	3	3	3	3	2
5	2	2	2	3	1	2	2	3	2	1
6	3	3	3	2	3	3	1	2	3	3
7	3	3	3	2	2	3	3	3	3	2
8	2	3	2	3	1	3	3	2	2	2
9	3	1	1	2	0	3	1	3	2	3
10	3	2	2	1	2	3	2	1	3	3
Total	26/30	26/30	21/30	25/30	15/30	28/30	23/30	26/30	26/30	22/30
Success Rates	**87%**	**87%**	**70%**	**83%**	**50%**	**93%**	**77%**	**87%**	**87%**	**73%**

Score Values Description: 0 - Task not Completed; **1**- Task completed with critical errors; **2** - Tasks completed with small errors; **3** - Task completed successfully.

Observations:

The interactive prototype used in the usability tests had practical limitations regarding AR navigation and interaction. This limitation was mitigated with an interactive mockup, separated from the main prototype, to showcase how and what AR elements would be integrated in the concept solution (9See annex 9 - Project Introduction).

Finding and Predicting Information

In general, participants felt confident that they could navigate through the app without losing track of their position in the system architecture. The bottom navigation bar proved to be appropriate as it offered quick access to the different parts of the app - Home, Profile, AR and Learning. However, the

AR and Learning icons displayed in the navigation bar appeared not suitable as some participants did not understand their functionality before interacting with them.

Another issue detected in the usability tests was related to UV and Beach Risk Level information. This information is only available on the top right corner of the AR main screen, presented by two widgets. These UI elements were not confirmed to be well designed, as most participants did not notice them, and when they did, the information presented was not clear enough. UV level should have more information regarding protection behaviour (e.g. integrate safety icons such as screen protector, sun glasses and look for a shadow on different UV levels).

AR Screen

The configuration of the AR screen was not clear enough to communicate its functionality. Some participants had difficulty finding how to access AR mode. This feature should have a dedicated CTA incorporated on the Home screen as well as on the beach detail screen. Apart from not being easy to find, the AR screen UI elements did not express their functions efficiently. The plus button should be presented with a different icon, the AR filter should be integrated into the main AR screen, and a back / Home button should always be visible on this particular screen.

The AR screen could also integrate a compass or map component to guide the user on the beach without the camera. In a practical use scenario, users are not likely to be walking along the beach with a mobile camera always pointing forward. Most certainly, users will use the camera to contextualise the data in their surroundings, but after that, they will most likely direct the device to the ground. In such a scenario, the compass or map could appear when the gyroscope detects the inclination of the device, and the user would still have a navigation tool at his disposal to guide him to a specific point (e.g. point of view, lifeguard, hazards or friends).

Rip Report

In this task, the tutorial designed to appear the first time a user performs a rip report was not interpreted as a tutorial, but as the task itself. This misinterpretation may have been caused by the restrictions of the prototype, since this screen has a transparent blue layer over the background of the camera mock-up. In addition to this limitation of the prototype, the layout of the tutorial screen should be reviewed and should integrate visual clues to indicate the number of steps to complete the task.

Eco, Wind and Crowd Reports

In general, there were no problems in interacting with these reports. However, many of the participants expected to find these elements on the home screen as well as on the beach detail screen. After observing the interactions with these reports, we believe that all these interactions should be combined into one beach report. Instead of having two or three separate reports, the user could answer to one, but more accurate, beach report. In addition to a qualitative review of crowd and wind levels, this new beach report could also include cloud level, sun strength and water temperature.

Profile Screen

The layout of the profile screen proved satisfactory for communicating the gamification elements. Access to the relevant gamification information, such as user level and XP, was not a problem. However, there could be more prominence to these graphical elements. Challenges and Vouchers have been verified as suitable for the concept idea. There was also feedback suggesting that the Friends section could be isolated from the Profile area and could have a dedicated social area to engage with other community users.

Learning Section

The visual representation of the videos in the learning section was not clear enough. Some participants interpreted the unseen videos as apparently unavailable. A change in the blur thumbnail graphic style should resolve this issue. There were also detected inconsistencies in graphical representations of design elements from different sections. Compared to the vouchers section, in which the used vouchers are presented in greyscale, in the learning section, the greyscale videos should also indicate the already seen videos.

Iconography & Search Screen

Regarding the iconography, the provided suggestions were focused on the navigation bar icons and widgets on the AR screen. The Blue Flag and Lifeguarded Beach icons were also problematic. These icons did not express their meaning effortlessly. In relation to the Search screen, the comments suggested having an Advanced Search feature, to filter results by different variables such as: beach type, safety level, crowd level, wind level, cloud level, type of local services.

Feedback and Recommendations

Overall, the concept of the proposed solution was well accepted and received positive feedback. **All participants recognized the usefulness of implementing AR to communicate beach hazards,** and considered the implementation of this technology for safety purposes an appropriate solution to communicate and contextualize beach data with bathers.

Our research suggests that 95% of participants would use the Beach Data Community App, but only 75% would be interested in sharing information with the community. The gamification strategy also had positive feedback, as each participant classified the challenges and levels presented to be appropriate for the concept solution.

There were reservations about the viewpoints' system, as **17% of participants admit that they did not like the premise of walking to a particular point to take a picture of the surf zone.** Another issue with the implementation of viewpoints would be a circumstance in which a group of bathers, who does not know about the existence of these digital viewpoints, plans to stay at the beach in the viewpoint position. This scenario presents an interaction problem, as a user who wants to create a report, won't be able to do so because a group of bathers occupies the position of viewpoint.

With regard to the motivational aspects of contributing to safety information, more than **70% of the participants stated that they would actively share beach information (crowd reports, wind reports, eco reports and rip reports) for intrinsic values rather than just for winning vouchers.** Our study suggests that Portuguese bathers are open to using their smartphones and AR features to access situational-awareness data at the beach and to collect data about potential hazards, including information on the status of active rip currents.

The detected design flaws such as UV and Risk Beach Level widgets, the AR and Learning navigation tab icons, the AR filter management, profile gamification data, the rip report tutorial and the graphic representation of the videos in the learning section should be reviewed. Moreover, it would be interesting to explore the idea of merging the wind and crowd reports into one beach report, with more information. This new beach report should also have a dedicated CTA on the Home screen and other on the Beach Details screen, when the user is at the beach. Another feature that should be considered in the next design iteration, is the compass or map assistance, which will complement the user's navigation at the beach, and improve the experience.

5. Conclusions and Future Work

5.1. Achievements Summary

Beach safety is nowadays foreseen as a topic of growing interest within the scientific community, as well as a significant concern within the society, in particular for the identified target-group (i.e., families and beach professionals). To address the identified research challenges, we have developed a conceptual solution addressing beach safety requirements and simultaneously to promote a beach culture. The creation of a Beach Safety Community (BSC) focuses on a service design approach for collecting data about potential hazards, including information on the status of active rip currents, which pose a severe threat to the safety of bathers. Despite lifeguard coverage, available in the most popular Portuguese beaches during the bathing season (from May 15 to September 15), existing safety strategies are not efficient in promoting an active beach-safety culture.

Furthermore, the characterization of the Portuguese coast as a dangerous and treacherous landscape was unanimously considered by beach experts, who also confirmed that rip currents and other beach hazards are common in the Portuguese coastal landscape. Nevertheless, beach experts consider the most dangerous aspect of a beach to be the bathers themselves, as most common beach rescues are caused by people who do not follow warning signs or lifeguard instructions. From the beach experts' point of view, most bathers do not understand basic principles of beach safety, nor do they understand the types of dangers that can occur in the beach environment. This perception was confirmed by the survey carried out during our investigation. As presented in section 3.2, only 40 % of the population know what a rip current is, and 61% do not know how or when a rip current is likely to appear. These findings show that Portuguese swimmers have gaps in understanding beach dynamics, and their awareness of beach hazards is worrisome. Our research also indicates that 74% of the population claim to comply with safety signs, but 73% do not know what a red and yellow flag means, which confirms that the beach safety communication system is not effectively perceived by bathers.

Risk perception is a key factor in beach safety. One of the main goals of the presented research is to contribute to improve beach safety through situational awareness data, and to enable bathers to fully understand the main hazards dynamics through educational methods and community responsibility. To this end, the service design approach was conceptualized to design a solution for collecting data about prevailing hazards, including information on the status of active rip currents. Our research has explored how interactive design & UX methodologies can be used to design a solution focused in delivering value to bathers, to mitigate the number of rescues and deadly incidents at the beach, with additional benefits regarding bathers beach-safety literacy and social conscience.

The architectural design of the platform consists of a combination of immersive technologies, including Augmented Reality (AR), Artificial Intelligence (AI) and Gamification. AR is foreseen as a powerful tool in providing a digital visualization able to capture the users' interest and, more importantly, to keep them motivated to proactively identify existing hazards. By helping users to see where the active threats are, the use of AR will contribute to improve bathers' consciousness regarding beach safety and support them to make safe decisions. Our investigation confirms that AR is useful to foster a safer beach culture, as each participant interviewed considered the implementation of this technology a suitable solution to communicate and contextualize beach data to bathers, as well as to keep them motivated to be informed of awareness information.

Gamification is another key element considered to be included in the experience strategy. The design of an interactive and gamified environment in promoting a beach-safety behaviour will encourage bathers to be aware of beach hazards, detect and communicate them with the community, and improve the beach-safety culture in Portuguese beaches. BSC explores an underlying learning strategy to keep users engaged with the platform, which focuses on the idea of the user becoming a master of beach safety. The gamification strategy is presented in section 4.4., and explains how user's intrinsic value of safety can be achieved by promoting the ability to identify active hazards (autonomy and competence) and by being able to communicate hazards with other swimmers (relatedness).

Overall, the conceptualized solution was well accepted and received positive feedback from user testing sessions. Our study suggests that portuguese bathers are willing to integrate a social movement to benefit from the services and informational artifacts provided by the Beach Safety Community App. In addiction, beach experts unanimously support the conceptualized solution to promote a safer beach culture and to mitigate beach risks. The potential implementation of AI algorithms to identify and monitor rip currents and other beach hazards, and the integration of AR to contextualize situational awareness data to the bather, make this project one of the most ambitious beach safety initiatives, capable of preventing deadly situations and fostering a strong and safe beach culture.

5.2. Future Work

The implementation of a conceptualized solution relies also on different key stakeholders, who need to be on board to enable the full potential of this digital platform. The next step for the implementation of the project will be to present the idea to professional Lifeguards to get their feedback and support. After gathering beach professional support, the following step should be to find a Telecommunications Operator, another key stakeholder to enable internet connection at the beach. This role could be assumed by the Vodafone Foundation, which in addition to having easy access to a telecommunication infrastructure, is one of the largest beach safety private investors in Portugal.

Upon stakeholders' support and investment, this project would start by implementing a local demo in a strategic location (e.g. Costa Vicentina, Ericeira or Costa da Caparica) to understand and solve challenges and constraints of the technology aspects behind the proposed solution. After a stable version of the app is achieved, the proposed solution could be extended to other beaches.

Gamification is an important aspect to achieve massive adoption and long term user engagement. Moreover, the gamification strategy is also seen as a source for revenue. Our gamification strategy will rely on *Partners,* which will be selected entities directly related to beach activities and local services. These *Partners* will be invited to sponsor gamification challenges and contribute to the dynamization of the user experience. Our research predicts that 30% of users will not be motivated to complete the challenges and contribute to the community on the basis of intrinsic values, thus an additional motivating factor is required. As the platform will be fed by the user community, the more active users there are, the more reliable information on the different beaches will be. Integrating beach-related entities to sponsor gamification challenges will have a positive impact on user motivation and will, therefore, engage more active users. In return, *Partners* will have AR exposure and will be related to a project that endorses the safety of the beach and helps to save lives.

Augmented Reality also provides new opportunities for the integration of advertising in the surrounding environment. Selling digital exposure spaces could be a profitable channel to support the costs of the structure and promote additional dynamics to the platform. In addition to *Partners* (entities integrated in the gamification strategy), the platform will be able to integrate *Sponsors* (advertisements from interested companies), which will be able to choose between three levels of AR marketing services that could be integrated into the platform:

1. **Exposure:** Exposure consists of AR ads for local services (restaurant, bar, surf school), represented by basic AR elements incorporating direct hyperlinks to the websites of entities that can be easily accessed by the user.

2. **Animation:** Animation consists of 3D AR animations that capture the user's attention. An example of animated advertisements could be a realistic animation of a virtual plane with a banner message, that every user could see flying across the beach while the device is pointing to the surf zone.

3. **Interaction:** The third level of marketing could consist of direct interactions between brands and users. The user would receive a notification with a storytelling of a brand and inviting him to play a specific challenge, sponsored by the brand (e.g., Treasure hunt at the beach sponsored by CocaCola).

The Beach Safety Community is an ambitious project, with a strong mission: Help to save lives. This research confirmed its meaningfulness, which encourages us to proceed for a further implementation project. An interesting and challenging journey lies ahead, involving different people with diverse backgrounds. We will rely on DesOps frameworks to orchestrate the best practices of Interaction Design, so to achieve a state-of-the-art product that delivers the intended value to the user and to the community.

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Annex 1: Examples of Rip Currents

This annex presents a collection of real examples of different types of Rip Currents captured in different beaches. These examples were chosen from Science of Surf, an educational program for the general public designed to reduce the number of drownings and injuries on our beaches, created by Dr Rob Brander, a coastal geomorphologist of the University of New South Wales and member of the Tamarama Beach Surf Life Saving Club.

The first rip example presented in figure 53, was taken by Jason Markland, producer of Rip Current Heroes, and it shows why rip currents can be so dangerous. This picture shows a fixed rip against the northern headland, and 3 more dynamics rips coming down the beach (the dark gaps). In total there's 4 rips in just a 500 metre section of beach.

Figure 53: September 2018 Dreamtime Beach, NSW, Australia,
Source:(http://www.scienceofthesurf.com/ripom.html)

Figure 54 presents a beach scenario where the waves are relatively big and it is possible to see a lot of sand being churned into suspension by the breaking waves all along the beach. This sand is ending up in some rip currents, particularly the one at the southern end of the beach (towards the bottom). It looks like the rip flow is starting off in a deeper channel and then being forced 100 m + offshore past the breaking waves. The strength of the current is evident not only by the distance it's flowing offshore, but by how narrow and contained the rip flow is.

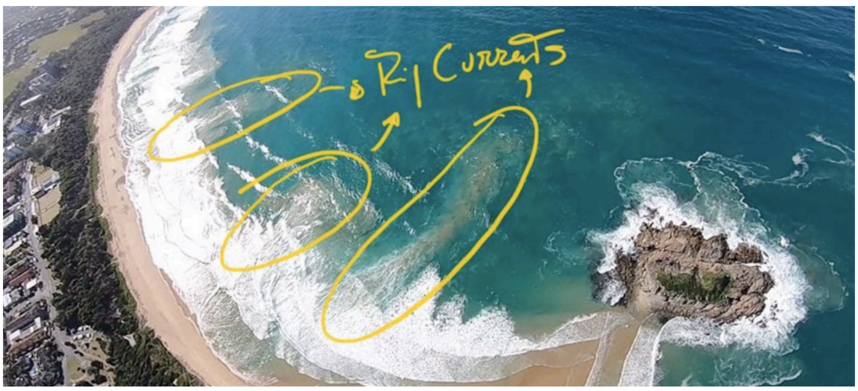


Figure 54: August 2019 Park Beach, Coffs Harbour, NSW Australia,
Source:(http://www.scienceofthesurf.com/ripom.html)

Figure 55 presents two rip currents. The one in the foreground is a typical channelised rip that appears as a dark gap, about 10-20 m wide, flowing through the sand bar at low tide. There is also a boundary rip (that is also in a deeper channel) against the rocks and headlands that is narrower, but just as dangerous given the adjacent rocks.

Figure 55: November 2019 Anglet, France
Source:(http://www.scienceofthesurf.com/ripom.html)

In Figure 56 all the dark channels in the surf zone (area where waves are breaking - the whitewater) are either deep rip current channels heading offshore or alongshore currents feeding the rips. It is possible to see prominent rip current embayments along the shoreline, particularly further down the beach. There's not a lot of safe places to swim in this picture.

Figure 56: May 2019 Lighthouse Beach, NSW, Australia
Source:(http://www.scienceofthesurf.com/ripom.html)

Figure 57 is a classic example of a channelised rip current that is common under normal, and even gentle, wave conditions. Channel rip currents can persist in the same location for days and weeks and tend to carve out their own embayment into the beach. This rip actually had distinct alongshore feeder channels transporting water into a narrow rip neck that is only about 5-10 metres wide. Flow in the rip current gradually increases from the feeders to the rip neck, where it becomes strongest and eventually slows down seaward of the line of breaking waves and decelerates into an expanding rip head. Most of that water is eventually returned landward across the sand bars by breaking waves.

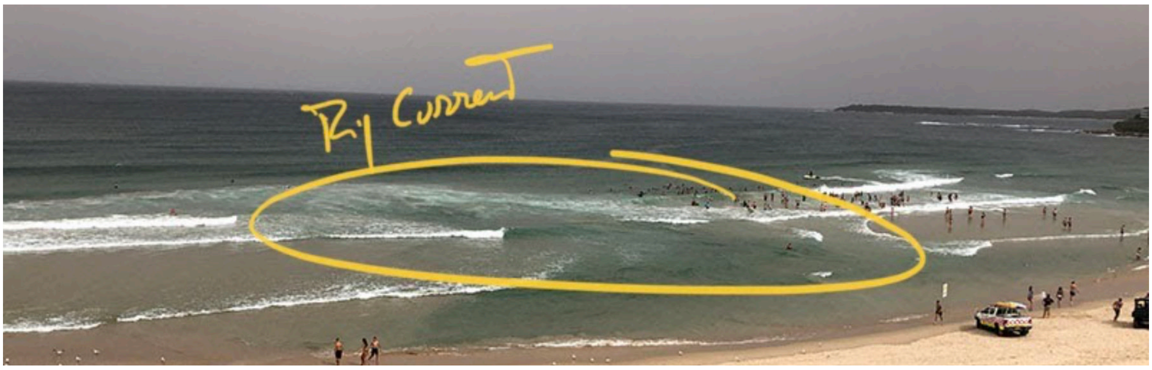


Figure 57: February 2020 North Cronulla Beach, Sydney, NSW Australia
Source:(http://www.scienceofthesurf.com/ripom.html)

Annex 2: Beach Types and Their Classification

Beach types and their average Wave height (Hb), the dimensionless fall velocity (Ω) and the relative tide range (RTR) values
Source: Adapted from Short (2006)

Beach Types	Beach State	Hb	Ω	RTR
Wave Dominated beaches	Dissipative (D)	1.9	9	0.6
	Transverse bar and rip (TBR)	1.5	3.6	0.8
	Longshore bar trough (LBT)	1.6	2.4	0.6
	Low tide terrace (LTT)	1	2.5	1.6
	Rhythmic bar and beach (RBB)	1.7	3.1	0.7
	Reflective (R)	0.7	1.1	2.8
Tide-modified beaches	Reflective and low tide terrace (R+LTT)	0.45	2.2	9
	Reflective and low-tide bar and rip (R+LT rips)	0.7	3	4.2
	Ultra-dissipative (UD)	0.5	4.1	10
Tide-dominated beaches	Reflective and sand ridges (R+ sand ridges)	0.5	2.6	9
	Reflective plus sand flats (R + sand flats)	0.2	0.7	20
	Reflective plus tidal sand flats (R + tidal sand flats)	0.2	0.7	32
	Reflective plus intertidal mud flats (R + tidal mud flats)	0.18	0.6	48
	Beaches Plus Rock Flats (R + rock flats)	0.5	1.3	16
	Beaches Plus Fringing Coral Reefs (R + coral reef)	0.3	0.6	22

Annex 3: Hazarding Rating of Different Beach Types

Table 2: Hazard rating for Australia beach types and states.
Source: Adapted from Short (2006)

Beach Types	Beach State	Wave Height (m)							
		<0.5	0.5	1	1.5	2	2.5	3	>3
Wave Dominated beaches	D	4	5	6	7	8	9	10	10
	TBR*	4	4	5	6	7	8	9	10
	LBT*	4	5	6	7	7	8	9	10
	LTT*	3	3	4	5	6	7	8	10
	RBB*	4	5	6	6	7	8	9	10
	R	2	3	4	5	6	7	8	10
Tide-modified beaches	R+LTT	1	1	2	4	6	8	8	10
	R+LT Rips	1	2	3	5	7	9	9	10
	UD	1	2	4	6	8	8	10	10
Tide-dominated beaches**	R+ Sand Ridges	1	1	2	.	.	.	.	.
	R + sand flats	1	1	.	.	.	.	.	.
	R + tidal sand flats	1	.	.	.	.	.	.	.
	R + tidal mud flats	1	.	.	.	.	.	.	.
	R + rock flats	1	.	.	.	.	.	.	.
	R + coral reef	1	.	.	.	.	.	.	.

* the four intermediate types (longshore bar and trough, rhythmic bar and beach, transverse bar and rip, low tide terrace) are all dominated by rip channels and rip currents.
** Waves height unlikely to exceed 0.5 - 1 m.

Annex 4: Survey

Beach Safety and Rip Current Knowledge Survey

As part of a research work, we ask you to answer this questionnaire which aims to obtain information about the bathers ' perception and knowledge of the risks on the beach, namely the risk of rip currents.

The questionnaire takes approximately 5 minutes to complete, participation is anonymous, so we ask you to complete all the questions in order to be able to have an expression in the statistical analysis of the answers.

Thank you for your time.

Rodrigo Alarcão,
Master degree in Interaction Design, IADE

User Beach Background

1. Q1.Which statement best describes how often you go to the beach?

   Marcar apenas uma oval.

   - All year round (with regularity)
   - Spring to Autumn months (April-November)
   - Spring and Summer months (May-September)
   - Summer months only (June-September)
   - I rarely go to the beach

2. Q2. How would you describe the beach that you most visit?

Marcar apenas uma oval.

- Beach with small waves.
- Beach with medium waves
- Strong waves are common.

3. Q3. Do you always go to a lifeguarded beach?

Marcar apenas uma oval.

- Yes
- No
- I don’t think it is relevant

4. Q4. How would you describe your swimming capability?

Marcar apenas uma oval.

	1	2	3	4	5	
Very poor						Very good

5. Q5. From the following, which beach activities do you usually practice? (Choose as many as you like)

Marcar tudo o que for aplicável.

- [ ] Bathe in the surf zone
- [ ] Swim
- [ ] Surf
- [ ] Bodyboard
- [ ] Kitesurf
- [ ] Paddle surf
- [ ] I usually don´t go to the sea

6. Q6. From the following activities, select the ones you apply in a beach context

Marcar apenas uma oval.

- ( ) Purchase literature objects (e.g., books, magazines and / or newspapers)
- ( ) Buying drinks at the beach restaurant / bar
- ( ) Buying food at the beach restaurant / bar
- ( ) Buying food from "beach food sellers" (e.g., soda, ice cream, cookies, etc.)
- ( ) Renting nautical equipment (e.g., wetsuits and surfboards)
- ( ) Renting nautical entertainment (e.g., jet ski)
- ( ) Renting awnings

7. Q7. Which of the following factors influence your beach choice? (Choose as many as you like)

Marcar tudo o que for aplicável.

- [ ] Distance
- [ ] Air temperature
- [ ] Wind Force
- [ ] Surf height
- [ ] Water temperature

8. Q8. Apart from the factors above, what other information do you think is relevant to know about a beach (e.g., car park, restaurant, WC, Wifi, etc ...)? Please provide at least 3 types information

9. Q9. Do you know what a yellow and red flag on a beach means?

Marcar apenas uma oval.

- ( ) Danger, don't swim here
- ( ) Area for surfing
- ( ) Strong winds
- ( ) Area patrolled by lifeguards
- ( ) I don't know

10. Q10. How often do you respect flag signaling when you go into the sea?

Marcar apenas uma oval.

	1	2	3	4	5	
Never	( )	( )	( )	( )	( )	Always

Rip Current Knowledge

11. Q11.How much do you assume you know about rip currents?

Marcar apenas uma oval.

	1	2	3	4	5	
I don't know	◯	◯	◯	◯	◯	Detailed knowledge

12. Q12.What is the greatest danger of a rip current?

Marcar apenas uma oval.

◯ Pulls you under the water
◯ Sweeps sideways across the beach
◯ Drags you out to sea
◯ I don't know, but I would like to know
◯ I don´t know

13. Q13.From the following descriptions, which best describe a rip current? (Choose as many as you like)

Marcar tudo o que for aplicável.

☐ There is churned up sediment and sand
☐ An area of water with no breaking waves
☐ It's all foamy/frothy
☐ A darker patch of water with rippled surface
☐ Shallow water area
☐ I don't know

14. Q14. What are the best strategies to get out of a rip current? (Choose as many as you like)

Marcar tudo o que for aplicável.

- [ ] Swim back towards shore
- [ ] Swim parallel to the shore
- [ ] Raise an arm or shout for help
- [ ] Float and ride the current out
- [ ] Dive down underneath the water
- [ ] I don´t Know

15. Q15. Where is a rip current likely to occur?

Marcar apenas uma oval.

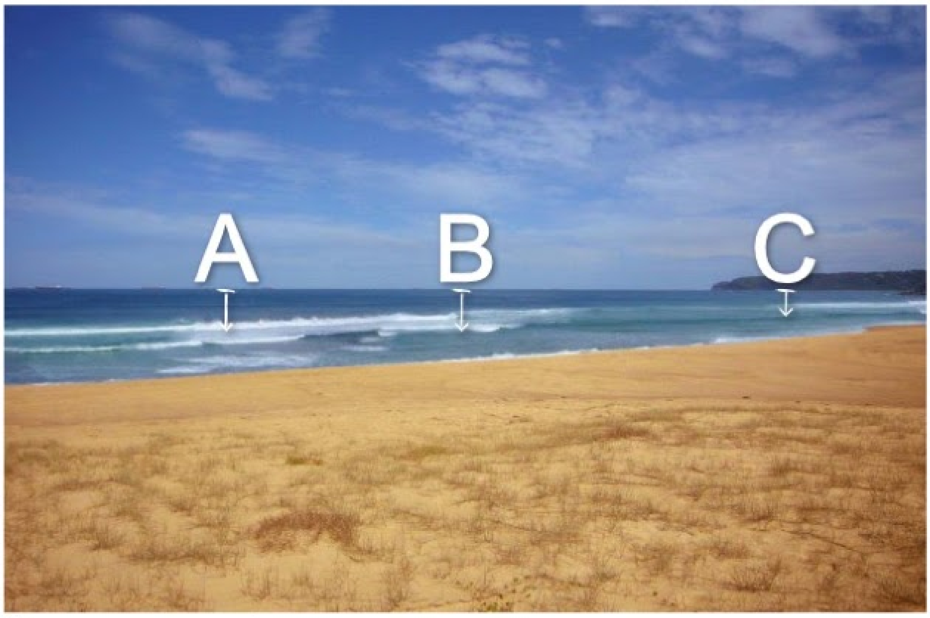
- ( ) On beaches over 5 km long
- ( ) Between sand bars
- ( ) Unprotected beaches from the wind
- ( ) I don't know

16. Q16. What key messages about rip currents do you know? (Choose as many as you like)

Marcar tudo o que for aplicável.

- [ ] Don't swim against the current
- [ ] They are safe to swim in
- [ ] White water is good, dark water is bad
- [ ] Stay calm, don't panic
- [ ] Swim towards waves if caught
- [ ] I don't know

17. Q17.Inthis picture, where do you think it's unsafe to swim/go in the water?



Marcar apenas uma oval.

- ( ) A
- ( ) B
- ( ) C

18. Q18.Do you remember reading or listening to any information related to rip currents? If so, in what situations? (Choose as many as you like)

Marcar tudo o que for aplicável.

- [ ] ISN Education program
- [ ] Face-to-Face from lifeguards
- [ ] Life-Saving club
- [ ] Media (TV/Radio/Print)
- [ ] School
- [ ] Signage at the beach
- [ ] Internet
- [ ] Talks with family and friends
- [ ] Do not recall any information

19. Q19.Have you ever been caught in a rip current?

Marcar apenas uma oval.

- ( ) Yes
- ( ) No
- ( ) I don´t know

Willingness to use a smartphone in a beach context

20. Q20. How often do you use your smartphone at the beach?

Marcar apenas uma oval.

	1	2	3	4	5	
Never	( )	( )	( )	( )	( )	Every time

21. Q21.When you use a smartphone at the beach, what kind of things do you find yourself doing? (Choose as many as you like)

Marcar tudo o que for aplicável.

- [ ] Calls and messages
- [ ] Camera (Photos and Video)
- [ ] Listen to music
- [ ] Play mobile games
- [ ] Internet
- [ ] Emails
- [ ] Social Media
- [ ] Other

22. Q22. Are you familiar with the Augmented Realityconcept?

Marcar apenas uma oval.

	1	2	3	4	5	
I don't know	◯	◯	◯	◯	◯	Detailed knowledge

23. Q23. Have you ever experienced any Augmented Realityinteraction with your smartphone?

Marcar apenas uma oval.

◯ Yes

◯ No

24. Q24. Would you be willing to use your smartphone at the beach to:

Marcar tudo o que for aplicável.

- [ ] Visualize hazards
- [ ] Visualize rip currents
- [ ] Report the location of new hazards
- [ ] Report new rip currents at the beach
- [ ] Help to update the location of existing rip currents at the beach

Demographics

25. Q25. Are you a resident in Portugal?

Marcar apenas uma oval.

- ( ) Yes
- ( ) No

26. Q26. Which best describes your gender?

Marcar apenas uma oval.

- ( ) Female
- ( ) Male
- ( ) Other

27. Q27. Age range

Marcar apenas uma oval.

- ◯ <15
- ◯ 15 - 24
- ◯ 25 - 34
- ◯ 35 - 44
- ◯ 45 - 54
- ◯ 55 - 64
- ◯ >65

Thank you for your time.

We appreciate the time you have dedicated to this project.

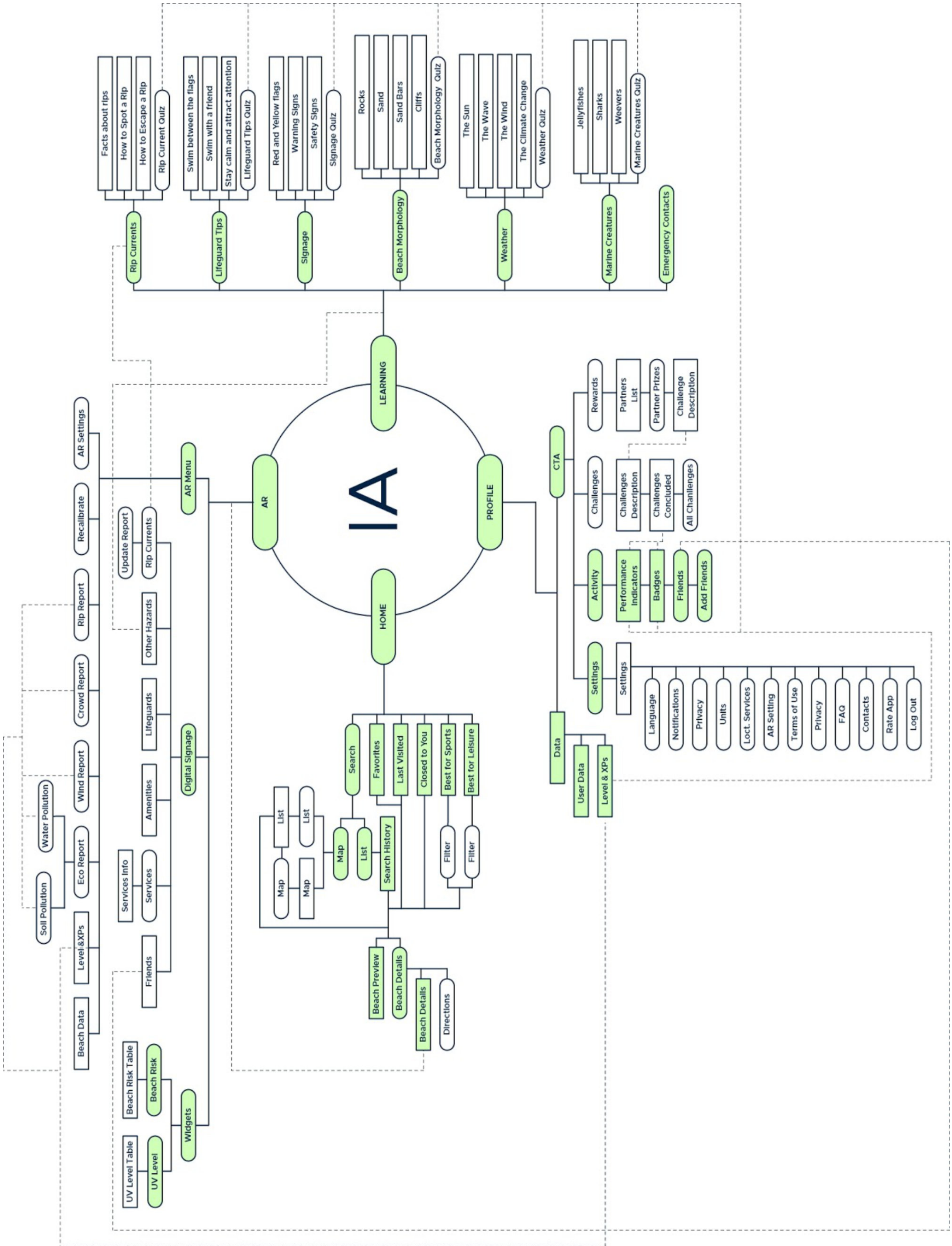
The answers will be analyzed so that it is possible to infer the perception of dangers on the beach.

If you are available to participate in the usability tests of an application under development related to safety on the beaches, please leave us your email contact.

Rodrigo Alarcão,
Master degree in Interaction Design at IADE

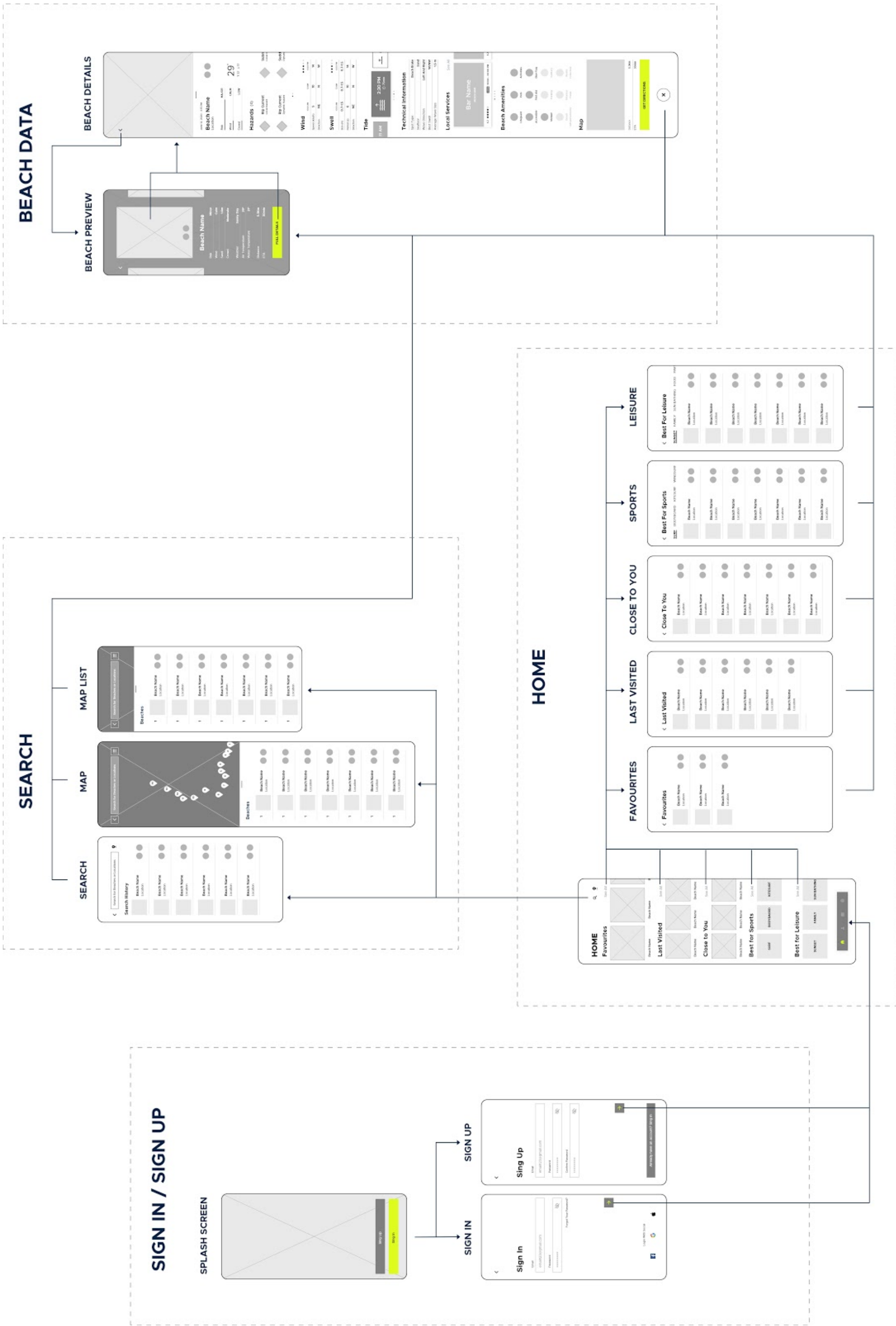
28. Email

Annex 5: Architecture Information

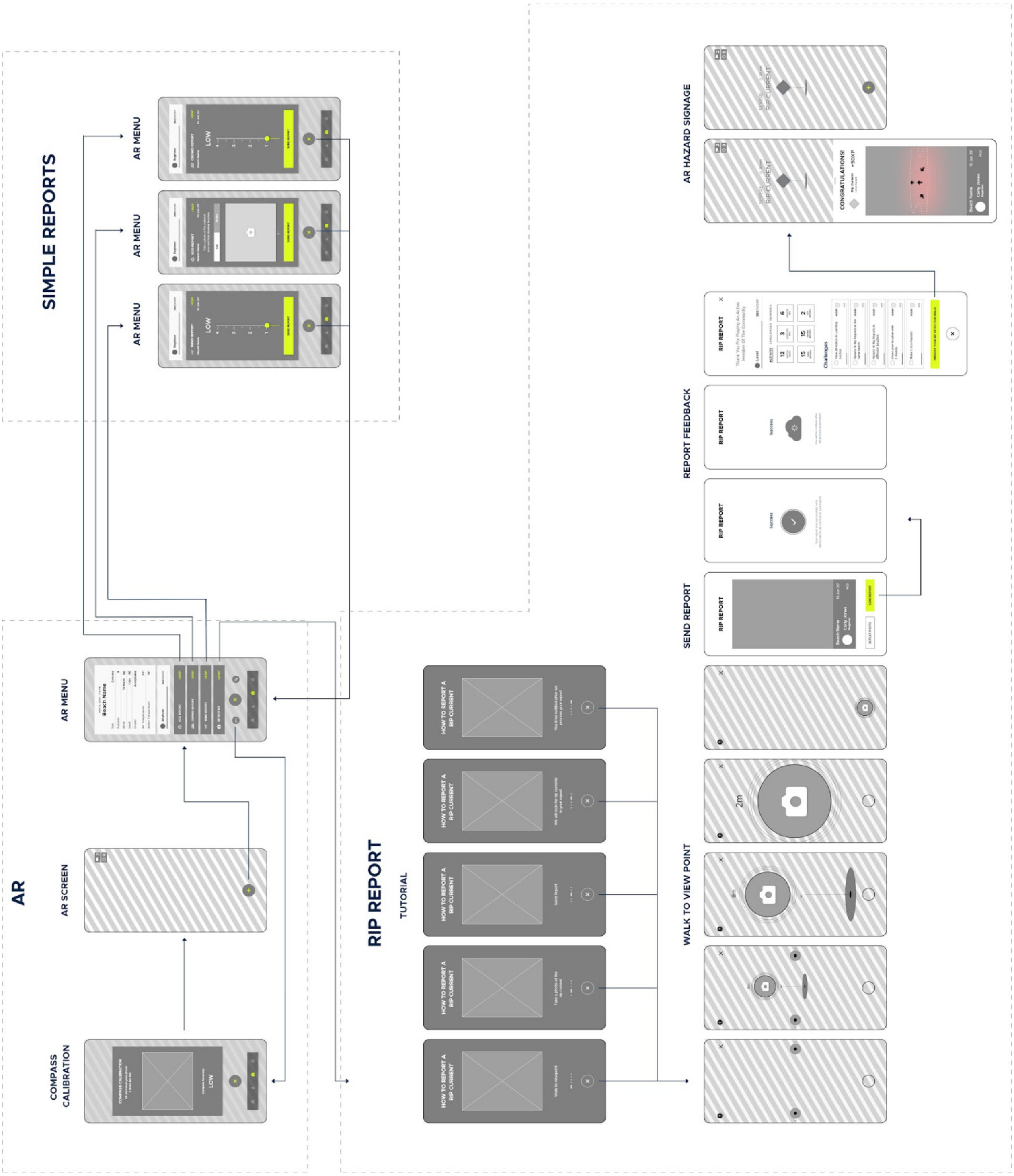


Annex 6: Wireframes

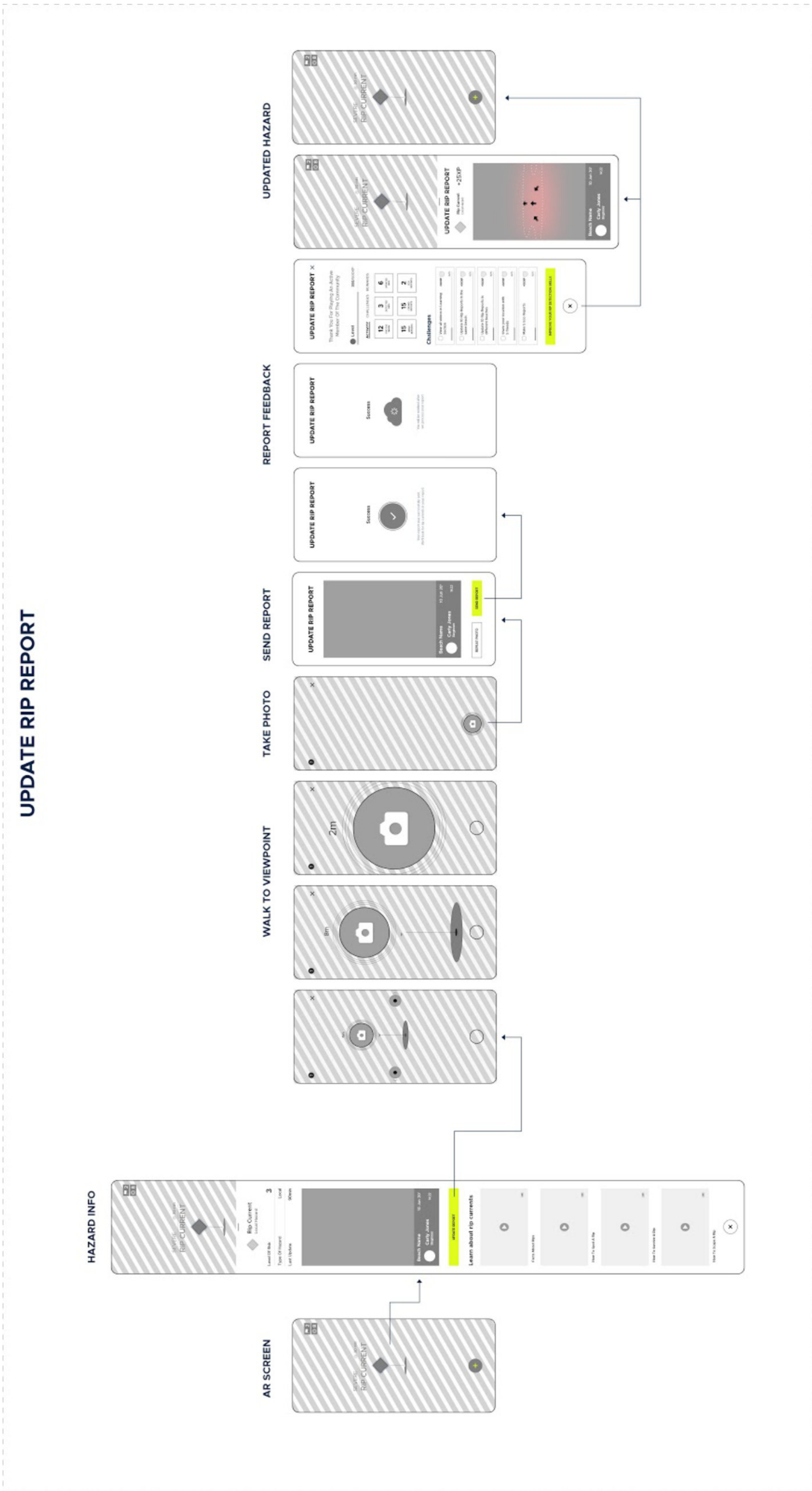
Sign In, Home, Search and Beach Details



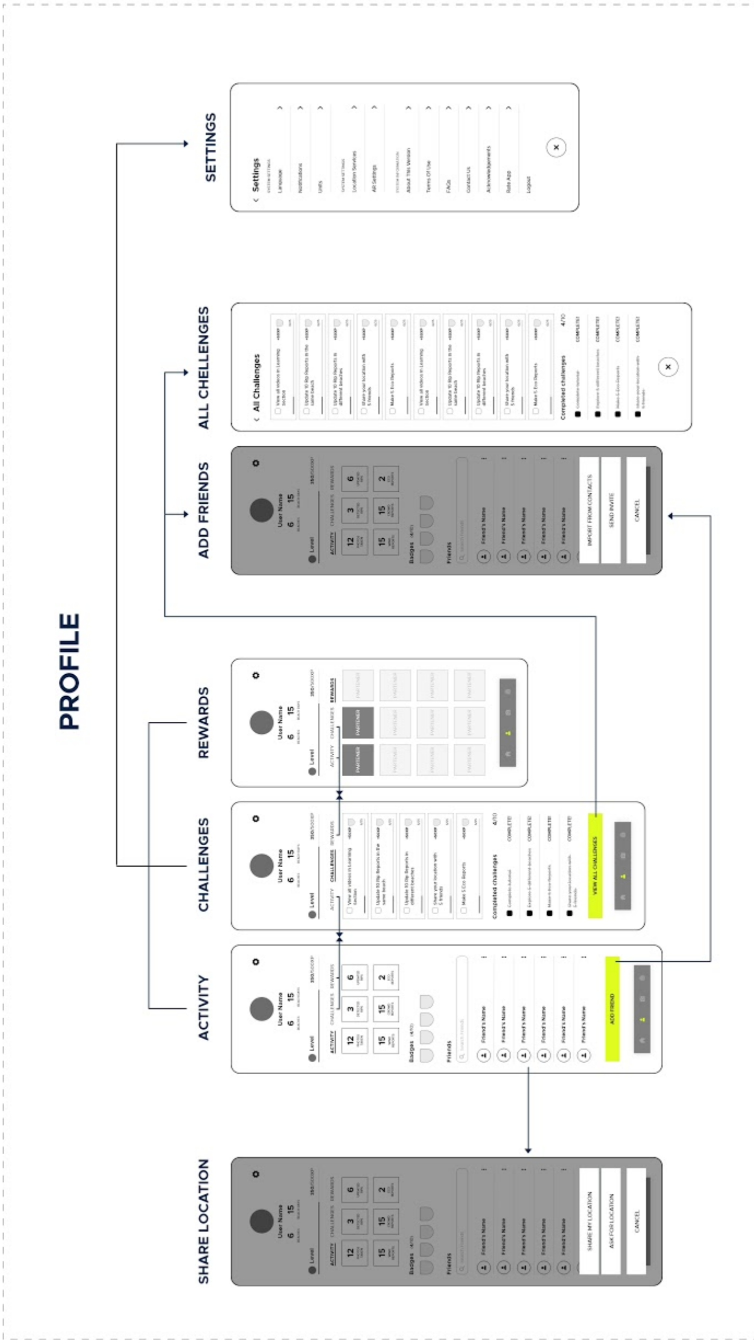
AR, Simple Reports and Rip Report



Update Rip Report



Profile and Learning



Annex 7: Design System

1. Colors

Main Text, Accent & Icons

#003465 #C6D3DF #3AEBEA #E8FF00 #417CBD #37F2EC

Alerts Colors

#FD4545 #5BFF80 #FFB300

2. Fonts

h1

ABC 123

Metropolis - Extra Bold - 32Px

h2

Abc 123

Metropolis - Bold - 22Px

h3

ABC 123

Metropolis - Extra Bold - 14Px

Paragraph

Sed ut perspiciatis unde omnis iste natus error sit voluptatem accusantium doloremque laudantium, totam rem aperiam, eaque ipsa quae ab illo

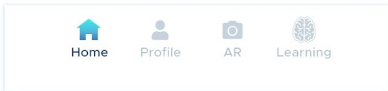
Metropolis - Regular - 14Px

3. Buttons

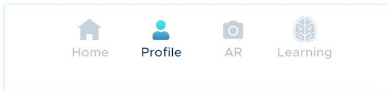
Buttons

Primary Button   Secondary Button   Unavailable Item

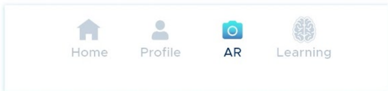
Menu 1: Navigation Bar



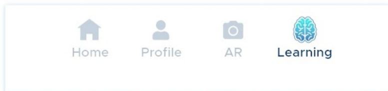
Home



Profile

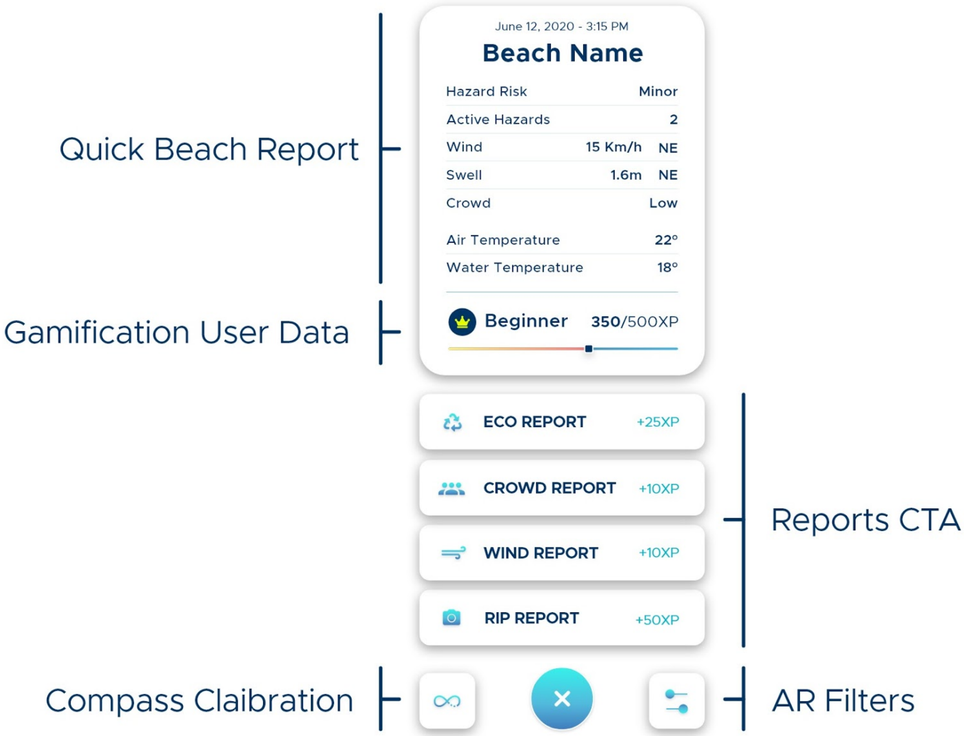


AR



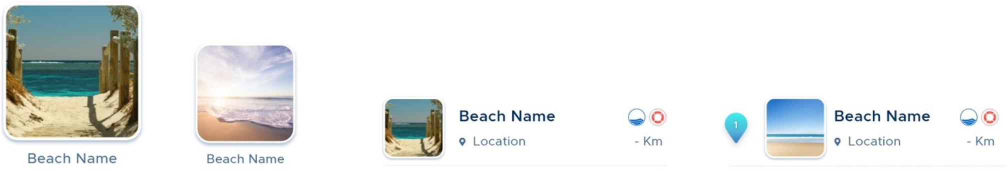
Learning

Menu 2: AR



4. UI Elements

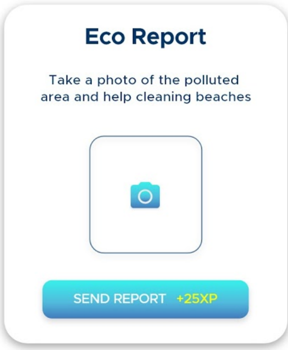
Beach Thumbnails



Beach Thumbnail 1　Beach Thumbnail 2　Beach Thumbnail 3 (List)　Beach Thumbnail 4 (Map List)

Reports Cards

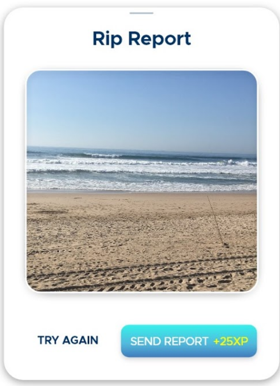
Eco Report



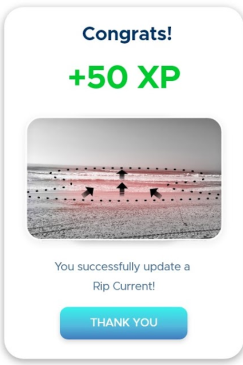
Crowd Report

Wind Report

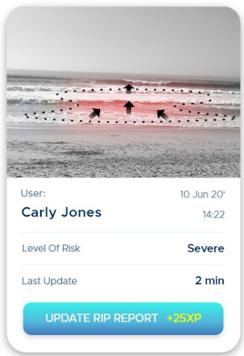
Send Rip Report



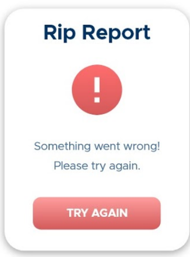
Rip Report Success



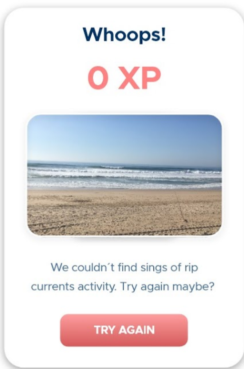
Rip Report



Rip Report Fail

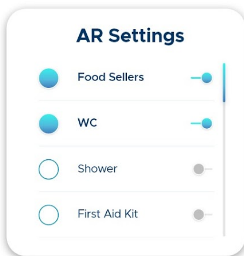


Rip Report Fail 2



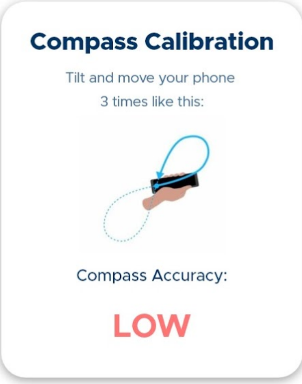
Rip Report Feedback Message

AR Filters

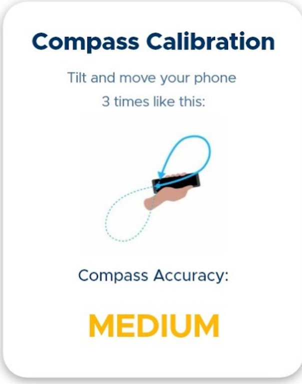


Compass Calibration

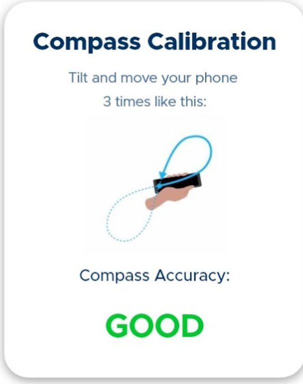
Accuracy 1



Accuracy 2

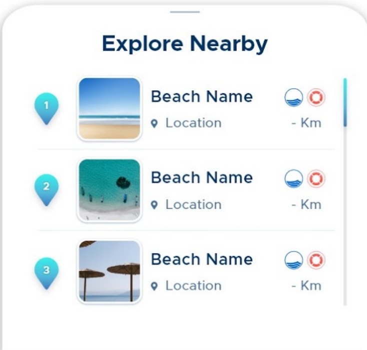


Accuracy 3

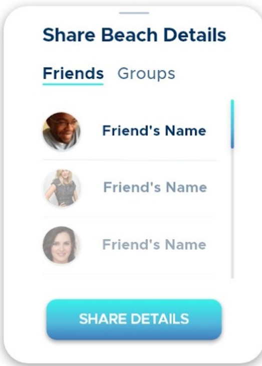


UI Cards

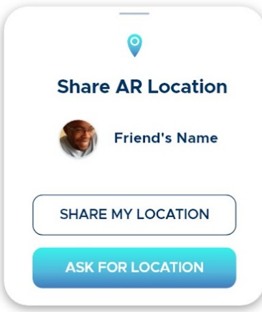
Map List Card



Share Beach Details



Share AR Locatoin



Learning UI Elements

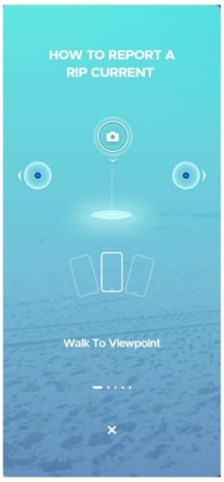
Learning Section

Seen Video Thumbnail

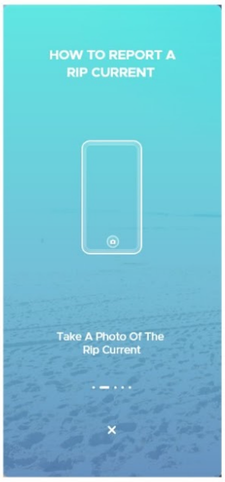
Unseen Video Thumbnail

5. Rip Report Tutorial

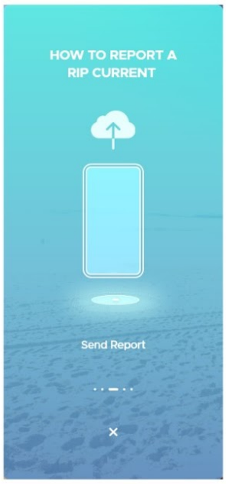
Tutorial Step 1



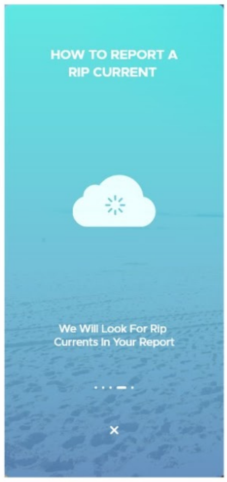
Tutorial Step 2



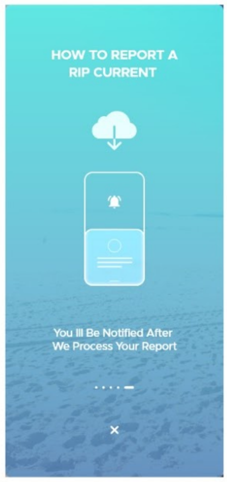
Tutorial Step 3



Tutorial Step 4



Tutorial Step 5

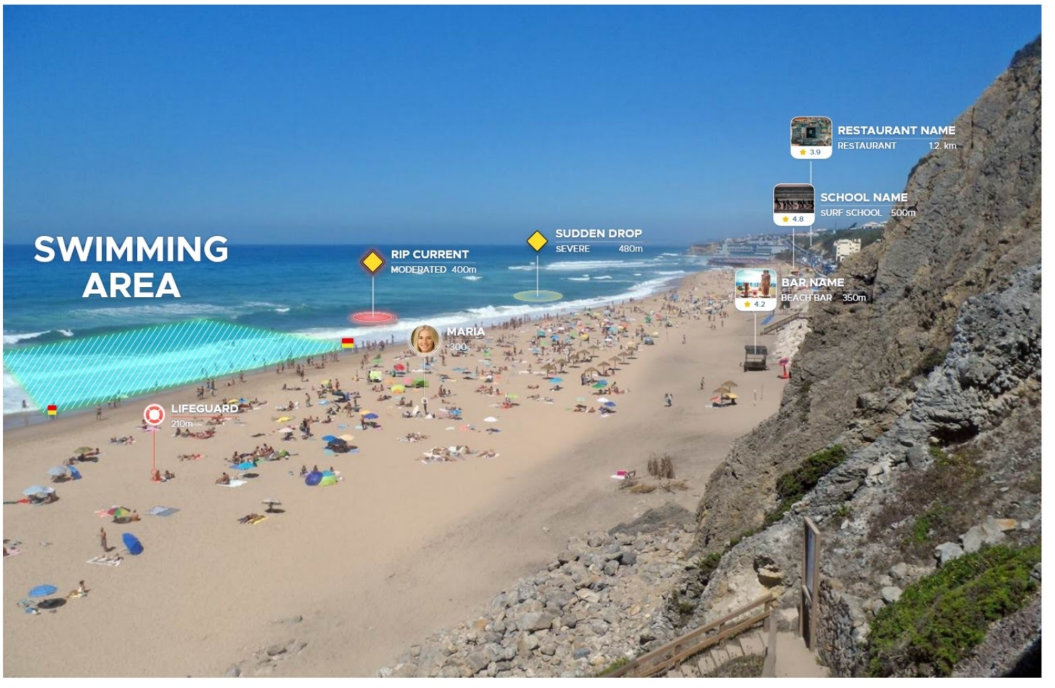


6. Viewpoints

Viewpoints Position

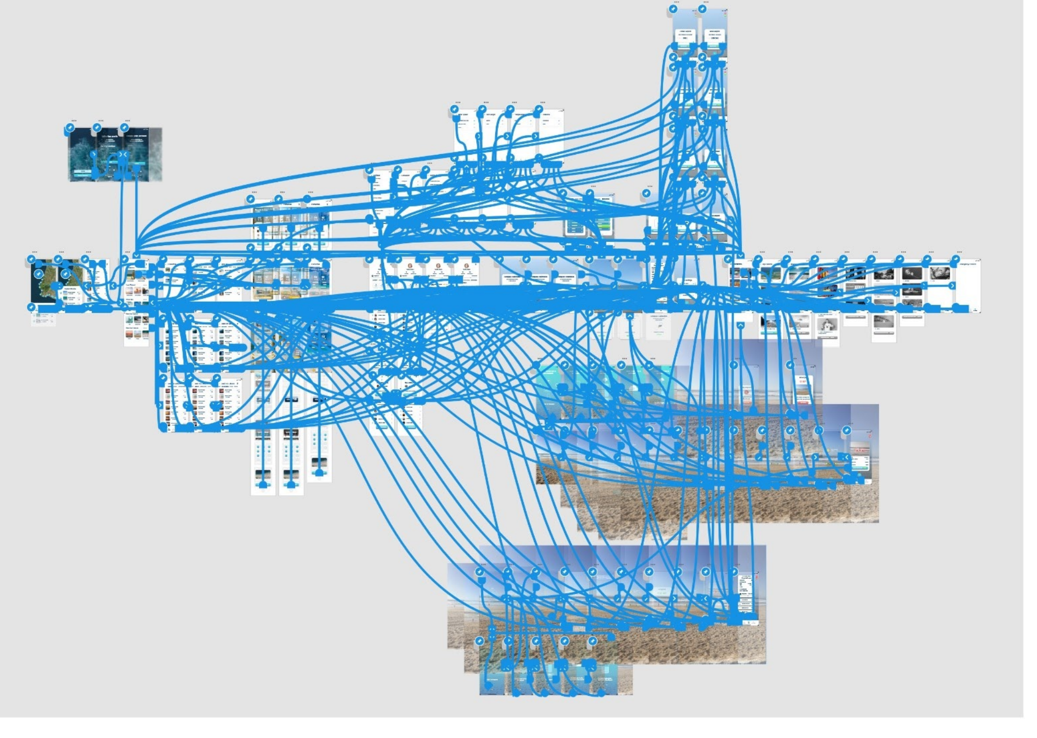
7. AR Signage

AR Signage



8. Interactive Prototype

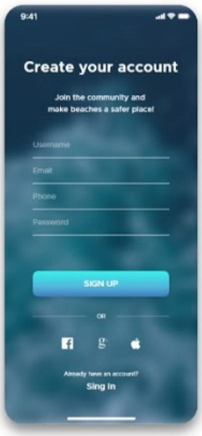
Screen Interactions - Adobe XD



9. Sign In & Home Screen

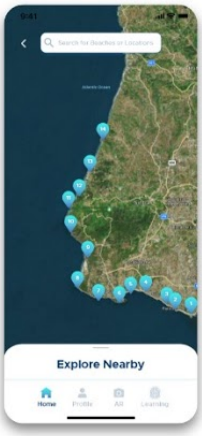
Splash Screen

Sign Up

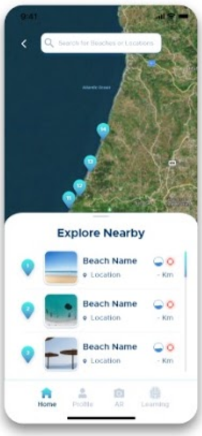


Sign In

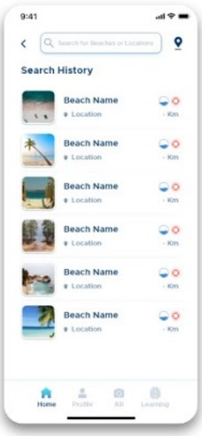
Search Map



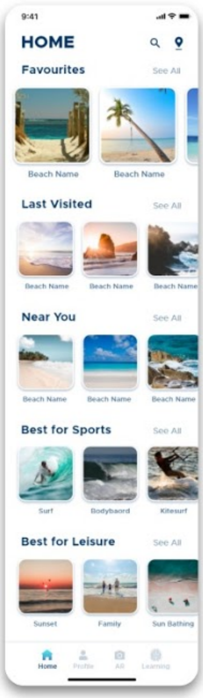
Search Map List



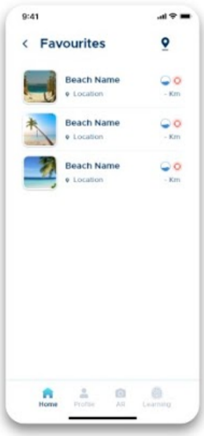
Search List



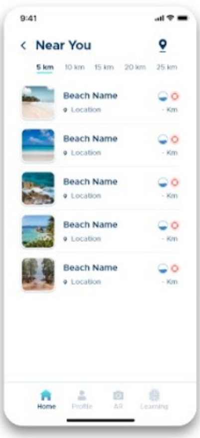
Home



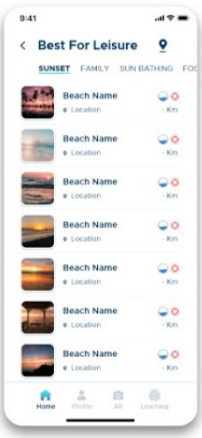
Favourites



Near You

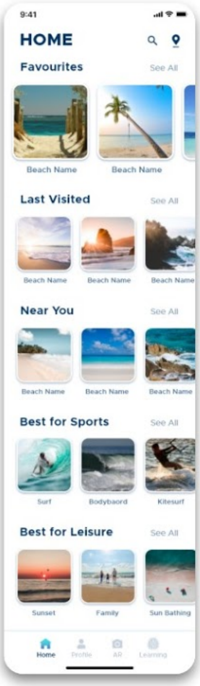


Collection



10. Beach Preview & Details

Home



Beach Preview 1

Beach Preview 2

Beach Preview 3

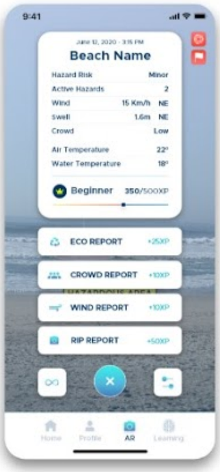
Beach Details

Favourites

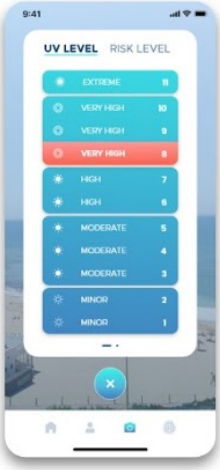
11. AR & Simple Reports

AR Screen

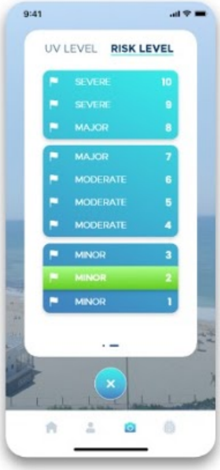
AR Menu



UV Level



Risk Level

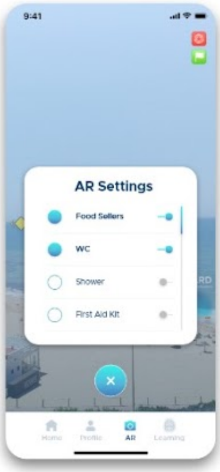


Compass 1

Compass 3

Compass 3

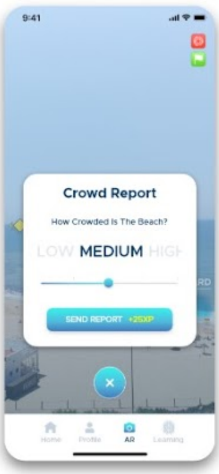
AR Settings



Eco Report

Wind Report

Crowd Report

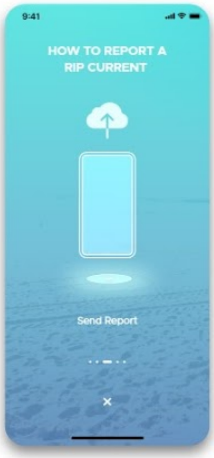


12. Rip Report

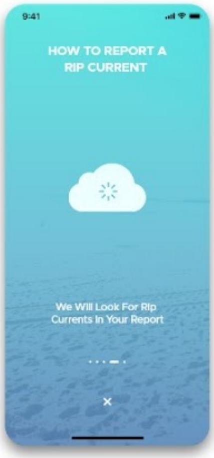
Tutorial Step 1

Tutorial Step 2

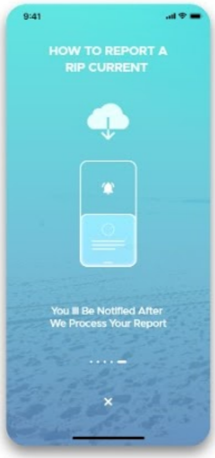
Tutorial Step 3



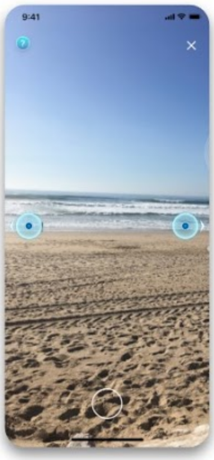
Tutorial Step 4

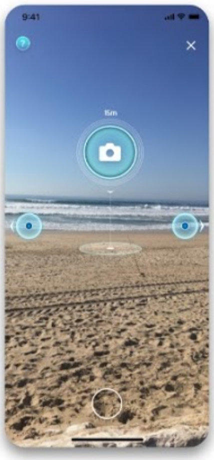


Tutorial Step 5



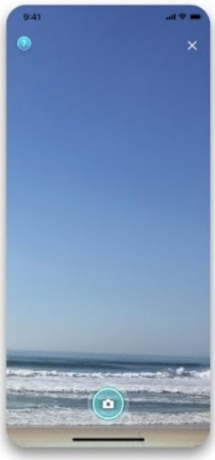
Out Of Screen Viewpoints



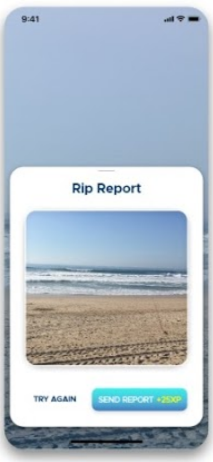


View Point

Take Picture

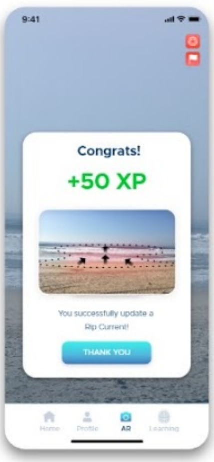


Send Picture



Feedback 1

Feedback 2

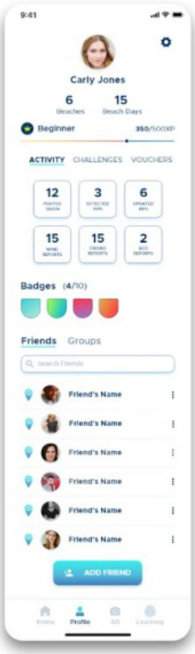


AR Sign

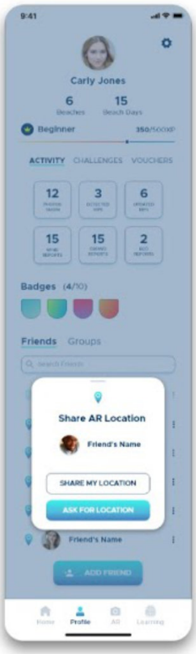
Rip Report Data

13. Profile & Settings

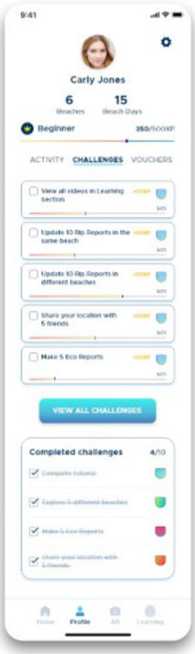
Activity



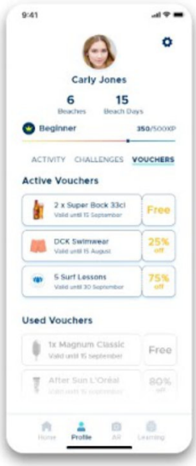
Share Location



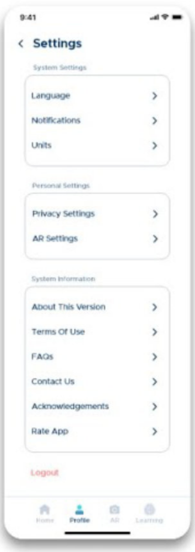
Challenges



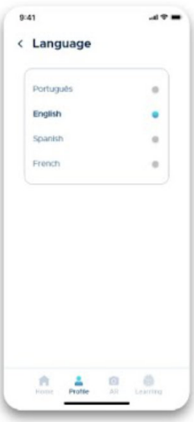
Voucher



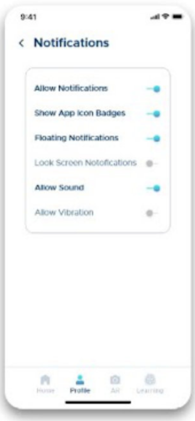
Settings



Language

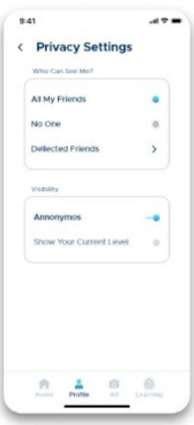


Notifications

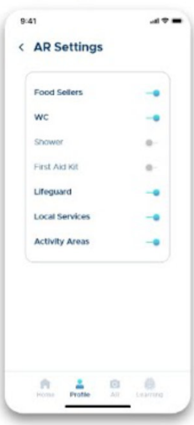


Units

Privacy Settings



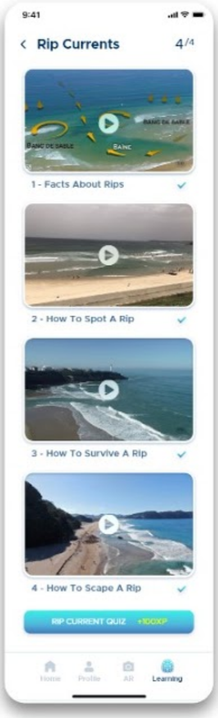
AR Settings



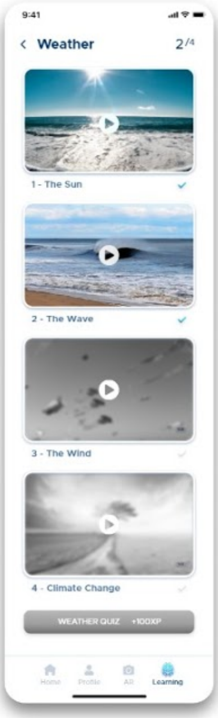
14. Learning

Learning Sections

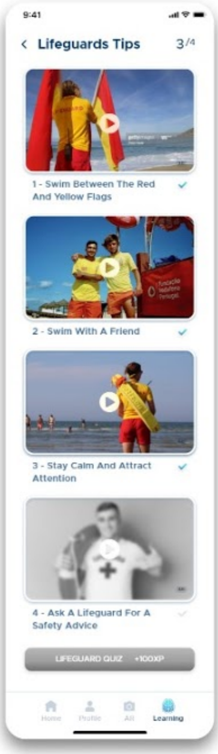
Rip Currents



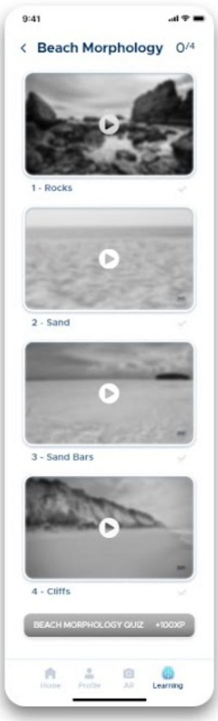
Weather



Lifeguards Tips

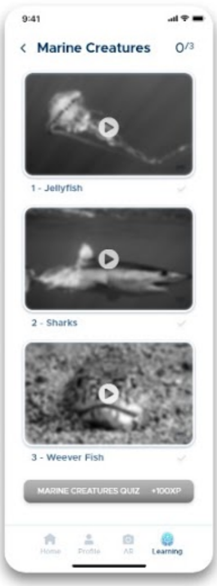


Beach Morphology



Flags And Signs

Marine Creatures



First Aids

Annex 8: Usability Test Consent Form

Please read and sign this form.

In this usability test:

- You will be asked to perform certain tasks on a computer.
- We will also conduct an interview with you regarding the tasks you performed.

Participation in this study of usability is voluntary. All details shall remain strictly confidential. Descriptions and results will be used to help to improve the project. However, your name or any other identification will not be used at any time. You may withdraw your consent to the experiment and stop participating at any time.

If you have any questions after today, please contact Rodrigo Alarcão at alarcao.rodrigo@gmail.com.

I have read and understood the information on this form and had all of my questions answered.

Subject's Signature________________________________

Date__________________________

Annex 9: Usability Test Protocol

1. **Presentation and Consent Form** (see Annex 8)

2. **Pre test questionnaire:** https://forms.gle/fSHfFDj8rerVQr6X8

3. **Project Introduction (Interactive Mock-Up)**
   https://xd.adobe.com/view/13b05db5-a2d8-4fe1-6d59-9d99e84e8d28-6581/

4. **Prototype:** https://xd.adobe.com/view/60fe0fa0-b7fa-4695-8934-b7e6bfb820c7-35ad/

   a. **a. Tasks Tests:**
      T1 - Find information about how to escape a Rip Current
      T2 - Find how many XP points and levels do you have in the app
      T3 - Can you try to Report a new Rip Current?
      T4 - Can you identify the rip current plume?
      T5 - How would you see the UV and hazard risk levels at the beach?
      T6 - Try to Update a Rip Current report?
      T7 - How would you turn on anonymity in the app
      T8 - You received a new free beer voucher. Try to find your voucher.

   b. Multiple Tasks Tests:
      T9 - Find a beach w/ no wind in the favorites section and share the beach details with a friend
      T10 - Share with the community the wind and crowd status.

   c. Open Analytics Tests:
   In these tests the participant can navigate openly on the prototype, think out loud and give feedback on what they think of the product, what can be improved and discover usability problems. During the course of this task, participants were asked questions to promote dialog. The casual conversation enables the usability test flow naturally and helps participants feel comfortable. The more comfortable the participants are, the better their chances of sharing their honest opinions. While the participants were completing the test tasks, the following questions were asked:

   b. How would you use this feature?
   c. What parts of the app would you use the most? Why?
   d. What do you think about how information and features are laid out?
   e. Do you find it easy to use? Why?

5. **System Usability Scale Questionnaire** (SUS)

   a. I think that I would like to use this system frequently.
   b. I found the system unnecessarily complex.
   c. I thought the system was easy to use.
   d. I think that I would need the support of a technical person to be able to use this system.
   e. I found the various functions in this system were well integrated.
   f. I thought there was too much inconsistency in this system.

- **g.** I would imagine that most people would learn to use this system very quickly.
- **h.** I found the system very cumbersome to use.
- **i.** I felt very confident using the system.
- **j.** I needed to learn a lot of things before I could get going with this system.

6. Post-test interview:

- **a.** Do you see any advantage of using AR to communicate beach hazards?
- **b.** What is your opinion about the intuitiveness of the App negation interfaces:
    - i. icons
    - ii. navigation features (w3c)
    - iii. usefulness of the information (first, intermediate and last level). Goal: analyse the self-use/intuitiveness of the App.
        1. If too critics: what information should be considered or needs to be reviewed
- **c.** In your opinion, the challenges are appropriate to motivate using the app?
- **d.** According to your opinion, did you find any features requiring improvements?
- **e.** Can you indicate any aspect that is missing or any additional feature that you consider relevant to be considered in the App?
- **f.** Can you outline what caught your attention in the App? why?
- **g.** How do you describe your experience with the app?
- **h.** What would motivate you to keep using the app?
- **i.** Your perception about beach safety before and after testing the App has changed? please explain.