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Abstract

In an era where smartphones have become an integral part of our daily lives [1], harnessing their potential to ensure personal safety and security is of paramount importance. As these devices continue to evolve and offer an ever-expanding array of features, leveraging their advanced capabilities to create innovative solutions for emergency communication and response can significantly enhance our society's overall resilience in the face of unforeseen crisis. The seamless integration of cutting-edge technologies, such as real-time video communication and location-based services, with the ubiquity of smartphones opens new horizons in the way emergency situations can be approached. By capitalizing on the widespread adoption of smartphones, individuals can be empowered with a powerful tool that not only connects them to immediate help but also bridges the gap in communication during high-stress scenarios. Additionally, it is essential to prioritize accessibility, especially for people with disabilities, as technology and applications continue to develop and improve. For instance, this is of utmost importance in emergency call systems, as individuals with partial or total hearing loss often face challenges in communicating with emergency services.

According to the state-of-the-art, several of the studied applications in Europe and America allow users to make emergency calls, but none of these applications, as far as we are aware, support emergency video calls. Furthermore, no application is known to exist in Greece, to the best of our knowledge, that enables users to contact emergency services through voice, video, or text message through the application itself, let alone one that can help users with partial or total hearing impairments.

This thesis presents the design and development of an innovative emergency call application aiming at revolutionizing emergency communication and response systems. The application, based on WebRTC (Web Real-Time Communication) technology, provides users with a range of features to enable swift and effective communication during emergency situations. Through the application, users can initiate video calls with emergency operators, facilitating real-time visual communication and assessment of emergency situations. In cases where verbal communication is challenging or impossible, a chat functionality is integrated into the video call interface, allowing users to interact with call operators through text messages. Finally, should the user opt not to initiate a voice or video call and instead intend to dispatch an emergency message, an additional functionality referred to as "Image to Text" comes into play. This feature enables the user to articulate an emergency message, using icons that most accurately depict their situation, and send it to the emergency services.

The Usability Evaluation of the application showcased highly promising results. User feedback highlighted the intuitive interface, seamless integration of video and chat functionalities, and the efficiency of the distress messaging system. Participants expressed high levels of satisfaction, particularly emphasizing the application's ability to support individuals with speech-related challenges, enabling them to communicate effectively either through text messages during video calls or by using the “Image-to-text” feature for sending emergency messages.

Περίληψη

Σε μια εποχή όπου τα smartphones έχουν γίνει αναπόσπαστο μέρος της καθημερινότητάς μας [1], η αξιοποίηση των δυνατοτήτων τους για την εξασφάλιση της προσωπικής ασφάλειας και προστασίας είναι υψίστης σημασίας. Καθώς αυτές οι συσκευές συνεχίζουν να εξελίσσονται και να προσφέρουν μια συνεχώς διευρυνόμενη σειρά χαρακτηριστικών, η αξιοποίηση των προηγμένων δυνατοτήτων τους για τη δημιουργία καινοτόμων λύσεων για την επικοινωνία και την αντιμετώπιση έκτακτης ανάγκης μπορεί να ενισχύσει σημαντικά τη συνολική ανθεκτικότητα της κοινωνίας μας απέναντι σε απρόβλεπτες κρίσεις. Η απρόσκοπτη ενσωμάτωση τεχνολογιών αιχμής, όπως η βιντεοεπικοινωνία σε πραγματικό χρόνο και οι υπηρεσίες που βασίζονται στην τοποθεσία, με την πανταχού παρούσα παρουσία των smartphones, ανοίγει νέους ορίζοντες στον τρόπο με τον οποίο μπορούν να προσεγγιστούν οι καταστάσεις έκτακτης ανάγκης. Αξιοποιώντας την ευρεία υιοθέτηση των smartphones, τα άτομα μπορούν να αποκτήσουν ένα ισχυρό εργαλείο που όχι μόνο τους συνδέει με άμεση βοήθεια αλλά και γεφυρώνει το χάσμα στην επικοινωνία κατά τη διάρκεια σεναρίων υψηλής πίεσης. Επιπλέον, είναι σημαντικό να δοθεί προτεραιότητα στην προσβασιμότητα, ιδίως για τα άτομα με αναπηρία, καθώς η τεχνολογία και οι εφαρμογές συνεχίζουν να αναπτύσσονται και να βελτιώνονται. Για παράδειγμα, αυτό είναι υψίστης σημασίας στα συστήματα κλήσης έκτακτης ανάγκης, καθώς τα άτομα με μερική ή ολική απώλεια ακοής συχνά αντιμετωπίζουν προκλήσεις στην επικοινωνία με τις υπηρεσίες έκτακτης ανάγκης.

Σύμφωνα με την τελευταία λέξη της τεχνολογίας, αρκετές από τις εφαρμογές που μελετήθηκαν στην Ευρώπη και την Αμερική επιτρέπουν στους χρήστες να πραγματοποιούν κλήσεις έκτακτης ανάγκης, αλλά καμία από αυτές τις εφαρμογές, απ' όσο γνωρίζουμε, δεν υποστηρίζει βίντεοκλήσεις έκτακτης ανάγκης. Επιπλέον, στην Ελλάδα, εξ όσων γνωρίζουμε, δεν έχει υλοποιηθεί προς το παρόν κάποια εφαρμογή που να επιτρέπει στους χρήστες να επικοινωνούν με υπηρεσίες έκτακτης ανάγκης μέσω φωνής, βίντεο ή γραπτών μηνυμάτων μέσω της ίδιας της εφαρμογής, πόσο μάλλον μια εφαρμογή που να μπορεί να βοηθήσει χρήστες με μερική ή ολική βαρηκοΐα ή/και απώλεια ακοής.

Η παρούσα διατριβή παρουσιάζει το σχεδιασμό και την ανάπτυξη μιας καινοτόμου εφαρμογής για κλήσεις έκτακτης ανάγκης με στόχο να ενισχύσει την επανάσταση στα συστήματα επικοινωνίας και αντιμετώπισης έκτακτης ανάγκης. Η προτεινόμενη εφαρμογή, η οποία βασίζεται στην τεχνολογία WebRTC (Web Real-Time Communication), παρέχει στους χρήστες μια σειρά χαρακτηριστικών που επιτρέπουν την ταχεία και αποτελεσματική επικοινωνία κατά τη διάρκεια καταστάσεων έκτακτης ανάγκης. Μέσω της εφαρμογής, οι χρήστες μπορούν να ξεκινήσουν βιντεοκλήσεις με τους χειριστές έκτακτης ανάγκης, διευκολύνοντας την οπτική επικοινωνία σε πραγματικό χρόνο και την αξιολόγηση καταστάσεων έκτακτης ανάγκης. Σε περιπτώσεις όπου η προφορική επικοινωνία είναι δύσκολη ή αδύνατη, μια λειτουργία συνομιλίας ενσωματώνεται στη διεπαφή βιντεοκλήσεων, επιτρέποντας στους χρήστες να αλληλεπιδρούν με τους χειριστές κλήσεων μέσω μηνυμάτων κειμένου. Τέλος, σε περίπτωση που ο χρήστης επιλέξει να μην ξεκινήσει τηλεφωνική κλήση και αντ' αυτού προτίθεται να αποστείλει μήνυμα έκτακτης ανάγκης, τίθεται σε λειτουργία μια πρόσθετη λειτουργία που αναφέρεται ως "Εικόνα σε κείμενο (Image-to-Text)". Αυτή η λειτουργία επιτρέπει στον χρήστη να διατυπώσει ένα μήνυμα έκτακτης ανάγκης,

χρησιμοποιώντας εικονίδια που απεικονίζουν με μεγαλύτερη ακρίβεια την κατάστασή του, και να το στείλει στις υπηρεσίες έκτακτης ανάγκης.

Η αξιολόγηση της ευχρηστίας της εφαρμογής έδειξε πολλά υποσχόμενα αποτελέσματα. Τα σχόλια των χρηστών υπογράμμισαν τη διαισθητική διεπαφή, την απρόσκοπτη ενσωμάτωση των λειτουργιών βίντεο και συνομιλίας και την αποτελεσματικότητα του συστήματος αποστολής μηνυμάτων κινδύνου. Οι συμμετέχοντες εξέφρασαν υψηλά επίπεδα ικανοποίησης, τονίζοντας ιδιαίτερα την ικανότητα της εφαρμογής να υποστηρίζει άτομα με προβλήματα που σχετίζονται με την ακοή και την ομιλία, δίνοντάς τους τη δυνατότητα να επικοινωνούν αποτελεσματικά είτε μέσω μηνυμάτων κειμένου κατά τη διάρκεια βιντεοκλήσεων είτε χρησιμοποιώντας τη λειτουργία "Εικόνα σε κείμενο (Image-to-text)" για την αποστολή μηνυμάτων έκτακτης ανάγκης.

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1. Introduction

In the last few years, the large adoption of mobile phones and the wide network coverage allows people to make emergency calls from almost anywhere. The importance of an emergency call application in today's society cannot be overstated. With the rapid advancement of technology and the widespread use of smartphones [2], harnessing these devices to provide a robust and efficient means of emergency communication has become crucial. In light of this, the idea of an emergency call application has grown in popularity. However, for people with partial or total hearing impairments, this can be extremely challenging, if not impossible. Such applications play a pivotal role in ensuring the safety and well-being of individuals in critical situations; therefore, an emergency application should offer a variety of different approaches and functionalities so the user can select between a call, video call or simply text message, all the while taking into consideration accessibility and usability regardless of one's diverse characteristics, disabilities or individual abilities.

First and foremost, emergency call applications provide a lifeline for people in emergency situations. Whether it's a medical crisis, a threat to personal safety, or a natural disaster, being able to seek help quickly and easily can have a huge impact on the outcome of the situation. By providing immediate access to emergency services, these applications can help individuals quickly initiate the response process, potentially saving valuable seconds or minutes in life-threatening scenarios [3]. Additionally, integrating video calling capabilities into emergency calling applications will further enhance the effectiveness and accuracy of the communication process. Visual contact with responders enables a better assessment of the situation, providing more specific instructions, assessing the severity of injuries, and identifying resources needed for response [4]. Video calls also help build human connections and bring reassurance and comfort to those in need, which is invaluable in stressful situations.

The ability to send emergency texts through emergency applications has been identified as an important alternative for situations where video calling is not possible or appropriate [5]. If there is a communication barrier (e.g., in a dangerous environment where speech is impaired or it is impossible to speak), sending a brief distress message may ensure that critical information reaches emergency responders. This feature can also prove invaluable in situations where people are in imminent danger and may not be able to communicate verbally. Moreover, integrating location-based services into applications greatly improves the efficiency and effectiveness of emergency response. Using GPS technology [3], applications can pinpoint the exact location of the user and relay it to emergency responders in real time. This information allows responders to quickly locate individuals, especially if they are unfamiliar with their surroundings or unable to provide precise location information. The time saved to spot an emergency can directly affect response time, reducing the risk of further harm or potentially saving lives.

In Europe, the emergency number 112 was officially launched in 1991[1] and serves as a crucial point of access for telecommunications as it effectively links callers to the appropriate emergency response organizations, such as the police, the fire department, and medical help. Notably, using the 112-emergency call number is especially helpful for travellers across Europe as it is universally recognized and accessible even though the local emergency numbers might not be the same. Currently, emergency applications in Europe aim to provide the ability of

[1] https://digital-strategy.ec.europa.eu/en/policies/112

communicating with emergency services through 112; however, integrating the possibility of video-calls with emergency services in emergency applications is still in its infancy. Additionally, the Pan-European Mobile Emergency Application (PEMEA) [6] is a recently new architecture that European countries have started adopting to their emergency applications. By enabling mobile applications to accurately communicate location and user information to the corresponding emergency answering point through a 112-emergency call, PEMEA overcomes the problem of localized emergency applications. Any mobile emergency application that wants to guarantee that the person is quickly located, can use PEMEA. Also, by adding further essential functions, the PEMEA architecture enhances the coverage that answering centers may offer to the public, modernizing the emergency services on a technological level. These qualities guarantee the coverage of unprotected populations, such as those with special needs.

In Greece, a few emergency applications are available however, these applications primarily serve as repositories of pertinent emergency contact numbers such as 100, 166, and 112, and do not offer the capability to directly initiate calls or enable users to transmit text messages. Nevertheless, none of these applications extend the functionality to facilitate in-app calling, video calling, or text messaging services.

1.1. Thesis Contribution

Harnessing the power of smartphone ubiquity and mobile connectivity provides a diverse approach to emergency communications. This thesis aims to contribute to the field of emergency response technology by presenting a novel and feature-rich emergency call application that enables individuals to seek help quickly and effectively. By harnessing the power of video calling, emergency text messaging and location-based assistance, the application aims to improve personal safety and ultimately promote a safer and more resilient society. The core functionality of the application will include video calling, which allows users to establish face-to-face contact with emergency responders, and emergency text messaging, through which users can send quick and concise emergency notifications to emergency services. This thesis is structured into five distinct chapters, each serving a specific purpose. In Chapter 1, the scope of the thesis is introduced, setting the stage for the subsequent discussions. Moving on to Chapter 2, a comprehensive overview of the State of the Art is presented, highlighting the existing knowledge and advancements in the field. Chapter 3 delves into the implementation phase, detailing the practical steps taken to realize the objectives of the thesis. The focus then shifts to Chapter 4, where the evaluation process and its outcomes are meticulously described. Finally, in Chapter 5, the thesis reaches its culmination with a conclusive summary and the identification of potential next steps for future research and exploration.

2. State of the Art

This section includes the state-of-the-art emergency applications that are currently being used around the world, as well as some of the features and standards that they implement.

Hand Help [7] is an application that is currently utilized in Germany, Switzerland, Austria, and Liechtenstein and allows people to call the police or ask for rescue. Once the call is initiated, the application automatically, without the need of voice input, sends the caller's personal emergency profile, precise location, time, and photograph or sound files to the control centre. Another application that is being used in Germany and allows the user to send emergency calls without voice input is Nora [8]. Nora is the official emergency call app system of the German federal states that enables users, including people with limited speech and hearing capabilities, to directly contact the police, fire brigade, and rescue services quickly and easily, in any case of emergency. The application uses the geolocation function of the mobile device and sends the exact location to the responsible emergency control centre. This enables responders to find the caller more easily, even if they are not aware of their exact location.

112 Suomi [9] is Finland's national emergency call application. This application uses the PEMEA architecture. Through the application, the user can make an emergency call to a Public Safety Answer Point (PSAP) and the call operator will forward their GPS position to the right authorities so help can arrive as fast as possible. Currently, the 112 Suomi is also available abroad, which means that the user can use this emergency application and its services in other EU countries that are part of the PEMEA network and send their location data to the emergency services of the country from which the call is initiated. Likewise, the 112 Where Are U [10] emergency application of Italy also follows the architecture of PEMEA and provides the location information of the user to the PSAP. Additionally, this application can be used even if the person may not be able to speak, by selecting the kind of help they need (e.g., Police, Ambulance). Thus, the requested rescue services will be notified by the operator that will receive the call.

Medical ID [11] is an application that allows the user to call any emergency number (911, 122 or 000) depending on the user's location. Upon installation, the user creates a medical profile that, in case of an emergency, is accessible through the lock screen via a notification. Afterwards, the user must fill in some personal information and their medical history, so, in case of emergency, someone can fast and easily have access to their medical notes. A premium feature of this application includes sending SMS alerts to some pre-selected contacts of the user's choice. However, despite its applicability, user feedback indicates the existence of many bugs. In a similar manner, Life360 [12] is an application that simplifies safety and is focused on families. The user may download the application, and after the setup, they are able to create private circles that they can add their family members into. That provides them with real-time whereabouts, location history, and place alerts, letting them know that their child, for example, has arrived home. They can see their circle members on the map, and with one tap on them they can get directions to their location. Also, an additional feature is the help alert, which sends an alert with the user's location to their circle members and their emergency contacts. Finally, if the user pays for the premium plan, Emergency call services can be used through the application. Furthermore, Noonlight [13] is an application that the person can use when they feel unsafe. The main screen of the app contains a large button that the user can press when they are in danger. The user can cancel the help by entering their pin. In case of not cancelling, an application operator is going to text the user and even if there is no response, they will extract the phone's information and dispatch aid by reporting the user's location to the appropriate authorities. The application also includes some features like

"check on me in 10 minutes" which may be used when the user is meeting someone they don't know (e.g., on Tinder). Furthermore, there is the Timeline feature, in which the user allows the application to know their location, and in case of emergency, the application can access their location history.

Unlike the aforementioned applications, which can be installed and utilized in all mobile devices, the Personal Safety application [14] can only be used in Google phones (Pixel) [15]. Some of its included features are the Emergency SOS, Emergency Sharing, Safety Check, and Crash Detection. The Emergency SOS feature can initiate an emergency call to 911 or 112, share the owner's location with their contacts and records, and back up and share those recordings. The Emergency Sharing feature shares the user's real-time location and information to their emergency contacts, while the Safety Check sets a timer and checks if the user is safe when the time ends. If the users don't confirm their safety or they don't answer, Emergency Sharing automatically starts. Finally, Crash Detection can detect whether the user has been in a car crash and, if so, it automatically initiates an emergency call. While Personal Safety is mainly used in the USA, another application that is used outside Europe is Emergency+ [16]. This application is free of charge and was designed by Australia's emergency services and several industry partners. It operates across Australia, using the GPS functionality that is built into smartphones to help a Triple Zero (000) caller to provide the actual location details, which are required to mobilize emergency services (000 is the respective 112 for Australia[17]). Location accuracy is critical information for Triple Zero call takers; As soon as a precise location is determined, emergency services can be dispatched and render assistance. With the vast majority of Triple Zero calls in Australia originating from mobile telephones today, the Emergency+ application is a vital government initiative to improve public safety and emergency service response times.

Next, GRSOS [18] is a mobile application for emergency situations in Greece. This application provides the phone numbers of the most important authorities and rescue services. It also provides the user with their geographical location so that they can copy and send it to the authorities. Another emergency application that was developed for Greece is Civil Crete Talos [19]. This application includes more functions than GRSOS, such as Maps, Weather, Earthquakes live, and First aid. Furthermore, it provides the phone numbers the user might need in an emergency. However, despite the importance of these applications, none of them offers a built-in call, a video call, and text messaging capabilities.

In Table 1 below, a comprehensive comparison between the reviewed applications is provided. In the first column of the table the name of each application is presented while columns two to seven present built-in features that each application offers, such as call, video call, real time chat, location access, and the "Image-to-Text" feature. Regarding the call built-in functionality, in case this is not supported from within the application the "redirection" keyword is recorded in the table, to indicate that a regular phone call through the device's default call functionality is utilized. Following, the eighth column is about the accessibility of the application by people with special needs while in the ninth column is reported whether the application is combatible with the PEMEA protocol. Lastly, the tenth column provides information regarding the country in which each application is supported. If the review of an application did not provide adequate information to identify its status regarding any of the reviewed features presented in the table, the Not Specified (N/S) value is recorded.

Table 1 Comparison of the reviewed Emergency Applications

App	Built-in Functionalities for Communication with Emergency Services						Accessible by people with special needs	PEMEA Compatible	Country
	Call	Video Call	Real-time Chat	Message	Location Access	Image-to-Text Feature			
Hand Help	Yes	No	No	Includes profile, location, time, photographs, and sound files	Yes	No	No	No	Germany, Switzerland, Austria, Liechtenstein
Nora	Yes	No	Yes	No	Yes	No	Yes	No	Germany
112 Suomi	Yes	No	No	No	Yes	No	N/S	Yes	Finland and PEMEA network EU countries
112 Where Are U	Yes	No	Yes	Yes	Yes	No	N/S	Yes	Italy
Medical ID	Redirection	No	No	Only to phone contacts	Yes	No	No	No	Global
Life 360	No	No	No	Only to phone contacts	Yes	No	No	No	Global
Noonlight	No	No	Yes	With call operator	Yes	No	No	No	USA
Personal Safety	Redirection	No	No	Only to user's emergency contacts	Yes	No	N/S	No	USA
Emergency +	Yes	No	No	No	Yes	No	No	No	Australia
GRSOS	Redirection	No	No	No	Yes	No	No	No	Greece

Civil Crete Talos	Redirection	No	No	No	Yes	No	No	No	Greece
Proposed Application	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Future Step	Greece (can be extended to Europe in the future)

Consequently, and as it can be noted through the comparison provided above, there are many applications that are trying to assist users in emergencies, each of which has their advantages and disadvantages. Although, based on the current state-of-the-art, many of the reviewed applications offer the user the ability to initiate an emergency call, none of these applications, to the best of our knowledge, offers the ability of an emergency video call. Furthermore, in Greece, there is no indication of an application that allows the user to make a voice call, video call or even send a text message to emergency services through the application itself and, more importantly, be able to assist users with disabilities. Therefore, this thesis proposes an application that will be able to initiate a voice call and video call, while also offering real time chat with the call operator. Additionally, the proposed application will provide a feature that will enable the user to transform images to text message for further assisting hard of hearing individuals that may find it hard to communicate through voice or video. The user will be able to select between a variety of images that best describe their emergency and send it to the call operator alongside their current location.

3.Technology Enablers

3.1.WebRTC (Real Time Communication)

WebRTC (Web Real-Time Communication) [20] is a free, open-source project that enables real-time communication (RTC) of audio, video, and data in web browsers and mobile applications. It allows for direct communication between peers, eliminating the need for plugins or native applications. WebRTC includes a set of APIs that provide access to camera and microphone, as well as facilitate audio/video communication and data transfer between users. These APIs include RTCPeerConnection, RTCDataChannel, and getUserMedia. WebRTC is supported by many modern browsers, including Google Chrome, Mozilla Firefox, and Microsoft Edge. It is widely used in various applications, such as video conferencing, file sharing, and live video broadcasting.

3.2.Android Studio

Android Studio [21] is a comprehensive Integrated Development Environment (IDE) designed specifically for Android application development. It is the official IDE for the Android operating system and is developed by Google. Android Studio provides a range of features and tools for the development, testing, and deployment of Android applications. It includes a layout editor for building user interfaces, a debugger for identifying and fixing errors, and an emulator for testing and profiling applications on various devices. It also offers integration with the Android Debug Bridge (ADB) and the Android Software Development Kit (SDK), enabling developers to build, test, and debug their applications. In addition to these features, Android Studio also supports a variety of programming languages and technologies, including Java, C++, and Kotlin. It is available for download on the Android developer website and is supported on Windows, macOS, and Linux operating systems.

3.3.Android Emulator

The Android Emulator [22] is a software program that allows developers to test and debug Android applications on their personal computers. It allows developers to run and simulate the behavior of an Android app on a computer, as if it was running on an Android device. The Android Emulator is included with the Android Software Development Kit (SDK) and is integrated into the Android Studio Integrated Development Environment (IDE). It is a powerful tool that allows developers to test their apps on various devices, configurations, and Android versions without the need of physical hardware. The Android Emulator is highly configurable and can simulate a range of hardware and software characteristics, such as different device models, screen sizes, Android versions, and network conditions. It also provides access to a range of tools for testing and debugging Android applications, including a built-in logcat viewer and a debugger. Overall, the Android Emulator is an essential tool for Android developers that allows them to test and debug their applications in a simulated environment before deployment.

3.4.Flutter

Flutter [23] is a free, open-source mobile application development framework created by Google. It allows developers to build natively compiled applications for mobile, web, and desktop from a single codebase. Flutter is based on the Dart programming language and utilizes the Skia graphics engine [24] to render high-quality, visually rich applications. It includes a rich set of customizable widgets and tools for building beautiful and responsive user interfaces, as well as a reload feature that allows developers to experiment, build, and debug faster. In addition to building mobile applications, Flutter can also be used to build applications for the web and desktop. It is compatible with a range of IDEs, including Android Studio and Visual Studio Code[25], and is supported on Windows, macOS, and Linux operating systems. Flutter is used by developers around the world to build a variety of applications, from small startups to large enterprises.

3.5.Dart

Dart [26] is a general-purpose programming language developed by Google. It is used to build web, server, and mobile applications. Dart is an object-oriented language with a C-style syntax that is easy to read and write. It includes features such as garbage collection, type inference, and a powerful library system. It also supports asynchronous programming, allowing developers to build responsive and scalable applications. Dart can be used to build applications for the web, using either the dart2js compiler or the Dart SDK, as well as for mobile devices, using the Flutter framework. Overall, Dart is a flexible and powerful language that is well-suited for building a variety of applications and it is widely used by developers around the world.

3.6.PSAP server with Go

PSAP [27] stands for Public Safety Answering Point, which is a facility where emergency calls are received and dispatched to the appropriate emergency responders, such as police, fire, or ambulance services. PSAPs are typically staffed by trained professionals who are responsible for handling emergency calls and dispatching emergency responders to the location of the incident. PSAPs are a critical component of the emergency response system, helping to ensure that emergency calls are answered promptly and that the appropriate response is dispatched quickly and efficiently.

3.7.Figma

Figma [28] is a cloud-based design and prototyping tool that enables designers to create and collaborate on user interface designs, wireframes, and prototypes. It is used by teams in various industries, including software development, marketing, and design. Figma offers a range of features for creating and editing designs, including a vector-based drawing tool, a library of customizable design components, and real-time collaboration capabilities. It also includes a prototyping feature that allows designers to create interactive mockups of their designs and test them on various devices. Figma is available as a web application and can be used on any device with an internet connection. Overall, Figma is a powerful and flexible design tool that enables teams to create, collaborate on, and prototype user interface designs in a cloud-based environment.

4.Implementation

This section presents the development process of the application as part of this thesis. The implementation of the application will be described, from start to end, in the following subsections, as well as the process steps that were undertaken for the application to reach its final version.

4.1.Background Theory

The integration of web design, User Experience (UX) research, and User Interface (UI) design within the implementation framework is imperative to engender a superlative user experience and realize the intended objectives of the project. Overall, these disciplines synergize to foster a sophisticated, user-oriented implementation, thereby fortifying the overall user experience and yielding a product of heightened resonance and impact.

4.1.1. Web Design

Web design is a dynamic and creative discipline that encompasses the art of creating visually appealing and functional websites. It involves the careful arrangement of elements such as layout, colours, typography, and images to deliver a seamless user experience. A well-crafted web design not only captivates visitors but also ensures easy navigation and accessibility across various devices. It encompasses the principles of User Interface (UI) and User Experience (UX) design, aiming to strike a perfect balance between aesthetics and usability. Web designers employ their expertise in HTML, CSS, and other programming languages to translate their artistic vision into a digital reality. By understanding end-user requirements, target audience, and current design trends, web designers bring concepts to life and play a vital role in shaping the online presence of businesses, organizations, and individuals, ultimately enhancing their brand image, and fostering engagement with their online audience [29].

4.1.1.1. User Experience (UX) Research

UX refers to the overall experience of a person using a product, system, or service. Designing for UX involves understanding the needs, goals, and behaviours of the users of a product or service and using this information to create a product that is easy, efficient, and enjoyable to use [30]. This involves a range of activities, including user research, usability testing, and prototyping, to ensure that the product meets the needs of the user and provides a positive experience. UX research provides design processes with relevant contexts and insights by methodically examining target users and their needs. UX researchers use a variety of techniques [30], [31] to identify issues and design opportunities so that they can make important discoveries that can be used to inform the design process.

4.1.1.2. User Interface (UI) Design

UI design can be crucial since it can increase or decrease the number of users on any system [32]. It can reduce issues, boost user engagement, perfect functionality, and forge a solid connection between end-users and the application. The goal of the UI design is to produce accurate visual representations or prototypes of a product or design (i.e., mock-ups) so that people can evaluate the UX/UI. Mock-ups can be used to test and communicate design ideas before the final product is produced [33], while they can be created for a wide range of products, including websites, software applications, packaging, and industrial designs. Mock-ups are often used in the early stages of the design process to help stakeholders visualize and provide feedback on a proposed design before it is finalized. Furthermore, Mock-ups can be designed to provide the developer with a preview of the actual application.

4.2. Design of the proposed application

Based on the background theory provided above, this section outlines the steps that were undertaken for the design of the application, which eventually led to the implementation of the proposed solution.

4.2.1. UX Research

For the implementation of this thesis, research was conducted about the UX of target users and their needs with the goal of offering pertinent settings and insights for design processes. The target audience included elderly people, or people with partial or total hearing impairments. The results indicated that the UI should be as simple as possible, easy to understand and use, and straightforward overall.

4.2.2. UI Design and Mock-ups

The following section presents the mock-ups that were designed for the development of the emergency call application. Those mock-ups describe the UI design of the Home, Call/Video Call, and Text pages of the application.

4.2.2.1. Home Page Mock-up

The Home Page, as it can be seen in Figure 1, contains a big red button in the center for the call or video call. The decision regarding the placement of the button in the center was to make it as easy as possible for the user to initiate a call. Below the main red button is another button that shows the user’s specific location and upon pressing it they can update their location.

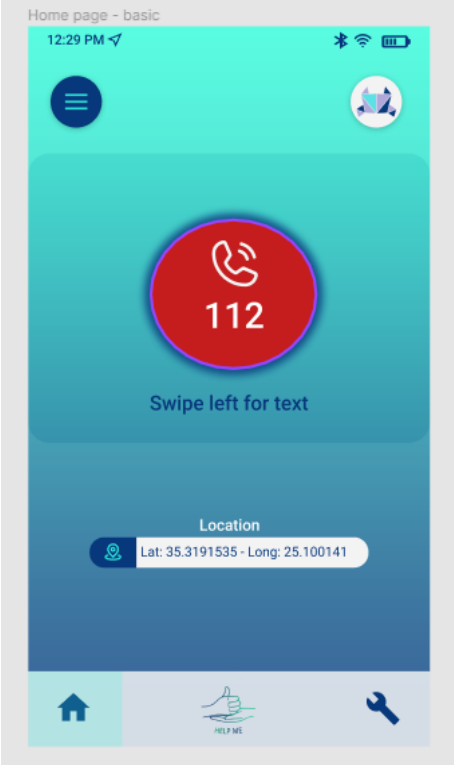

Figure 1 Home Page Mock-up

On the top left corner of the application there is a drop-down menu that folds horizontally and has settings regarding the call including opening or closing the camera, microphone, and speaker, as it is showcased in Figure 2. The user can choose to initiate the call in two different modes, which include the Call/Video Mode and the Text Mode which includes the feature Image-to-Text. The default Mode is set to Call/Video Call. In case the user wants to switch Modes, they can swipe left or right. By pressing the button on Call/Video Call Mode, a three second countdown allows the user to cancel their call if they want to, otherwise, after the timeframe of three seconds, the app automatically initiates the call/video call, and the user is being transferred to the Call/Video Call Page. If the user swipes to Text Mode, upon pressing the big red button, they are automatically transferred to the Text Page.

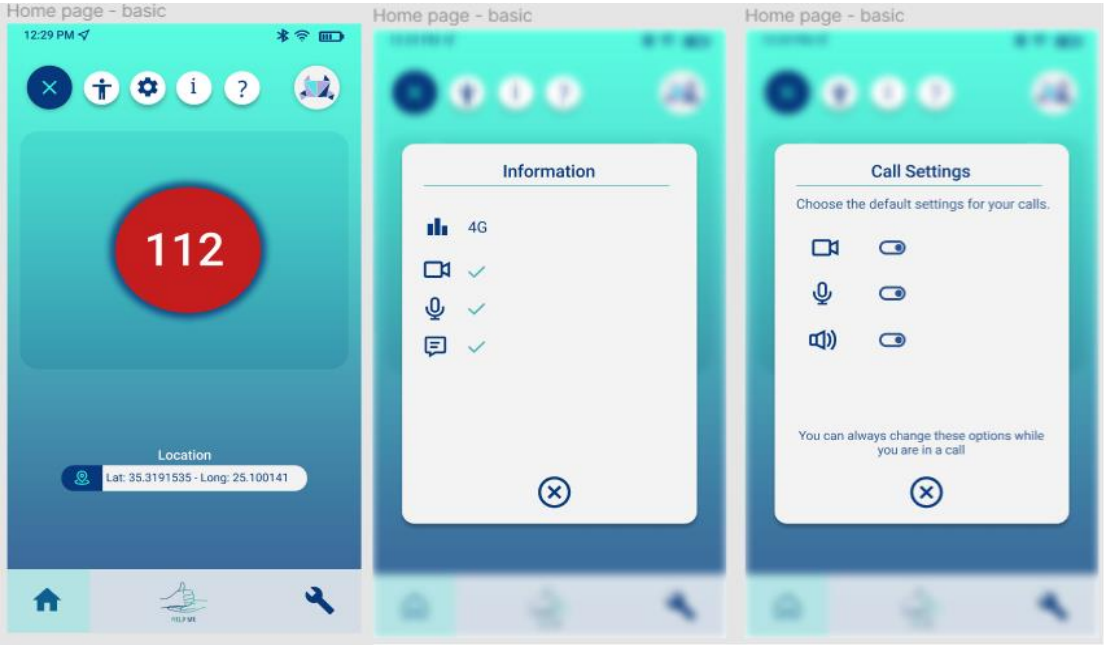

Figure 2 Drop down menu Mock-ups

4.2.2.2. Call/Video Call Page Mock-up

As soon as the user joins a call, they switch to the Call/Video Call Page. This page displays the frame of the call operator and includes a few information and buttons with different features regarding that call, as it can be noted in Figure 3. Starting from the top of the page there is some information about the call, the name of the call operator and a timer for how long the call is active. Next to this information, there is a Switch Camera Button that allows the user to reverse their camera from the front-facing to the back-facing view. Also, there is the Close Call Button that ends the call and navigates the user back to the Home Page. In the top-right corner of the screen there is a small container that displays everything the call operator sees. At the bottom of this page there are four buttons for different controls, which include the Speaker Button that allows the user to enable the loudspeaker or switch to the front-facing speaker; the Mute Button that mutes or unmutes the user's microphone; the Camera Button which turns on or off the user's camera; and the Chat Button that allows the user to enter a chat with the call operator for the case they may want to write about their emergency rather than speak. Moreover, there are some hidden features which include the Double Tapping of the screen to easily switch cameras, or the Single Tap on the screen to clear it from the buttons and the information so the user can have a clear view of the call operator.

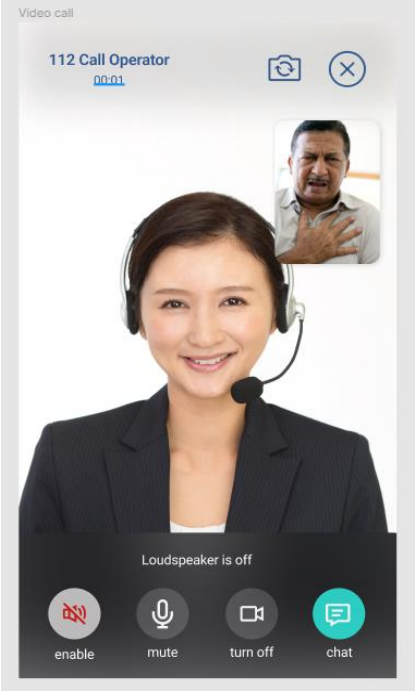

Figure 3 Video Call Page Mock-up

4.2.2.3. Text Page Mock-up

When the user selects the Text Mode, they are automatically transferred to the Text Page, as it is illustrated in Figure 4. This page is implemented in three phases, with the first two being the syntax of the emergency message through the feature called "Image-to-Text", and the third one being the delivery of the user's actual message.

Figure 4 Text Page Mock-up

4.2.2.4. Preliminary End-user Feedback

An initial round of UI/UX evaluation had to be performed in order to ensure that the proposed solution is tailored to end-user needs and objectives before starting with the implementation process. This preliminary end-user feedback was provided by an individual with partial hearing impairment, and, after its completion, the UI engineering was initiated taking into account the feedback of the end-user. Because the results of the first round of evaluation had positive answers, the Figma Mock-ups were implemented without any changes. Descriptions regarding the functionality and integration of these Mock-ups, in the application, are analysed in the following sections.

4.3. Implementation of the proposed application

For the graphical representation of the physical flow of the application, a flow diagram was developed, which presents all the possible routes the user may take in the application to navigate through its pages and perform their actions. Upon launching the application, the user is automatically navigated to the “Home Page” and is presented with the choice between two distinct modes. The initial mode, denoted as "Call/VideoCall," empowers the user to initiate a call, tailor-fitted to precise preferences. Notably, the user retains the privilege to revoke the call within three seconds after activating the call button. After call initiation, the user is afforded the opportunity to engage in a chat with the call operator or to exit the call, reacquiring access to the “Home Page”.

The secondary mode, herein referred to as the "Emergency Message" mode, introduces various options, thereby enabling the user to make an informed selection. Specifically, the user is prompted to select either the nature of the emergency currently being experienced or to opt for a return to the prior phase. In the event where the user opts to specify the type of emergency, a subsequent obligation emerges, wherein the user is prompted to provide details encompassing any injuries or medical conditions, prior to progressing or reverting to the antecedent phase. In the final step, the user is empowered to transmit the generated message or, alternatively, to revert to the “Home Page”. It is noteworthy that even post-commitment to transmitting the message, the user is presented with the option to countermand this action and navigate to the “Home Page”. The flow diagram of these processes is illustrated in Figure 5 below.

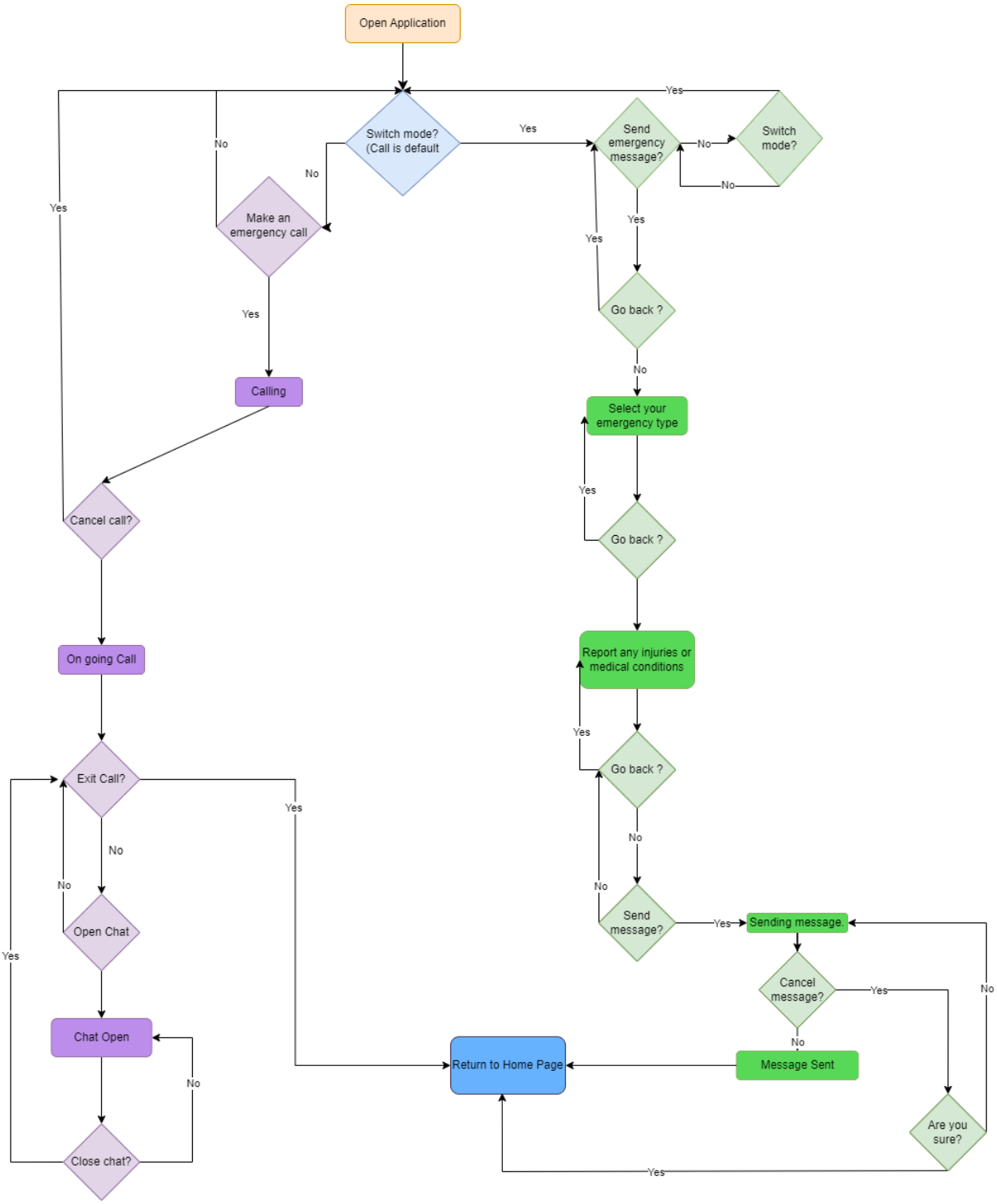

Figure 5 Flow Diagram of the application

4.3.1. Home Page

The implementation of the application started with the Home Page. The background colors were set according to the Mock-ups. As presented in Figure 6, in the centre of the page there is a container that contains the Big Red Button with two functionalities that relate to the different call Modes. The user can choose their preferred Mode by swiping left or right on the container and the container will change to its corresponding functionality. Below the main container with the Big Red Button, there is the Location Button; It contains the accurate location of the user that gets automatically updated when the application gets started. The user can also update their location, at any given time, by pressing that button.

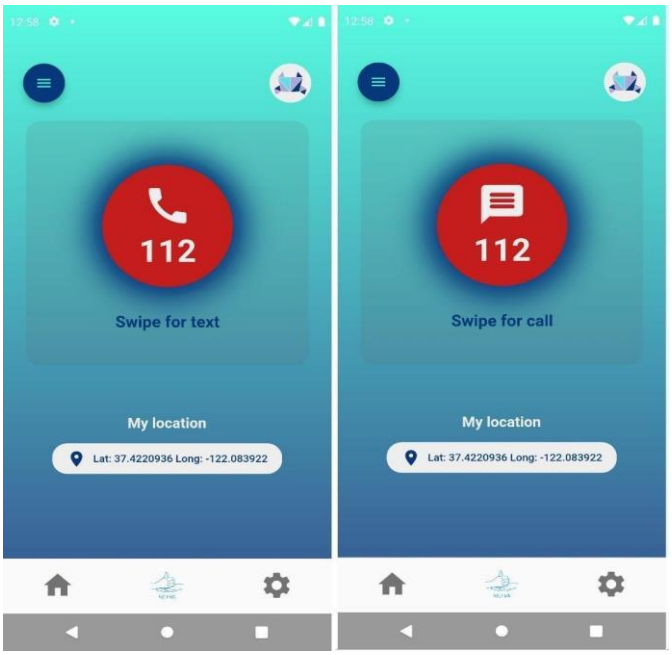

Figure 6 Home Page of Application

On the top of the screen the two components, as those were described in the Mock-ups, were added. Those components include:

- The dropdown Menu Button on the top-left part of the screen, which upon pressing it, reveals four different controls of the application (Figure 7):
    - The Call Settings Button: By pressing the Settings Button, the user can access the settings of the video call before it is initialized, and toggle the microphone, camera, or loudspeaker on/off so they can apply their preferences.
    - The Device and Signal Information Button: By pressing the Information Button, a pop-up window displays some information about the signal of the phone and whether the camera, microphone, and speaker are properly functioning.
    - The Accessibility and Questions Buttons: These refer to the accessibility and questions the user might have. Although those buttons exist in the application, their functionality has not yet been implemented due to the focus on proof of concept of this thesis and will be approached as future steps.

- The Profile Icon on the top-right part of the screen, that displays the user's profile picture.

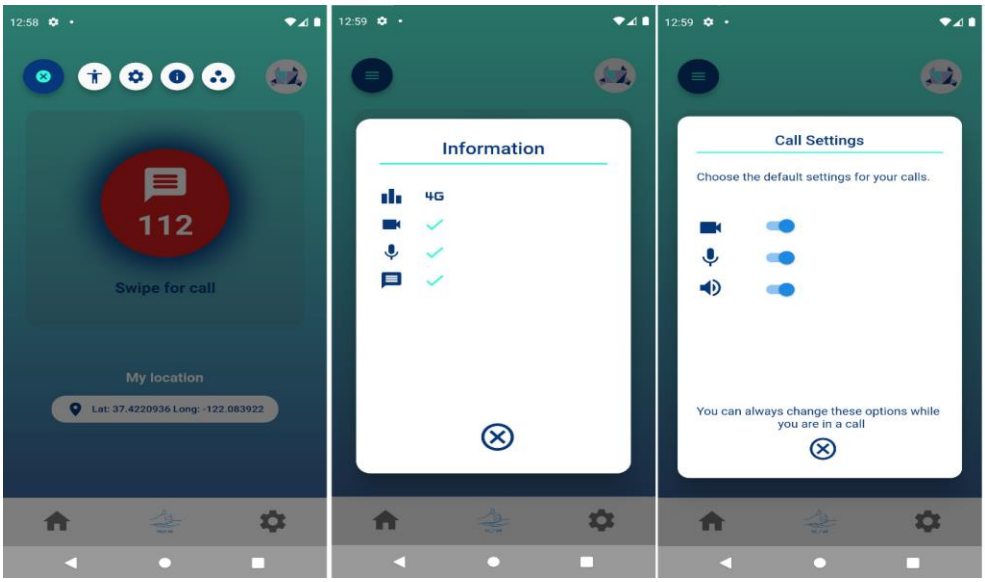

Figure 7 Home Page Menu/Settings Button

In the Home Page, the first Mode initializes the Call/Video Call. After the user presses the button, a three second countdown will start, so the user is able to cancel the call if they want to, and if the call does not get cancelled during the three seconds countdown, the call will start (Figure 8). The second mode refers to the text feature called “Image-to-Text” and it can be triggered by pressing the text button.

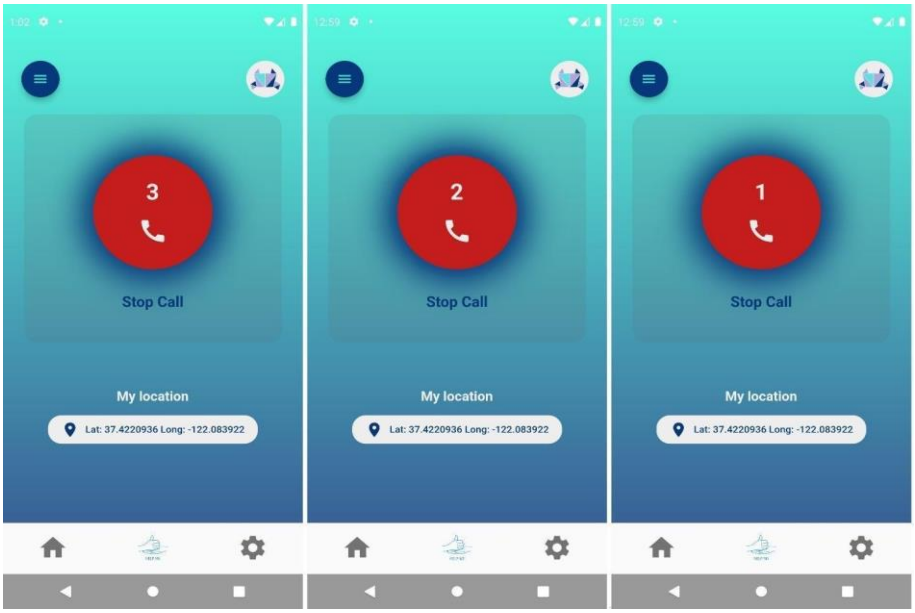

Figure 8 Countdown after the user press the call button

To further describe the process of initiating the emergency calling process in the application a “Call” sequence diagram was created, which is presented in Figure 9. The user's engagement with the process commences by launching the application, subsequently progressing to the deliberate action of pressing the designated Call button, which in turn serves as the pivotal trigger for initiating the call procedure.

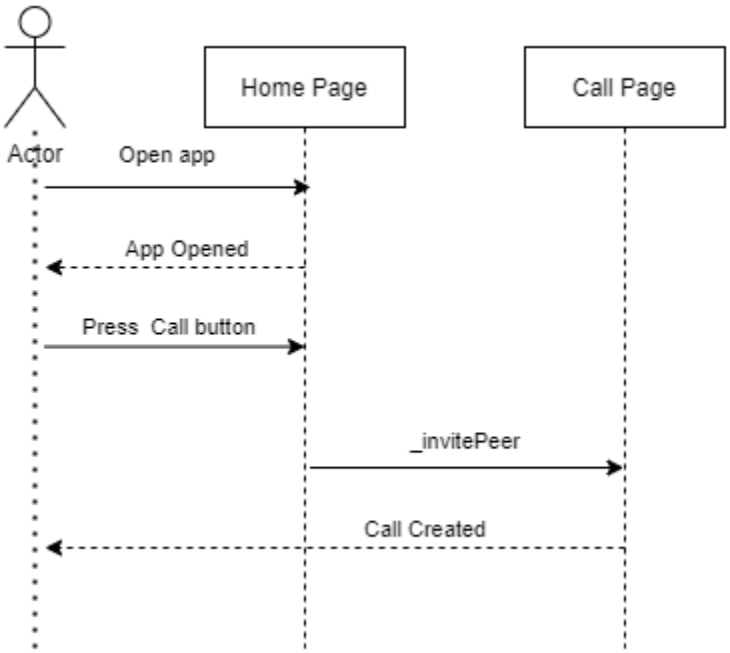

Figure 9 Call Sequence diagram

4.3.2. Call/Video Call Page

To initialize a video call, the user must press the call button. After the user presses the button, a three second countdown will start, so the user is able to cancel the call if they want to. If the call does not get cancelled, the call starts, and the user is presented with the main screen of the call (Figure 10).

On the call page there are a several buttons the user can interact with while being in the call. On the top of the screen there is some information about the call; The time of the call and the name of the call operator, along with two buttons; one for letting the user change between the front and rear camera of his smartphone and the other for closing the call.

On the bottom of the screen there are four buttons: One for controlling whether the loudspeaker of the phone is on or off; One for muting and unmuting the microphone of the phone; One for enabling or disabling the camera; And the last one for opening the chat feature while being in the video call. By pressing the chat button, a pop-up chat opens, and the user is able to text, instead of talking, to the call operator.

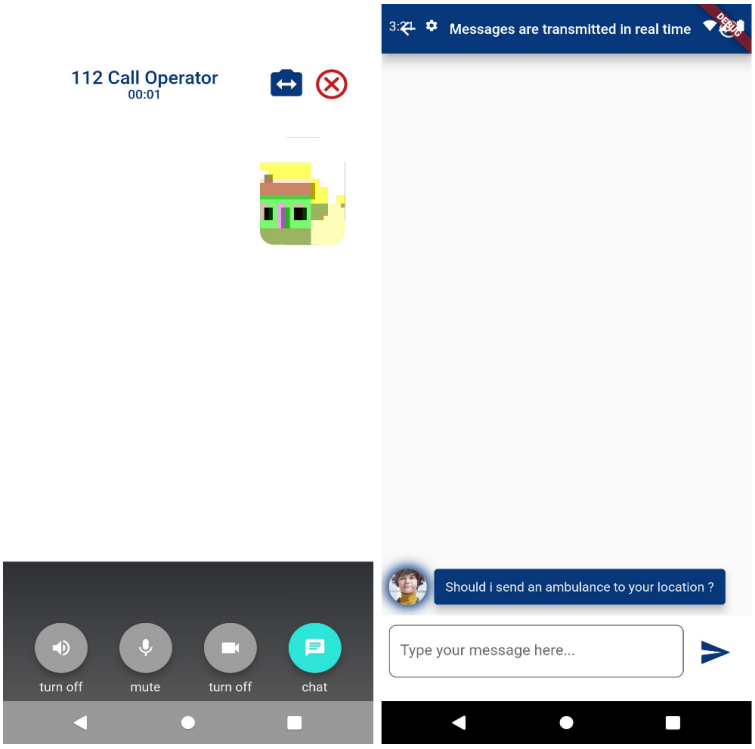

Figure 10 Video Call Page & Chat Page

To further describe the process of initiating the emergency texting process in the application, a “Call and Enter Chat” sequence diagram was created. In Figure 11, an intricate depiction of the "Call with Close Camera" sequence is presented, followed by the subsequent "Joining the Chat" process. This sequence of actions is initiated by the user accessing the application interface. Thereafter, the user proceeds to engage with the speed dial functionality, leading to the activation of the settings button. Within this submenu, a purposeful selection is made to disable the camera functionality, resulting in its closure. In continuation of this sequence, the user presses the call button, consequently instigating the initiation of the call. Following this, a deliberate step is taken to join the ongoing call, thereby entering the interactive virtual space. Subsequently, the user seamlessly reinstates camera functionality, facilitating visual interaction. Lastly, the user's engagement culminates by opting to enter the chat room associated with the active call, effectively establishing a comprehensive communicative environment within the context of the call's ongoing proceedings.

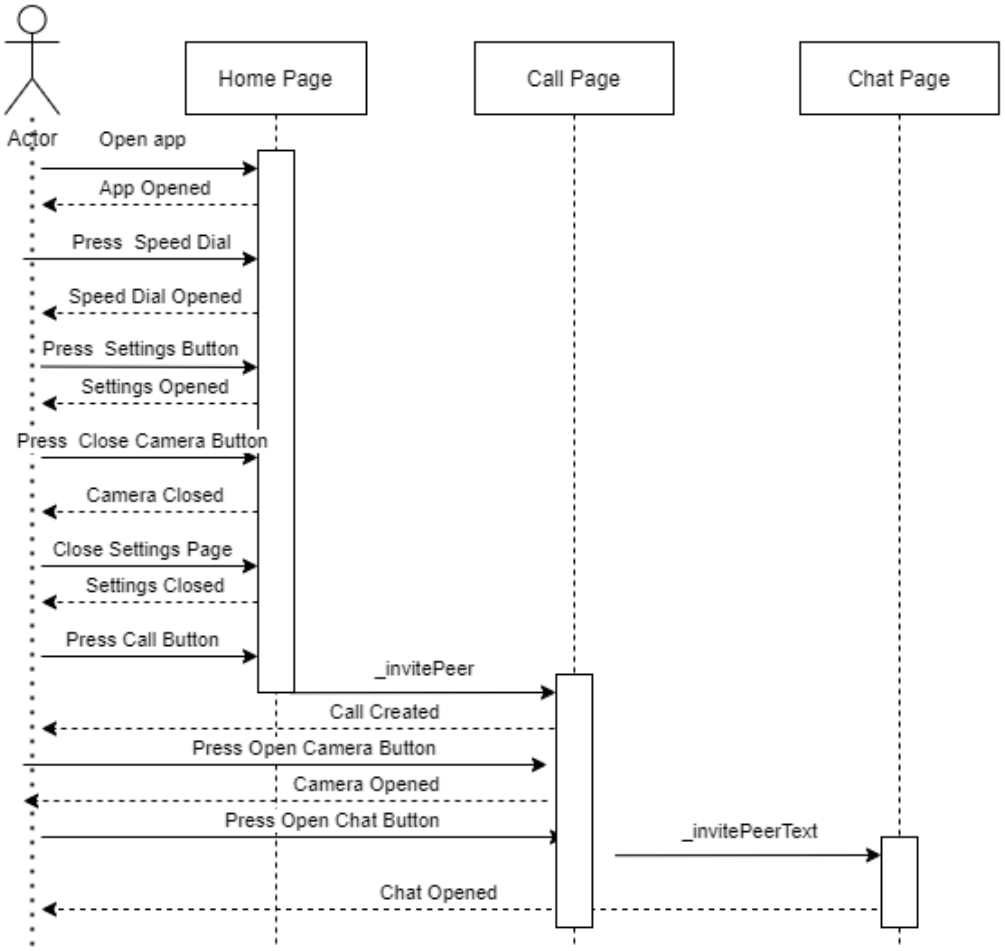

Figure 11 Call and Enter Chat Sequence Diagram

4.3.2.1. Web Real-Time Communications (WebRTC)

For the development of the Call/Video Call functionalities, the Web Real-Time Communications (WebRTC) project was utilized. WebRTC can be used to enable real-time communication in mobile applications, including those built with Flutter. To initiate a call using WebRTC in a Flutter application, a plugin called flutter_webrtc was used, which provides a set of APIs for creating a peer-to-peer connection, exchanging session descriptions, and sending and receiving real-time audio, video, and data. To initialize a call with flutter_webrtc, a few steps were followed: First, a local peer connection object was created, which represents the client's end of the connection. Next, the local audio and video tracks to the peer connection object were added, which enables the client to send audio and video to the other peer. Then, an offer session description was created, which describes the client's media capabilities and connection preferences, and sends it to the signaling server. The signaling server functions by forwarding the offer to the other peer, which creates its own peer connection object and responds with an answer session description. The signaling server forwards the answer back to the initiating client, which sets the answer as the remote session description, completing the process of establishing a peer-to-peer connection. Once

the connection is established, both peers can send and receive real-time audio, video, or data using the WebRTC APIs provided by flutter_webrtc.

The implementation of the server for the present application was sourced from a pre-existing GitHub repository[2] originally formulated for a different software application. Following its integration, the server underwent meticulous modifications, involving intricate configuration and adjustments, undertaken with the objective of ensuring seamless connection with the specified application's requirements. This purposeful adaptation culminated in its proficient transformation into a functional PSAP server.

4.3.3. Text Message Page

The Text Page can be accessed by swiping on the container in the centre of the Home Page and pressing the message button. After the user clicks the Message Button, they are automatically transferred to the Text Page (Figure 12). The Text Page is implemented in three phases. The select emergency icon, the select injury / medical condition icon and lastly the send message. At first, nine different icons are displayed on the screen. The user can choose the icon that best describes their emergency and click it. By selecting the icon that best describes their emergency another list of nine icons is displayed so that the user can describe the medical conditions or injuries they might have. After choosing the icon that matches their circumstances, the user enters in the last phase of the Text Page. If the user wants to change any of the emergency or the condition that they have chosen there is a Go Back Button on the bottom of the screen in all three phases.

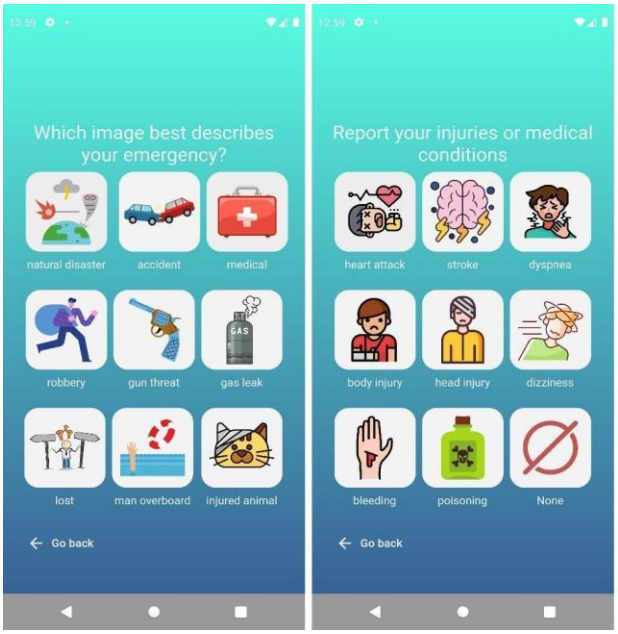

Figure 12 First & Second Phase of Text Page

[2] https://github.com/flutter-webrtc/flutter-webrtc-demo

On the last phase the user can see the emergency and condition that they chose at the top of the screen and decide whether they want to send the message (Figure 13). In the centre of the screen, there is a button with the label “Send Message” and by pressing it, the message will be sent within a three second countdown, which allows the user to cancel it by pressing the Cancel Button (Figure 14). In case the user doesn’t cancel the message, after the countdown, the message will be sent, with their accurate location, to the emergency call operator.

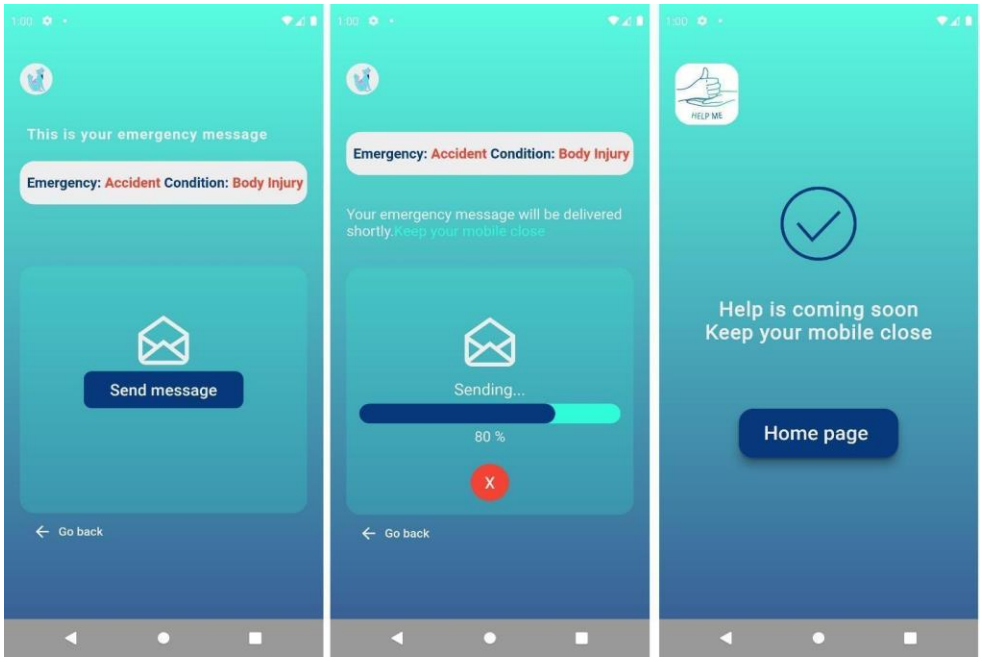

Figure 13 Third Phase of Text Page

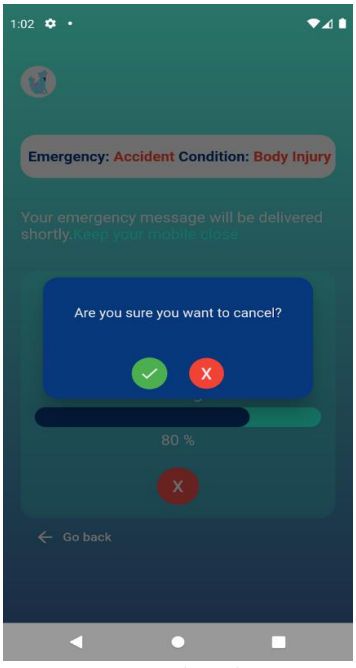

Figure 14 Cancel Send Message

Within Figure 15, a meticulously detailed sequence diagram encapsulates the intricate process of initiating an emergency message. Commencing this illustrative sequence, the user's interaction is initiated by accessing and launching the application interface. Afterwards, the user proceeds to actively engage with the application's Emergency Message feature, by swiping for text and pressing the message button. As the user delves further into this sequence, a decisive selection ensues wherein the user chooses for the specific icons that most aptly encapsulate and describe the urgency of their particular situation. In our case the users first choses the Robbery Button, the interface then navigates to the second page. Then the user chose the Body Injury Button, and the interface navigates to the final page. The culmination of this sequence is marked by the user's action of pressing the send button. This critical action instantaneously triggers the transmission of the composed emergency message, dispatching the encoded information to the intended recipients and inform the user that the message is send. Lastly, the application steering the user back to the Home Page.

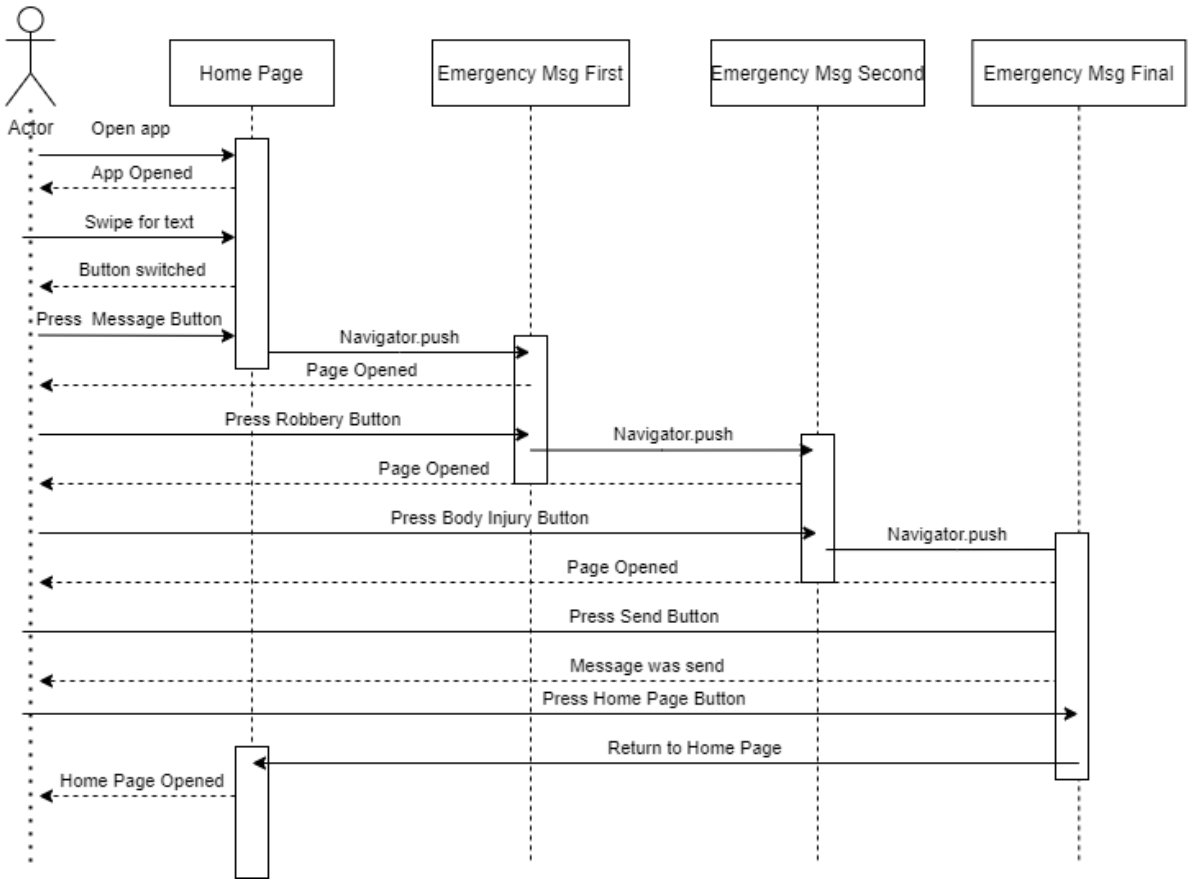

Figure 15 Text Message Sequence Diagram

5. Evaluation

A usability evaluation is a methodical technique for determining how user-friendly and efficient a system or product is [34]. It entails evaluating how well people can engage with the product to complete their objectives and goals while taking efficiency, user happiness, and usability into account. Designers and developers gather user feedback and data using tools including usability testing, expert reviews, and surveys. This information is then analysed to spot usability problems and potential areas for development. Organizations may improve user experience, maximize productivity, and develop products that are in line with user demands and preferences by carrying out usability tests.

Prior to the usability evaluation of the application, it is important to showcase the status of the proposed application (Table 2) as opposed to the emergency applications that were reviewed and presented earlier in SOTA chapter (Table 1). It is noteworthy that the poof-of-concept application proposed in this thesis covers all the features that were identified as important to be implemented in the context of modern emergency applications. As it can be seen in the last two columns of the following table, the proposed application is foreseen to be integrated with the PEMEA protocol in the future, which will be further discussed in the Conclusion chapter. Additionally, the proposed application offers an enhanced solution for communication with emergency services in Greece which, by the proposed future adoption of the PEMEA protocol, will be able to be extended for use across Europe.

Table 2 Proposed Application

App	Built-in Functionalities for Communication with Emergency Services						Accessible by people with special needs	PEMEA Compatible	Country
	Call	Video Call	Real-time Chat	Message	Location Access	Image-to-Text Feature			
Proposed Application	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Future Step	Greece (can be extended to Europe in the future)

5.1. UX/UI Evaluation of App

For the evaluation of the application proposed in this thesis, two separate usability testing procedures were utilized. The first usability testing was performed by potential end-users of the application in order to identify any usability issues while a second usability testing performed by a number of technical experts/developers in the domain to identify potential areas of improvement.

5.1.1. UX/UI Initial Interview

As mentioned earlier in the Implementation Chapter, after the mock-up design process was completed, a review followed, which was aided by a participant with partial hearing loss. The review from this participant could have significant implications for the development process, therefore their opinion was extremely important. A meeting was arranged where the participant

was shown the mock-ups and was given the chance to provide their thoughts on the application's impending implementation. The discussion covered elements of liking, aversion, and potential changes. The user's reaction after exploring the interface was one of praise and interest, demonstrating a strong feeling of appreciation for the complete project. Notable was the evident delight for the Image-to-Text capability, a feature designed to ease the grammatical difficulties, sometimes experienced by those with hearing impairments, and speed up the creation of important communications. In conclusion, the participant expressed pleasure with the project's idea and thought that the mock-ups had a high level of comprehension, as well as endowed with user-friendly features.

5.1.2. End-User Usability Testing

An End-User Usability Testing was conducted with real users to simulate, as close as possible, real-life situations. The goal of this experiment was to check whether the end-users were able to use the application for making a call or texting in case of emergency through a series of realistic use case scenarios. Before starting the evaluation, the fifteen (15) people that were recruited as participants were split into two groups. Group 1 included eight (8) of the participants, and they were asked to get familiar with the application (the users were given 1-2 minutes to navigate through the application) before requesting them to perform pre-defined use case scenarios. The remaining seven (7) participants were assigned to Group 2 and saw the application for the first time with the beginning of the first use case scenario. The rationale behind this decision emanated from our desire to ascertain the comparative ease with which participants in Group 1 could accomplish the assigned tasks in comparison to participants belonging to Group 2. Also, we encouraged five (5) of the participants, both in Group 1 and 2, to use the Think-Aloud [35] protocol. The Think-Aloud protocol is a cognitive technique where individuals verbalize their thoughts and decision-making processes while performing a task or solving a problem. It is commonly used in research and usability testing to gain insights into the participant's cognitive processes and understand their reasoning and problem-solving strategies. By encouraging users articulating their thoughts aloud, researchers can uncover valuable information about how people approach tasks and make decisions.

5.1.2.1. Preparation

For the preparation phase of the usability testing, three (3) basic use case scenarios were developed to lead the users to interact with the application. These scenarios were developed in order to make the user interact as much as possible with the application and force the user to use every possible action of the application. Additionally, further research indicated the possibility that some participants may not use the fundamental feature "Image-to-Text", and therefore, to ensure the users would go through all the features of the application, one more scenario was added. These scenarios, with their corresponding actions, are described below.

Use-Case Scenario 1

"Let's assume that you are on vacation with your family. Coming back from your morning walk you notice smoke coming out from your apartment":

1. You want to call for help with the application.

Use-Case Scenario 2

"Let's assume that on a visit to your local bank a robbery takes place. You want to call for help but you realize that you can't make a call because the bandits might hear you and take away your phone":

1. Send a message for help using the application.

Use-Case Scenario 3

"Let's assume that there was an earthquake, and you are trapped in a building where the roof has fallen off."

1. Make a call using the application
2. Close and then open the camera
3. Close and the open the microphone
4. Turn on and then off the loudspeaker

"The call operator asks you to show him the place around you"

5. Use the back camera of your phone and then switch again to the front camera

"During the call you can't hear clear the call operator, so you assume that your signal isn't strong enough"

6. Enter the chat room without closing the call

Extra Use-Case Scenario

In case the user never used the Image-to-Text feature:
"Send an emergency message without making a call."

In order to assess the usability of the mobile application and the level of overall user satisfaction, the System Usability Scale (SUS) [36], [37] (Table 3) was employed for the post-evaluation surveys. Ten (10) questions were included, and the respondents had a choice of five different answers, ranging from "strongly disagree" to "strongly agree". For the preparation of the experiment, the application was installed on a mobile phone. After the installation, it was tested to verify that it works properly with no existing bugs so the users could have a seamless experience. Moreover, the questionnaire was printed and was ready to be shared. Additionally, for the collection of more data, the interviews with the end-users were recorded. The time each participant took to complete each Use-Case Scenario was also measured.

Table 3 System Usability Scale (SUS)

I think that I would like to use this system frequently.
I found the system unnecessarily complex.
I thought the system was easy to use.

I think that I would need the support of a technical person to be able to use this system.
I found the various functions in this system were well integrated.
I thought there was too much inconsistency in this system.
I would imagine that most people would learn to use this system very quickly.
I found the system very cumbersome to use.
I felt very confident using the system.
I needed to learn a lot of things before I could get going with this system.

5.1.2.2. Participants

Before the experiment, some data were collected from the fifteen (15) participants, as follows: age, gender, highest educational level, and how many hours they spend online on a regular basis. Illustrated in Figure 16 is the delineation of distribution amongst participants who have acquainted themselves with the application. Evidently, 53.3% of participants were afforded the opportunity to navigate through the application prior to the onset of the experiment, whereas the remaining 46.7% encountered the application for the first time at the initiation of said experiment. Throughout the duration of the experiment, it is noteworthy that 33.3% of the participants adhered to the prescribed protocol of Think-Aloud, while the remaining majority it was called not to employ it, as visually depicted in Figure 17.

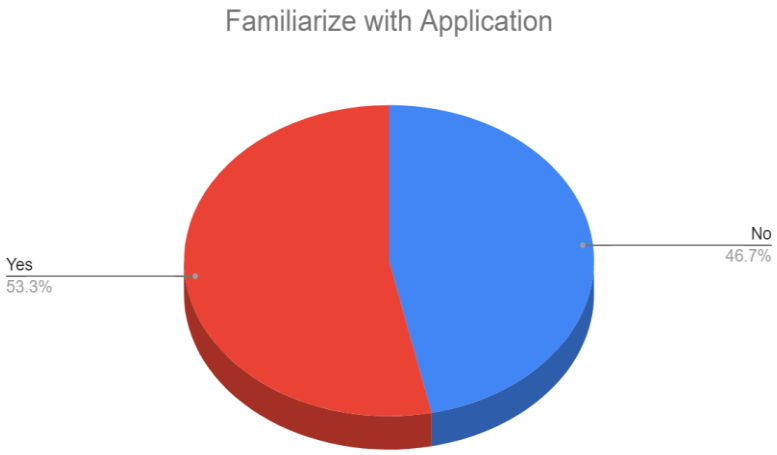

Figure 16 Familiarize with Application

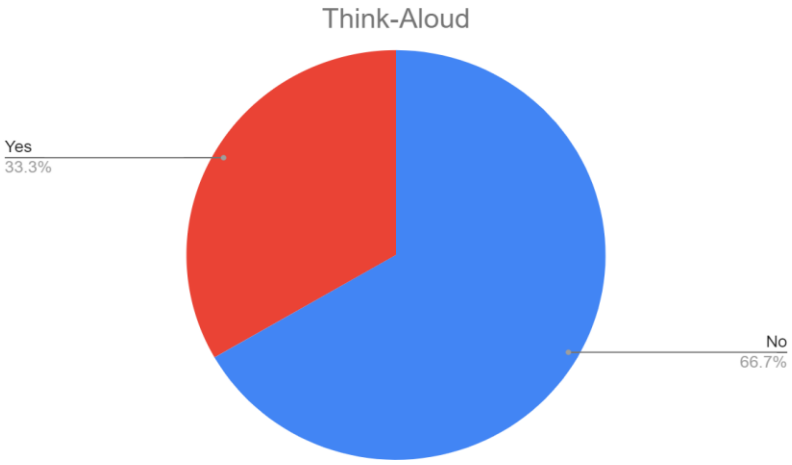

Figure 17 Think-Aloud

Figure 18 illustrates the gender distribution of the participants, where it can be seen that 26.7% of them were female and 73.3% were male.

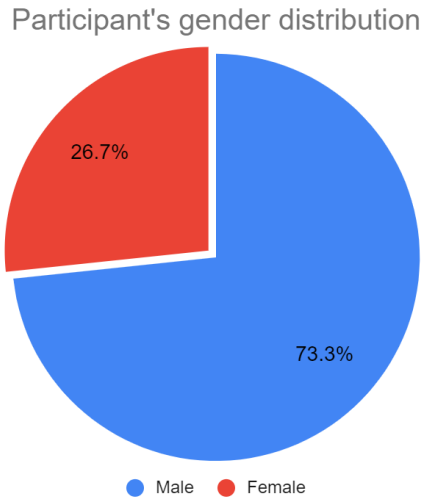

Figure 18 Participant's gender distribution

Figure 19 presents the participants age distribution, where 46.7% of them ranged in the group 18-34 years old, 20.0% ranged 35-49 and the rest 33.3% of the participants was 50 + years old.

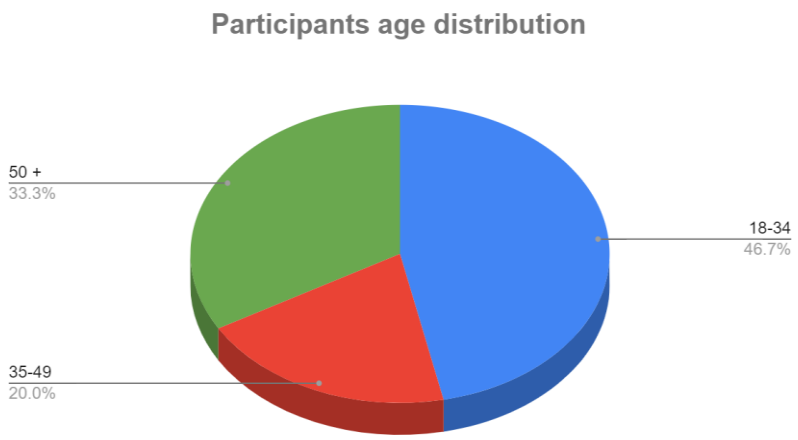

Figure 19 Participant's age distribution

Figure 20 provides an elucidation of the participants' attained highest levels of education. Notably, the data therein demonstrates that a substantial majority, encompassing 75% of the participants, hold a bachelor's degree. Additionally, a minority fraction, comprising 8.3%, have achieved a master's degree, leaving the remaining 16.7% to possess a Doctorate (PhD) level of education.

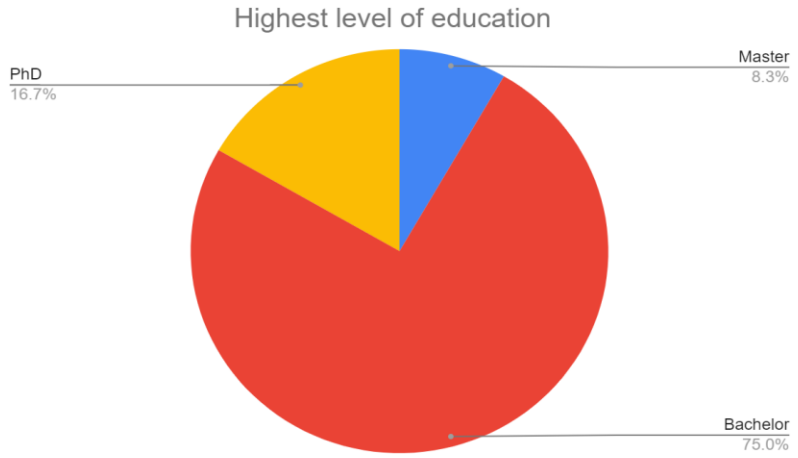

Figure 20 Highest level of education

On Figure 21, one may observe how many hours the participants spend online daily. They are categorized in 4 groups as follows: one group for 1-3 hours a day (8.3%), one 4-6 hours (41.6%), one 6-10 hours (16.7%), and last one 10-16 (33.4%).

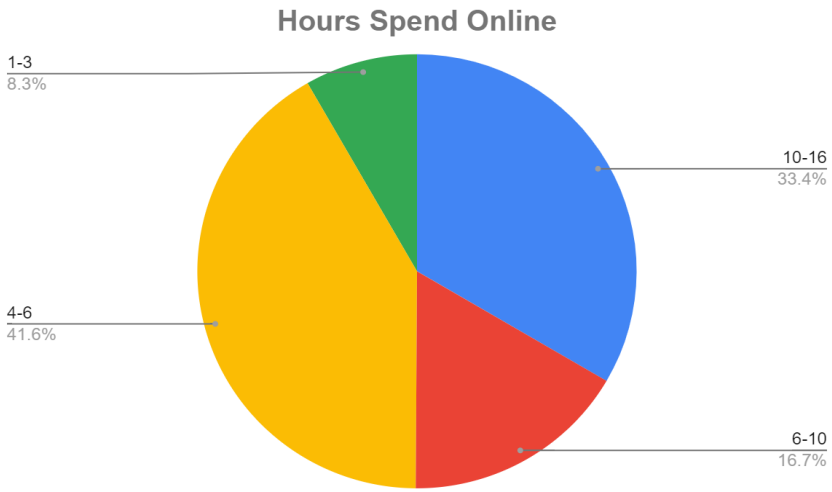

Figure 21 Hours spend online

5.1.2.3. Usability Evaluation Process

5.1.2.3.1. Introduction

At the introduction stage the participants were welcomed, and after an explanation of the purpose of the experiment they were asked for permission to record the interview. After the agreement, they were provided with a small briefing regarding the evaluation, its purpose, and the importance of their participation.

5.1.2.3.2. Running the Experiment

Each participant had their own session one at a time. After the introduction, the scenarios were read to the participants one by one. For each participant the time that took them to complete each task was recorded. All the tasks were the same for each participant. The coordinator didn't talk to the participants throughout the testing process and didn't offer any advice on the degree of success or lack thereof they attained. The only time this rule was broken was when participants were obviously frustrated, or they could not proceed with the scenario.

5.1.2.3.3. Concluding the Experiment

As the experiment came to an end, the coordinator thanked all the participants for their help to run this test. Afterwards, the coordinator asked them to fill the SUS Post-evaluation questionnaires. After the participants filled the SUS, a small discussion took place regarding the overall impressions of the application, which included the following questions that were posed to the participants:

- “Did you like the concept of the application?”
- “Would you employ the application in the event of an emergency?”
- “Which particular feature left the most indelible impression upon you?”

5.1.2.4. Usability Evaluation Results

The assessment of End-User usability yielded notably positive outcomes, which are discernible across various dimensions. Primarily, the recorded task completion times underscore the impressive nature of the results. In the context of the first Use Case Scenario, the average time required to successfully accomplish the task was an exemplary 11 seconds (Figure 22). Evidently, User 6 allocated a significantly greater amount of time compared to the remaining users. This variance can be attributed to User 6's lack of comprehension regarding the assignment, leading them to opt for transmitting an emergency message utilizing the "Image to Text" feature. Similarly, in the context of the second Use Case Scenario, participants demonstrated a commendable performance with an average completion time of 18 seconds (Figure 23). However, it is noteworthy that three participants (specifically, User 3, User 5, and User 7) invested a significantly greater amount of time than the established average. This occurrence could potentially be attributed to the fact that these users belong to the demographic age group of 50 and above (Figure 19), as illustrated in the corresponding figure. Despite these users' extended time commitment in comparison to the average, it is essential to underscore that each of them successfully completed the task within a timeframe of less than fifty (50) seconds. For the third use case scenario, the average time spanned a duration of 1 minute and 21 seconds (Figure 24); however, such a result was anticipated since the third Use Case Scenario included the most steps to be completed for its realization and, thus, required substantially more time to be invested in comparison to the rest of the Use Case Scenarios. Pertinently, in tasks 1 and 3, a minor 3-second allowance is factored to account for the provision wherein a user may choose to cancel a call within the initial 3 seconds of initiation. Use Case Scenario 4, as it transpired, remained unused, given that participants extensively availed themselves of all available features within the application. The primary intent of this scenario had been to engage the "Image to Text" feature.

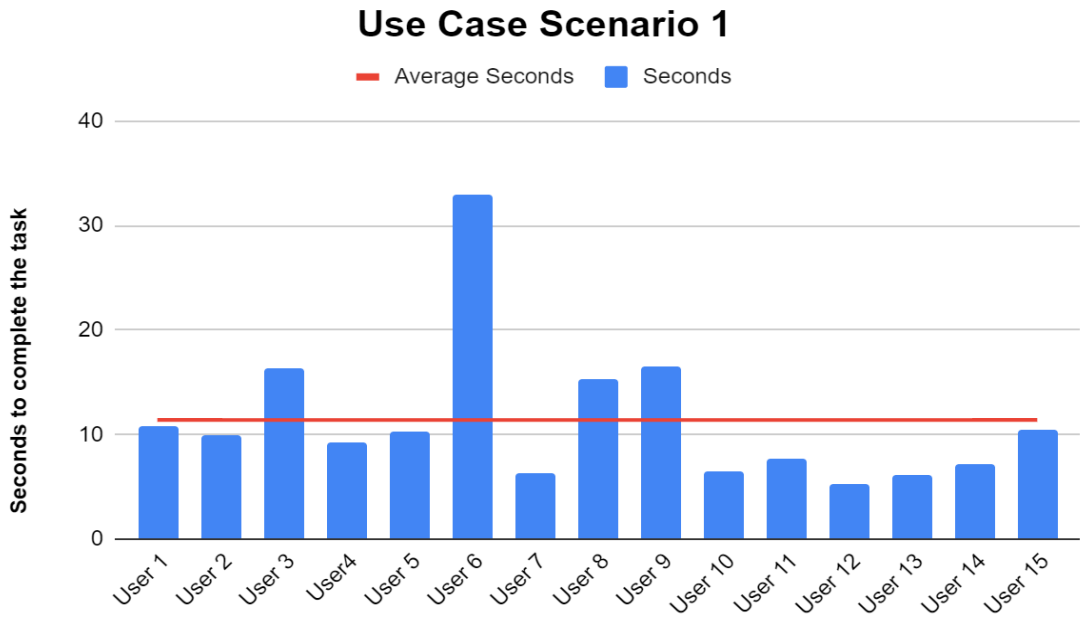

Figure 22 Use Case Scenario 1

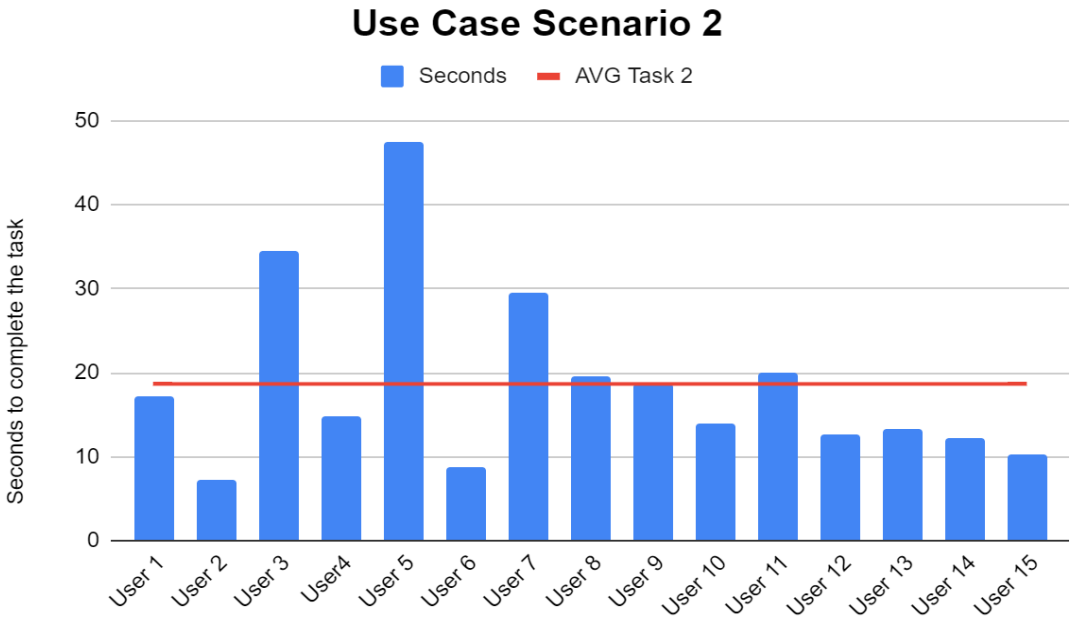

Figure 23 Use Case Scenario 2

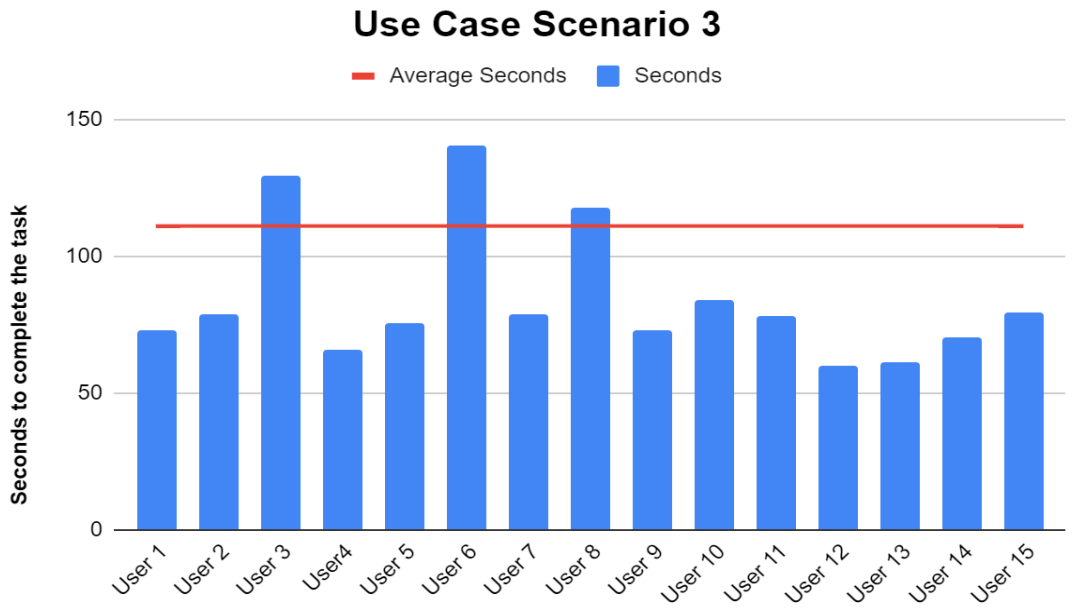

Figure 24 Use Case Scenario 3

Overall, the SUS questionnaire results of the end-users (Figure 25) were very positive because most of the users scored more than the typical average score of 68 in SUS scale (yellow line) and the overall score of the end-users was 80 (red line). That translates to a very pleasant user experience and signifies an easy-to-use application where the average user can use without the help of an expert.

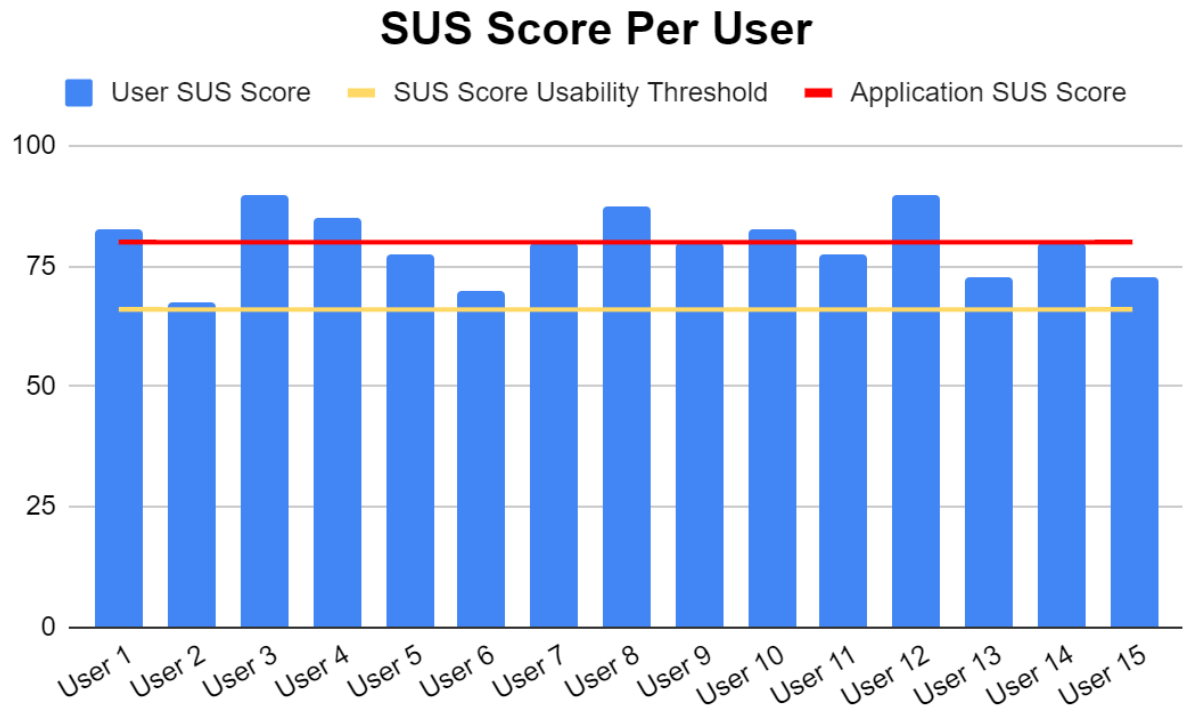

Figure 25 SUS Score Per User

The discussion that followed the conclusion of the experiment including the questions that were posed by the evaluation experiment coordinator to the participants, as explained above, showcased a noteworthy uniformity in responses among the 15 participants. In response to the initial query, "Did you like the concept of the application?" unanimous sentiment prevailed, wherein all participants exhibited a clear enthusiasm for the conceptual framework, expressing substantial favourability with 86.7% answering “Yes”. (Figure 26). Turning to the second inquiry, "Would you consider employing the application in the event of an emergency?", a substantial proportion of participants indicated a desire to use the application in such situations, with 86.7% responding positively, thus illuminating a general tendency toward practical use. (Figure 27). Lastly, in response to the third question, "Which particular feature left the most indelible impression upon you?" a clear majority of participants (60%) attested to their notable fascination with the "image-to-text" feature, thereby underscoring its prominence and impact in garnering participant appreciation (Figure 28).

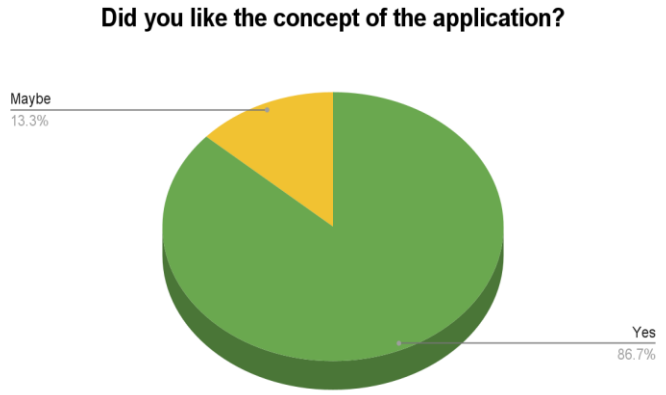

Figure 26 Did you like the concept of the application?

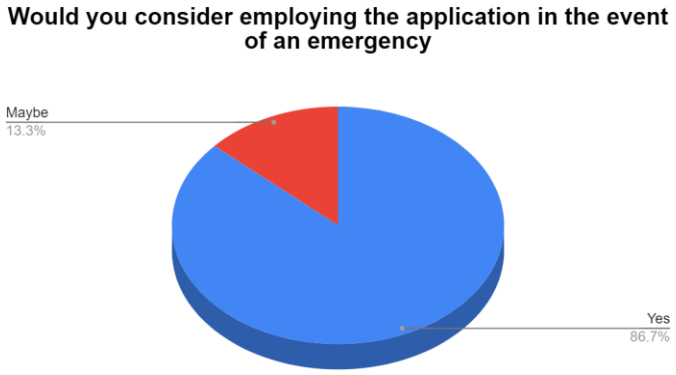

Figure 27 Would you consider employing the application in the event of an emergency

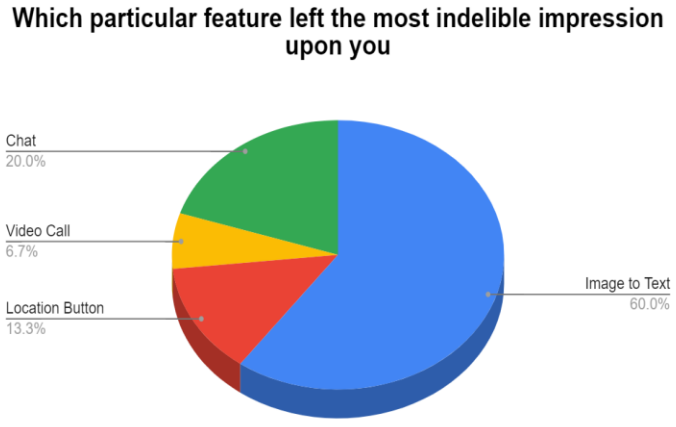

Figure 28 Which particular feature left the most indelible impression upon you

5.1.3. Expert Usability Evaluation

A comprehensive Expert Usability Evaluation was undertaken with the primary objective of garnering a maximal amount of information pertaining to the application in question. Expert users, endowed with their proficiency, are capable of readily identifying discrepancies such as bugs and usability concerns through mere interaction with the application interface. Then, these discerned usability issues are aggregated and compiled into a list, which is then submitted to the expert users for their evaluation and rating.

5.1.3.1. Preparation

In preparation for the experimental testing, a thorough blueprint for the execution of the experiment was formulated. The principal objective of this testing was to amass a comprehensive corpus of information pertaining to the application. Guided by this aim, a judicious decision was made to afford domain experts unrestricted access to navigate through the application interface, enabling them to systematically identify any instances of software anomalies and identify any potential usability issues. Additionally, a decision was made on how to explain to the participants the fundamental principles of the Think Aloud protocol. Subsequently, participants were earnestly requested to conscientiously adhere to this protocol throughout the experimental undertaking. This strategic approach was adopted with the express purpose of maximizing the depth and breadth of information acquisition during the experiment.

5.1.3.2. Participants

To effectively execute a Usability Testing, five expert evaluators were given a smartphone with the application preloaded for them extended use it. The selection of these participants had as a criterion to be an expert in the domain.

5.1.3.3. Evaluation Process

The primary goal of the Expert Evaluation Process was to identify usability vulnerabilities by creating and distributing a list of usability issues to experts and analysing their feedback. The evaluation experiment included four stages: (i) introduction, (ii) experiment, and (iii) usability issues.

5.1.3.3.1. Introduction

Following the completion of the preparation phase, the experiment started, and the expert users were invited, one at a time, in separate sessions. Each session included an overview of the experiment's goals, as those are described in the preceding section, and a brief introduction to the application and its features. Also, they were provided with a description of the Think Aloud protocol and were instructed to adopt it during the evaluation.

5.1.3.3.2. Running the Experiment

After the brief, the goals of the experiment were presented to the participants. The goals could be to make a video call or send a message through the application. Also, throughout each session, the Think Aloud protocol was used, where all users were encouraged to speak out loud because their feedback served as the foundation to quickly detect the system's usability problems. This protocol's purpose is for the participants to speak their thoughts during the evaluation, to receive feedback that could be very valuable.

5.1.3.3.3. Concluding the Experiment

For each user, upon the completion of the experiment, they were asked to provide the usability issues that they may have identified during the process. Upon finishing all sessions, all the usability issues, that were provided by the users, were collected and merged into one list. This list was handed to each participant in a subsequent and final phase of the Expert Usability Evaluation process, so they could rate it based on their preferences; These ratings varied from zero (0) to four (4), with zero being classified as "not a usability issue" and four as "big usability issue". Table 4 below showcases all the usability issues that the experts point out.

Table 4 Usability Issues

Usability Issue	Severity Rating
Timer (countdown to start the call) should be more visible, maybe add a pulse animation	
Change color of the chat icon in the chat button inside the videocall to the primary color (blue) for better visibility	
The message text holders (of the user) in the chat room should change color for better visibility	
In the emergency message flow, the text holder of the final message should be more spacious	
The images used in the emergency message flow should have shadows to look more like buttons that the user can click on	
Big space on the bar on the top of the buttons of mute camera etc	
Make the main call / message button actually turn (animation) when changing from call to message and back	

The logo on the navigation bar at bottom should be unclickable	
Text for Swipe should change to white	
Notification bar (top) during the video call and in the chat room should be more spacious	
The buttons on the cancel screen, which appears when the user wants to cancel sending an emergency message, should be bigger	
The navigation bar should be visible in all app pages so the user can easily return to the Home page	
The "stop call" text that appears after intitating a call is confusing and should change	
In the emergency message flow after sending the message, the app should inform the user that "your message has been delivered" instead of "help is coming"	
Make the app rotatable	
Floating Menu don’t close after 1 click	
Long Press on the main call / message button should be disabled	
The swipe for call / message option should be more visible, with some icons	
The button for ending the call during a videocall should be on the other side (LEFT SIDE) or in the bottom bar	
The user should not be able to send an empty message in the chat room	
When you press cancel while sending the emergency message, the app should wait until the user makes a choice (cancel or not cancel) and not close after a while	
The back gesture of android should not close the app	

5.1.3.4. Evaluation Results

The experiment revealed 22 usability issues that were sorted based on the median value of the usability issue from "not a usability issue" to "big usability issue". Also, the issues were rated based on the work it would be required to solve them; These rating varied from zero (0) to four (4), with zero being classified as "easy to fix" and four as "difficult to fix". Presented in Table 5 below is a comprehensive synthesis of the evaluations proffered by the experts, inclusive of the corresponding average ratings, medians, and the discernment of ease pertaining to the rectification of each identified usability concern.

Table 5 Usability Issues Results

Usability Issue	Severity Rating					AVERAGE	MEDIAN	EASY TO FIX
	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5			
Timer (countdown to start the call) should be more visible, maybe add a pulse animation	3	1	1	1	1	1.4	1	2
Change color of the chat icon in the chat button inside the videocall to the primary color (blue) for better visibility	1	1	2	1	1	1.2	1	1
The message text holders (of the user) in the chat room should change color for better visibility	1	1	1	1	1	1	1	1
In the emergency message flow, the text holder of the final message should be more spacious	3	1	1	2	0	1.4	1	1
The images used in the emergency message flow should have shadows to look more like buttons that the user can click on	1	1	1	1	1	1	1	2
Big space on the bar on the top of the buttons of mute camera etc	3	1	2	1	0	1.4	1	1

Make the main call / message button actually turn (animation) when changing from call to message and back	2	1	3	1	1	1.6	1	2
The logo on the navigation bar at bottom should be unclickable	2	1	0	2	0	1	1	1
Text for Swipe should change to white	1	2	3	2	3	2.2	2	0
Notification bar (top) during the video call and in the chat room should be more spacious	2	2	2	1	0	1.4	2	2
The buttons on the cancel screen, which appears when the user wants to cancel sending an emergency message, should be bigger	3	2	4	2	2	2.6	2	1
The navigation bar should be visible in all app pages so the user can easily return to the Home page	3	2	2	2	3	2.4	2	2
The "stop call" text that appears after intitating a call is confusing and should change	2	2	0	2	0	1.2	2	1
In the emergency message flow after sending the message, the app should inform the user that "your message has been delivered" instead of "help is coming"	2	1	both (2)	2	2	1.75	2	0
Make the app rotatable	4	2	0	0	3	1.8	2	5
Floating Menu don’t close after 1 click	2	2	1	2	2	1.8	2	1
Long Press on the main call / message button should be disabled	3	1	4	2	2	2.4	2	1
The swipe for call / message option should be more visible, with some icons	3	3	3	2	1	2.4	3	1

The button for ending the call during a videocall should be on the other side (LEFT SIDE) or in the bottom bar	3	3	4	2	0	2.4	3	1
The user should not be able to send an empty message in the chat room	4	2	3	3	0	2.4	3	1
When you press cancel while sending the emergency message, the app should wait until the user makes a choice (cancel or not cancel) and not close after a while	3	3	4	3	2	3	3	1
The back gesture of android should not close the app	4	3	4	3	4	3.6	4	2

5.1.4. Overall Usability Testing Evaluation Results

The evaluation of the emergency call application yielded highly promising results, affirming its effectiveness and potential impact on emergency communication and response. User feedback indicated a high level of satisfaction with the application's intuitive interface, seamless integration of video and chat functionalities, and the ease of composing location-specific distress messages using the icon-based system. Participants praised the application for its user-centric design, which allowed individuals with speech-related challenges to effectively communicate with emergency operators through text messages during video calls. The application's robustness was demonstrated by its ability to maintain stable video communication and prioritize the delivery of emergency messages even in adverse network conditions. Furthermore, the evaluation highlighted the application's role in expediting emergency response times, which could eventually lead the emergency operators to quickly assess situations, allocate appropriate resources, and provide timely assistance. These positive results affirm the potential of the developed application to significantly enhance emergency response systems and contribute to saving lives in critical situations.

6. Conclusion

The research-developed emergency call application is a ground-breaking method of rapid and effective emergency communication. The application provides users with a simple and effective way to request assistance in urgent circumstances by combining the capabilities of video chatting, emergency messaging, and an intuitive icon-based system. The outcomes indicated that it can possibly speed up communication and deliver precise location information, establishing it as a useful tool for both users and emergency responders.

The contributions of this thesis are multifarious and impactful. The integration of video calls not only modernizes emergency communication but also offers emergency responders a real-time visual understanding of situations, thereby optimizing their ability to provide tailored assistance. The innovative use of icons for generating pre-defined text messages simplifies emergency messaging, prioritizing the rapid conveyance of critical information in high-pressure scenarios. The application's capability to share precise geographical coordinates alongside distress messages could accelerate response times and directly contributes to more effective emergency interventions, potentially saving lives.

The thorough evaluation of the application's usability, effectiveness, and user satisfaction provides empirical insights into its practicality and potential real-world application. By elucidating both strengths and limitations, this research informs future development iterations, steering the direction of emergency response technology towards enhanced user experience and more efficient emergency services. The integration of location-based services stands out as a pivotal aspect of this work.

As a broader implication, this thesis underscores the pivotal role of technology in shaping modern emergency response systems. By capitalizing on the widespread use of smartphones, this application exemplifies the potential for technology to empower individuals and communities, promoting safety, security, and resilience.

6.1. Future Work

Future development should concentrate on strengthening privacy and data security safeguards because the emergency call application captures and sends sensitive user data. This may entail installing end-to-end encryption for video conversations and text messaging, making sure that location data is securely stored, and complying with stringent data protection laws. Regular security audits and the implementation of sophisticated authentication methods will assist to reduce possible dangers and guarantee user confidence in the application.

Working together with first responders and emergency services can result in beneficial synergies and advancements in the application. The application might be integrated with the systems of emergency service providers in the future, allowing for smooth data sharing and improving communication between users and first responders. Participating in usability testing with emergency service providers and getting their comments may also help to improve the entire emergency response procedure and optimize the functioning of the application.

Examining the possibility of integrating the emergency call app with wearable technology, such as smartwatches or fitness trackers, may provide more accessibility and convenience. Users will be able to start emergency calls or transmit distress signals straight from their wearable technology, ensuring rapid access to emergency assistance even if their cell phones are not

immediately available. Additionally relevant information may be transmitted by smartwatches or fitness trackers, such as heart rate and blood oxygen levels, which can be used to assess the user's status.

Lastly, the incorporation of the PEMEA protocol stands poised to substantially enhance the scalability of the application, thereby contributing significantly to the evolutionary trajectory of emergency applications. With the PEMEA protocol, the app becomes capable of providing services across different regions and countries, making sure that the right emergency responders get the right information about the user's location quickly.

By pursuing these steps of future work, the proposed proof-of-concept emergency call application can continue to evolve, adapt, and stay at the forefront of technological advancements in emergency communication, ultimately improving the safety of users in critical situations.

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