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A mobile design of an Emergency Service System for Deaf people

By:

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Declaration of authorship

I, Miss Anuoluwapo Esther Semande Tovide, hereby declare that this thesis submitted to the University of the Western Cape for a degree of Master's in Computer Science has not been previously submitted by me for a degree at this or any other university, and that all material contained therein has been duly acknowledged.

Signature: 

Date: April 2021

Dedication

I dedicate this thesis and the journey thus far to Almighty God, Family, and my Fiancé for all the support and the pillars of strength through this journey.

Acknowledgements

I would like to say a big thank you to my parents and siblings for always having my back, my senior colleague Shree for always checking on my work progress. I thank the entire member of Deaf Community of Cape Town, Western Cape Provincial Emergency centre, always prepared for me during data collection and presentation of my work and all their involvement at all stages of development; gratitude to my Supervisor, Bill Tucker for always giving his support and guides to the success of my thesis. I would also like to thank Hugo Vaughan for all his effort and willingness and push to ensure success of this work.

Abstract

The importance of mobile technology in improving the quality of life is not restricted to only a Hearing person, and the use of mobile devices among Deaf people is no longer limited, due to the advancements in technology Hearing loss cannot be seen but its effect is clearly visible to the persons suffering the loss. This results in a limited ability to communicate with the large world of hearing people. This research effort aims to design a SignSupport for emergency mobile application for Deaf people in Cape Town, empowering them with the same access to emergency service resources as hearing people. The proposed approach is to use a mobile application to contact standard emergency services on behalf of a Deaf person to a representative. The app will use a phone's GPS module to share the location of the victim and contact the nearest emergency service provider to attend to the Deaf victim; as well as keep the victim's circle of family and friends informed. The app design is intuitive, simply requiring the Deaf victim to launch the app and choose an emergency type from the available options. The app then transfers the request using a representational state transfer application programming interface to the emergency service provider for the corresponding assistance. The emergency service receives the location of where assistance is needed via integration into Salesforce platform emergency system to receive and act according to the victim's request. Pre-registered family and/or friends will also get a notification of the victim's current situation. The designed app is a cross-platform application which allows the technique, and framework used to develop one service to be deployed to diverse operating systems and serve a homogenous and native feeling. This makes this application available to various mobile device operating systems. This research was conducted co-design and participatory design methods, through an iterative cycle of building, testing and evaluation by conducting a collaborative partnership with participants and domain experts which a close involvement with members of local Deaf communities and Emergency service provider, iteratively tested for usability and evaluation for performance by end-users is the main result of this thesis. The end goal is to present a well-designed and evaluated prototype for further implementation. The research concludes with a summary of recommendation, future work and lessons learnt.

Keywords: — **Internet Services & End-User Applications; Mobile Apps, Software Design; Location-based Services, GPS-enabled Cell-Phone, Sign Language, Emergency Services, Co-Design Methodology, Communication. Cross-Platform Development.**

Glossary

ABI: Auditory Brainstem Implant

AUSLAN: Australia Sign Language

BAHA: Bone Anchored hearing system

BES: Bangladesh Emergency Service is a mobile application that provides emergency service for reporting fire incidents, street fights, harassment and locating hospitals for medical emergency.

CHAT API: Is a WhatsApp API gateway service for sending and receiving messages with an integration protocol using REST API

CODA: Child of Deaf Adult

DCCT: Deaf Community of Cape Town

DEAFSA: Deaf Federation of South Africa

EMS: Emergency Service

ESP: Emergency Service Platform provides an interface for managing public safety answering point.

GPS: Global Positioning System, it is a global navigation satellite system that produce location, velocity, and time synchronization.

I3: this is the technical specification for the next generation 9-1-1, which is the evolution of an improved 911 to an internet protocol-based emergency communication system.

ICDL: International Computer Driving License

IMS: Internet protocol multimedia

IP: Internet Protocol

ISP: Internet Service Providers

LIS: Italian Sign Language also known as

MATLAB: Matrix Laboratory, it is a programming language platform, which primary aim was for calculating numerical computing.

NGO: Non-Governmental organization

NID: National Institute of Deaf

NMS: Network Management System

PaaS: Platform as a service

PERS: Personal Emergency Responses is an alarm system designed to summon medical personnel.

PSAP: Public safety Answering Point, it receives emergency service calls from internet protocol network.

REST API: Representational state transfer Application Programming Interface

SASL: South Africa Sign Language

TTY/TDD: Telephone Typewriting and Telecommunication Device

UCD: User Centred Design, this is an iterative process that focus on the user throughout an entire design.

UI: User- Interface

USSD: Unstructured Supplementary Service Data

VOIP: Voice over Internet Protocol, is a communication session for voice or video over internet protocol.

Web hooks: this is often called HTTP Push API; it delivers data to other applications in real-time.

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1. Introduction

The importance of mobile technology in improving quality of life is not restricted to only a Hearing person, and the use of mobile devices among Deaf people is no longer limited, due to the advancements in technology. The use of Telephone Typewriting and Telecommunication Devices (TTY/TDD) have become obsolete. Currently, access to mobile technology eliminates barriers for people with disabilities, as information and communication technology (ICT) has opened the world of information and communication to people with hearing impairment such as SMS texting, text and video-base relay, and other non-voice options for Deaf people (Samant, Matter, and Harniss 2013). Correspondingly, many video calling applications enable communication between Deaf people using sign language, these applications include FaceTime, WhatsApp, and Skype. On the other hand, these applications are not for emergency medical services (EMS) (Leib 2012).

Medically, deafness is described as the actual loss of hearing. Another definition from a cultural viewpoint defines Deaf (emphasis on the uppercase 'D') to be when an individual has a severely reduced hearing capability and identifies themselves with a Deaf community that 'speaks' a certain signed language (Bakken 2005). Hearing loss cannot be seen and its effects can only be visible to a person suffering the loss which results in frustration of not being able to communicate normally with hearing people; some of these individuals get isolated which leads to depression among this group of people (Bakken 2005), (Varshney 2016). Conversely, the severity of hearing-loss to deafness ranges from mild, moderate, moderately severe, severe and profound (deafness) (Bornman et al. 2016). Deaf people are normal individuals who lost their hearing abilities either because of disease, accident, environmental factors, or simply old age. Research shows that there are various causes of hearing loss such as hereditary hearing loss and deafness which could be pre-lingual losses that are present before speech is developed as an infant. However, not all pre-lingual hearing losses are congenital (Ordonez 1993), (Gonzalez 2017).

The magnitude of challenges faced by Deaf people creates struggle not only with communication but also marginalization emanating from both environmental discrimination that puts them in a vulnerable state, along with exclusion from socioeconomic involvement. Moreover, Deafness or hearing impairment can be severe enough that little or no processing of audio information is possible, and the individual is unable to communicate with their hearing and voice (Gonzalez 2017). Deaf people prefer to communicate in signed language, e.g. South African Sign Language (SASL) (Chininthorn et al. 2015). Thus, Deaf people should have equal access to mobile phone usage in comfort and should not be dependent on text messaging as this is not their first language; and that they face great intimidation participating in socioeconomic activities and can also suffer from the barrier of low education. Deaf people should be given the same services and privileges as hearing people with the consideration of their disabilities and they should not have to spend such high cost on video calls which are more than the cost for a voice call (Samant, Matter, and Harniss 2013), (Cohen, Durstenfeld, and Roehm 2014), (Gonzalez 2017) . Several studies have deliberated on some of these challenges faced by Deaf people (Kuenburg, Fellinger, and Fellinger 2016). Some studies spotlight the lack of education for Deaf people which prevent them from recognizing their human rights in the community; and lack of access to healthcare, and their cultural behaviour (Swanwick 2017). Also lack access to information and emergency services, creates a significant communication gap with health care providers (Cohen, Durstenfeld, and Roehm 2014). Few research demonstrated an interest in the area of communication between the hearing and Deaf people, appertaining different approach such as interpreting sign language to speech for the hearing and speech interpretation to sign language for the Deaf (Jemina Napier 2017).

South African Sign Language (SASL) is the language used by Deaf people in South Africa for communication amongst themselves. Again, Deaf with a capital 'D' denotes people (either deaf or hearing) who converse with sign language as their primary means of communication. For instance, a situation which includes a hearing child of a Deaf adult (CODA). Deaf with a lowercase 'd' usually refers to people who can cope with written and spoken languages in their environment, despite the struggles to hear (Reagan 2012), (Blake, Tucker, and Glaser 2015). SASL is the linguistic and cultural foundation for Deaf people in South Africa (Chininthorn et al. 2011). According to Padden *et al.* (2016), the Deaf community is a group of people who shared the common goals of its members and work towards achieving these goals (Cripps and Al. 2016).The sociolinguistics perspective is that sign language represents a significant part of their cultural and linguistic minority (Cripps and Al. 2016). Several Deaf organizations exist in Western Cape Province, and some are involved in this research.

The National Institute for the Deaf (NID) was established in 1881 and has become a private, powerful, and innovative non-profit company. The organization started with the aim of training deaf people how to read and write[1]. NID also provides care services such as adult and elderly care, and it also offers integrated support services involving pre-lingual, post-lingual and Deafblind.[1] The organization services also involve sensitization and awareness including educating Deaf persons living with HIV/AIDS. Another Deaf organisation, the Deaf Federation of South Africa (DeafSA), formerly known as South African National Council for Deaf (SANCD), was founded in 1929 and became

[1] National Institute for the Deaf, About NID, 2019. [Online]. Available: http://www.nid.org.za/our-story/. [Accessed: 03- Oct-2019]

DeafSA after its transformation to a new democratically elected organization. DeafSA's objective is to promote the interest of Deaf and hard of hearing dynamically in South Africa.[2] Similarly, the Deaf Community of Cape Town (DCCT) is a pioneering Deaf non-governmental organization (NGO) established in 1987 with a small group, and initiated offices in a building owned by South African Deaf people in Newlands in 1994 under the leadership of Father Cyril Axelrod who was Deaf at the time and later became blind (Deaf Community of Cape Town, 2016) (Bamberg 2008).[3] The goal of the organization is to serve the needs of Coloured and Black Deaf people in Western Cape, caused by the negligence of the national bodies starving the Deaf of their needs.[3] In general, these organizations aim at encouraging the Deaf people to be empowered and find their voice in the community where their needs, well-being and growth is a priority (Blake, Tucker, and Glaser 2015), (Cripps and Al. 2016).

1.1. Background

SignSupport is a conjunction of a multidisciplinary teams involving the departments of Computer Science at the University of the Western Cape (UWC) and the University of Cape Town (UCT); the Faculty of Industrial Design Engineering at the Technology University of Delft (TU Delft); Deaf communities around Western Cape such as DCCT, NID and DeafSA; and other expert partners like Diabetes SA and Western Cape Provincial EMS. SignSupport is an umbrella of assistive tools for providing communication amongst Deaf and hearing people based on Deaf culture adoption. Moreover, SignSupport has produced several beneficial projects, such as:

Sign Support for Pharmacy: This is an app designed to assist a Deaf patient and provides health information in SASL for them to understand their diagnoses and treatment desertion. The patient is able to provide a medical profile such as food allergies, current medication, weight, smoking status, drinking status, medicine allergies and current sickness (Chininthorn et al. 2012). SignSupport for Pharmacy prompts interaction between the Deaf patient and a pharmacist on instructions about the prescribed medicine. After the prescriptive session, the app merges and orchestrates all instructions in SASL video format for the patient to watch and save for playback on a mobile device (Motlhabi et al. 2013).[4]

SignSupport for International Computer Driving License (ICDL): This provides a convenient learning atmosphere for interested Deaf adults to learn computer skill literacy at their own pace on a mobile device. ICDL utilizes SASL pre-recorded videos on a smartphone to deliver learning content.

[2] Deaf Federation of South Africa, About DeafSA, 2019. [Online]. Available: http://deafsa.co.za/about_us/ [Accessed: 03-Oct- 2019

[3] Deaf Community of Cape Town, About DCCT, n.d. [Online]. Available: http://www.dcct.org.za/?q=about. [Accessed: 03-Oct- 2019]

[4] SignSupport Project, Pharmacy, [Online]. Available: https://signsupport.org/portfolio/pharmacy/ . [Accessed: 08- Mar- 2020]

This helps the Deaf adult reduce dependency on the teacher for instructions (G. Ng'ethe, H. Blake, and Glaser 2015), (Chininthorn et al. 2011).[5]

SignSupport for Diabetes: This is designed as an information pool, which can be referred to by a health professional to retrieve relevant health information on a Deaf patient diagnosis (Chininthorn et al. 2015).[6] This system was develop to provide solutions for Deaf adult with comprehensive information in signed language and presented in various ways. The design choices were made based on the ideas and requirements from Deaf and health knowledge providers involved in the development (Chininthorn et al. 2015).

1.2. Problem description

Consider the following scenario illustration: Johnson is a Deaf person involved in a car accident with two other hearing passengers on a lonely route. One of the two hearing passengers was the driver seat and the other sat on the seat beside the driver. These two passengers died instantly while Johnson, sitting in the car's back seat, was brutally injured and helpless. Johnson picked up his phone to call for help. Unfortunately, the emergency service agent assumed it was a false alert due to the non-responsive conversation. Johnson could not hear the service centre agent or give any detail to the agent that could help and after a long struggle in pain, Johnson died. This identifies a major communication gap between the hearing people and Deaf community and how important a solution to bridge this communication gap is needed.

In an emergency, a hearing person simply picks up a phone and communicates with the emergency service provider to get help. Communication here is simple and direct: they both speak and hear, and therefore understanding each other would not be difficult. However, Deaf people are less privileged in relations with communication. Presently, the available emergency services that provide a supporting system for Deaf people in an emergency are dependent on text messaging communication.

1.3. Research aims and objectives.

1. To address the need of an emergency medical service for Deaf people.
2. Introduce a bridge between a mobile interface for Deaf people and a standard hearing-based EMS call centre.

1.4. Proposed solution

We recall from the Johnson case illustrated above; if a system such as mobile app with simple and direct interface is available to serve Deaf people at the time when Johnson needed to pass a crucial message to request help and if the proposed system, SignSupport for emergency app, was available at the scene, the story will go thus, Johnson was able to pick up his phone which he already have the

[5] SignSupport Project, ICDL, [Online]. Available: https://signsupport.org/portfolio/ICDL/ .[Accessed: 08- Mar- 2020]
[6] SignSupport Project, Diabetes Care, [Online]. Available: https://signsupport.org/portfolio/diabetes/. [Accessed: 08- Mar- 2020]

emergency app installed and ready to use on, it only takes few clicks for Johnson's request to be sent with all the necessary information needed to the first responder (contact centre agent) which includes Johnson's location and will notify his emergency contacts about his current situation.

An emergency is an unforeseen circumstance that requires immediate or urgent action of assistance to prevent the situation from becoming worse (Council 2007). However, in this research, we define an emergency as an unexpected occurrence in need of swift attention to prevent the situation from getting worse (Cabo et al. 2013). Equal access to technology services for Deaf people is a priority here, as it also contributes to digital divide and providing e-inclusion (Yeratziotis and Van 2013).

To achieve the research stated objectives, the proposed SignSupport for emergency app will focus on some core features which are highlighted below in Figure 1-1: Deaf User Interface (UI) Mobile Application, Location Detection, and SASL first-aid videos.

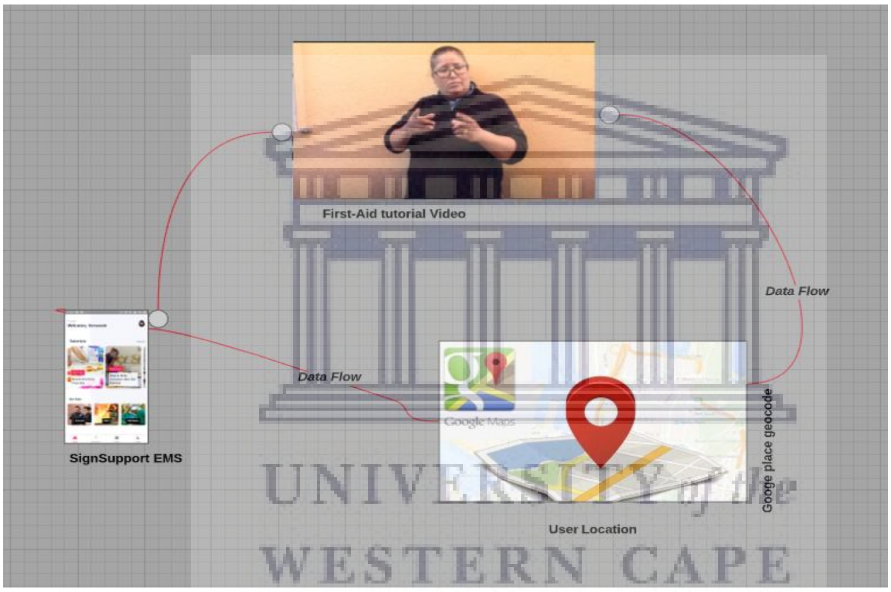


Figure 1-1 Flow within the SignSupport for EMS app

This figure shows the major features of the SignSupport for emergency app. A Google Map displays the user location when help is requested, and first-aid video tutorials recorded in SASL to assist the user before the EMS provider arrives at the scene of incident. The SignSupport for emergency provides a clear picture icon describing their functions for an easy and effortless Deaf user interface.

1.5. SignSupport for emergency and the EMS provider

The SignSupport for emergency app communicates directly with the Deaf contact centre, which is the support infrastructure, for processing and forwarding requests to the appropriate EMS service provider. In our case, the Deaf contact centre is a custom-built Salesforce app that uses web hooks to automate the process of identifying requests and deciding on the appropriate responses. SignSupport for emergency app captures personal details from the users and stores it in a secure database. The user uses the app by logging in and sending requests to the Deaf contact centre. The Deaf contact centre processes the requests and may modify it with additional information they have on hand or retrieved from the secured database before the requests are transferred to the appropriate EMS provider for service.

1.6. Role of the author

DCCT identified the need for an emergency service platform, because of our research team meeting with Deaf community members. Their demand was for an emergency service system that caters for their needs as a community. This research is a new scenario in SignSupport, which introduces Emergency service app and first aid treatment videos such as: helping a drowning person, fainting person, asthma attack, cardiopulmonary resuscitation (CPR) and stroke victims. The focus of the SignSupport emergency app is the communication between the EMS provider and Deaf people, providing all necessary information to the EMS provider through a Deaf contact centre at the push of a button on the designed Deaf UI and all requests including the user details and location will be sent.

The testing of SignSupport for Emergency app will be done with a role-play scenario involving members of the Deaf community. This app is integrated into a Deaf contact centre to receive a request and format the message in the EMS provider's acceptable format. This research meticulously worked with four entities: the computer scientist who created the SignSupport emergency for Deaf app from first throwaway prototype to the functional prototype, the co-researcher who worked on the Deaf contact centre for easy integration of emergency app, Western Cape Provincial EMS and the Deaf communities who gave feedback on each designed prototype for changes and improvement. Working with these group of people helped to ensure that the SignSupport for emergency app meets the required intentions.

1.7. Thesis outline

The rest of the thesis is constructed as follows. Chapter two reviews the current literature and research in the field of emergency service systems from other countries and in South Africa for the general population and Deaf population, respectively; to analyse the topic, key concepts and understand the viewpoints of researchers in the field. Chapter three describes the research methods and design tools required for this research, presenting a detailed report of each activity done, details relating to the design and implementation of the research methodology to investigate the relevant research questions. Chapter four gives the results of the analysis of the data collected, and a discussion on the findings. The thesis is concluded in Chapter five, with recommendations and future work.

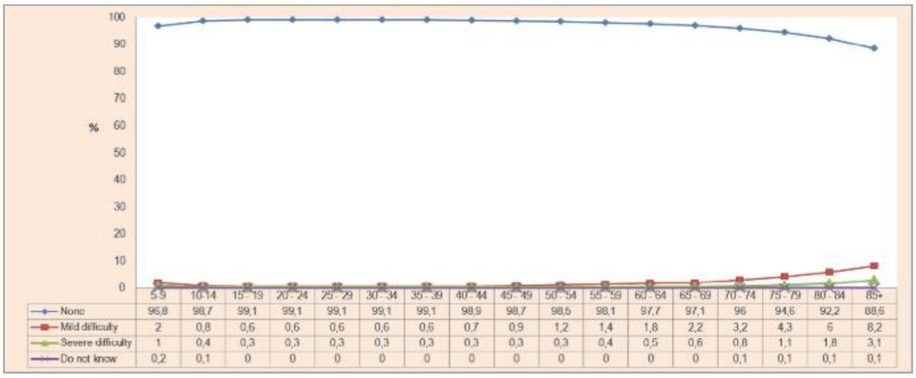
2. Related work

This chapter presents related work consulted to get ideas on how different approaches have been made on emergency systems in general and Deaf emergency service systems. Section 2.1 presents the demography of the Deaf population. Section 2.2 enumerates on the importance of mobile devices among Deaf people. Section 2.3 describes emergency service systems in general while section 2.4 discusses emergency services specifically for Deaf people. Section 2.5 addresses different approaches to the problem of EMS contact centres and EMS for Deaf people. Finally, Section 2.6 summarises the chapter.

2.1. Demographics of Deaf people

Deafness or hearing impairment is one of the most frequent sensory deficiencies and affects more than 360 million (5%) people and quality of life worldwide (De Clerck 2016). The European Union population of about 44 million recorded 9% of this population to be deaf (Constantinou, Ioannou, and Diaz 2017). There is no exact or accurate record of the Deaf population in the United States; this difficulty is as a result of various hearing loss and ages onset (Cripps and Al. 2016). Australia recorded 30,000 people with hearing loss who use the Australia Sign Language (AUSLAN) with total hearing loss (Australian Network on Disability 2018).

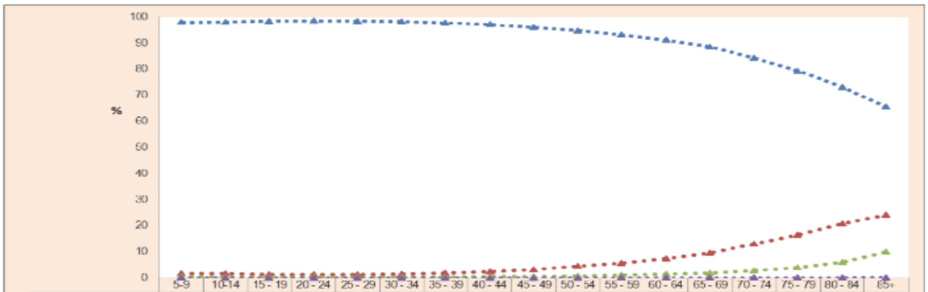
In South Africa, hearing impairment prevalence rate is 3,5% and population with communication disability is 2% of the country's population (Lehola 2011), (Statistics South Africa 2011). Furthermore, South Africa's statistics from the 2011 census conducted gave an insight on the number of total population of about 38,084,876 (100 %) and the total number of people with all kinds of disabilities 2,870,130 (7,5 %) intersecting all provinces and diverse race groups in South Africa. That census also reckons the number of people with hearing and communication difficulties of minimum of 2,247,661 population (Lehola 2011), (Statistics South Africa 2011).



	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
None	96,8	98,7	99,1	99,1	99,1	99,1	99,1	98,9	98,7	98,5	98,1	97,7	97,1	96	94,6	92,2	88,6
Mild difficulty	2	0,8	0,6	0,6	0,6	0,6	0,6	0,7	0,9	1,2	1,4	1,8	2,2	3,2	4,3	6	8,2
Severe difficulty	1	0,4	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,4	0,5	0,6	0,8	1,1	1,8	3,1
Do not know	0,2	0,1	0	0	0	0	0	0	0	0	0	0	0	0,1	0,1	0,1	0,1

Figure 2-1 People with hearing and communication difficulties in South Africa.

The figure above shows the percentage proportion of people with no hearing difficulty to mild and severe difficulty. The figure showed that 9 out of 10 people from age 5 to 9 had no hearing difficulty. There was an increase from age 40 to 49 showing people mild hearing difficulty and highest severe hearing difficulty is from age 85+ (Lehola 2011), (Statistics South Africa 2011).



	5-9	10-14	15 - 19	20 - 24	25 - 29	30 - 34	35 - 39	40 - 44	45 - 49	50 - 54	55 - 59	60 - 64	65 - 69	70 - 74	75 - 79	80 - 84	85+
None	97,9	98	98,4	98,5	98,4	98,2	97,7	97,1	96	94,7	93,1	91,2	88,6	84,2	79,3	73,1	65,5
Mild difficulty	1,6	1,6	1,3	1,2	1,2	1,5	1,8	2,4	3,3	4,5	5,8	7,4	9,5	13	16,6	20,7	24,3
Severe difficulty	0,5	0,4	0,3	0,3	0,3	0,3	0,4	0,5	0,6	0,8	1,1	1,4	1,8	2,8	4	6,1	10
Do not know	0,1	0	0	0	0	0	0	0	0	0	0,1	0,1	0,1	0,1	0,1	0,1	0,2

Figure 2-2 People with communication disability in South Africa.

Percentage distribution of persons aged 5 years and older (in five-year age groups) by a degree of difficulty in communicating (Lehola 2011). *The figure shows that the older age categories becomes prevalent from age 70 years onwards, people from age 85 and older documented the highest proportion of severe difficulty in communicating* (Lehola 2011), (Statistics South Africa 2011).

2.2. Importance of mobile devices among Deaf people

Technically, SMS, TTY's, Fax and email were regular means of communication among Deaf people, where each of these technologies serve a purpose. For instance SMS for personal and social interaction, TTY's for long communication, fax for social and business contacts, as well as other web access (Power, Power, and Horstmanshof 2007). For over 100 years since the telephone was invented, SMS showed more equilibrium among Deaf people as they previously did not have use for mobile phones. SMS changed this as it improves the existing technology and enabled interaction between Deaf and hearing (Power, Power, and Horstmanshof 2007). Research done in Norway shows positive embracement of how Deaf teenagers see this opportunity as a means of increasing their social network, exchanging contacts as normal teenagers and/or young adults and establish a bond with their new network with SMS communication (Bakken 2005). However, mobile technology has shown a stronger perspective tool in assisting Deaf people as they continue to age. According to Singleton (2019) revealed in its survey, the adoption of technology increase amongst both young and old Deaf people, following that they show acceptance to various kinds of technology devices to accomplish their day-to-day activities. On the contrary, they disregard the sound-based alerts technology approaches (Singleton et al. 2019).

There are also some hardware technology approaches to assisting the deaf and hard of hearing which includes hearing aids, cochlear implants, Auditory Brainstem Implant (ABI) and bone anchored hearing system (Baha).[7] This technologies assist deaf people who are not Deaf and can still hear and speak with the help of these technology devices (Ladner 2010). Other Deaf user-friendly app includes Amplified phones, FaceTime video calling, iChat, Purple communication videophones, and relay services, Sign Language Translator, , Frequency Modulation system (Leib 2012).

[7] Laurent Clerc National Deaf Education, 2017. [Online]. Available: https://www3.gallaudet.edu/clerc-center/info-to-go/cochlear-implants.html [Accessed: 03- May- 2020]

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2.3. Emergency medical service systems

Location is perhaps the most important data point for an EMS system. A GPS enabled device is a key tool, and it is important to mention the signal frequency approximate is 1.5GHz and the power level is at -160dBW at the receiving antenna. It is a time synchronizing space-based satellite system that transmits speed spectrum codes across a titular constellation (Guo et al. 2016) as shown in Figure 2-3. Furthermore, the constellation consists of 24 satellites, 24 codes are transmitted instantaneously on each GPS frequency. For instance, Herrera *et al. (2010)* conducted a survey on the use of GPS. One of the purposes was to evaluate speed measurements accuracy from GPS-enabled mobile phones under both free flow and congested traffic conditions and the feasibility of a traffic monitoring system based on GPS-enabled mobile phones (Herrera et al. 2010), (Herrera and Bayen 2010). The survey showed GPS to be more accurate than cell tower signals for tracking purposes and a large number of smart mobile devices come with GPS as a standard feature which grants more accurate location-based information and additional details such as the direction of travel which can also be obtained (Herrera et al. 2010).

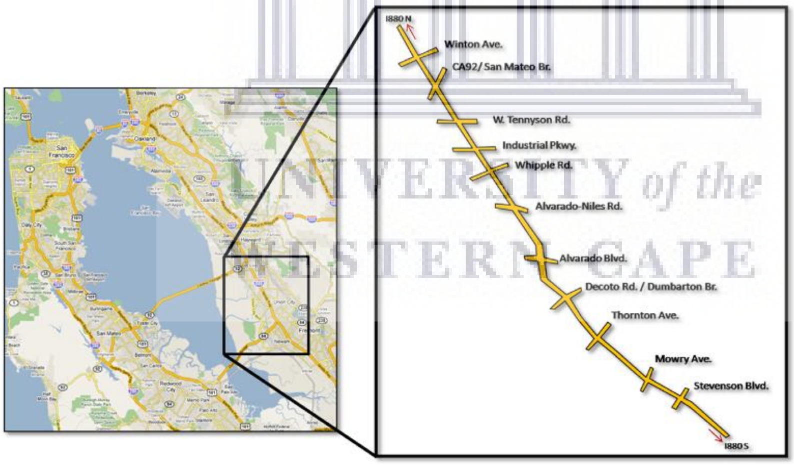


Figure 2-3 GPS used in the Mobile Century experiment.

The experiment indicates that GPS enabled mobile phones recorded quality data for the experiment. Such that, travel time and speed were produced in real-time travel time and velocity estimate which showed exactness (Herrera et al. 2010).

2.4. Emergency services for Deaf people

The World Federation of the Deaf (WFD) and a worldwide association of sign language interpreters published a set of guidelines in January 2015 outlining a series of recommendations for including Deaf people in communication during natural disasters and mass emergencies (Cripps and Al. 2016). This inclusion of Deaf people during disaster has taken several areas to manifest, however different authors and researchers have implemented numerous ideas; one of which mobile technology plays an immense role.

2.4.1. Mobile-based Emergency service systems for Deaf people

Comparatively various work has been done and reviewed on emergency services for Deaf people, one of which includes a mobile app support for communication amongst emergency medical responders and Deaf people. However, the aim of the system is addressing the communication issue *after* the emergency medical service has been called to attend to a Deaf person in need of medical services (Buttussi et al. 2010). The linguistic barrier between medical emergency responder and a Deaf person that communicates with sign language becomes difficult. PDAs and smartphones are the mobile choice with a touch screen as target devices, and for easy pocket fit for the EMS responder's uniform. It support VGA video replay of sign language sentences and also thumb based interaction for the Deaf person (Kristoffersen Et al. 1999), (Buttussi et al. 2010).

Minimal attention user interfaces (MAUIs) were used for the system design, where the interface provides mechanisms to decrease the amount of user attention required to perform a specific task (Pascoe, Ryan, and Morse 2000), (Buttussi et al. 2010). PDA was recommended for the use of audio feedback to cut required visual attention, and offers a system that can function using only a few buttons as displayed in Figure 2-4 and how it is used as shown in Figure 2-5, which allows the medical responder to quickly browse a collection of emergency related sentences and show the video of the corresponding translations in sign language to the Deaf person. This research involved experts from the medical practitioners and Deaf community. Specifically, an emergency physician and a deaf sign language expert were part of the team, various sessions with three ambulance nurses, and engagement with the members of the Deaf community. All this were done through focus group meetings, interviews, and observation throughout the development cycle (Buttussi et al. 2010).

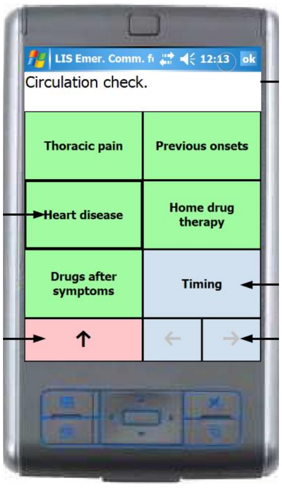


Figure 2-4 Screenshot of LIS phone

The upper section describes the current menu. This example is the "circulation check". The green buttons select topics to show in sign language. The blue button is for entering the sub-menu. The red button goes one level up in the tree, and the blue buttons are for navigating menu pages. The application is in Italian. This screenshot shows English for readers' convenience (Biage et al. 2012).

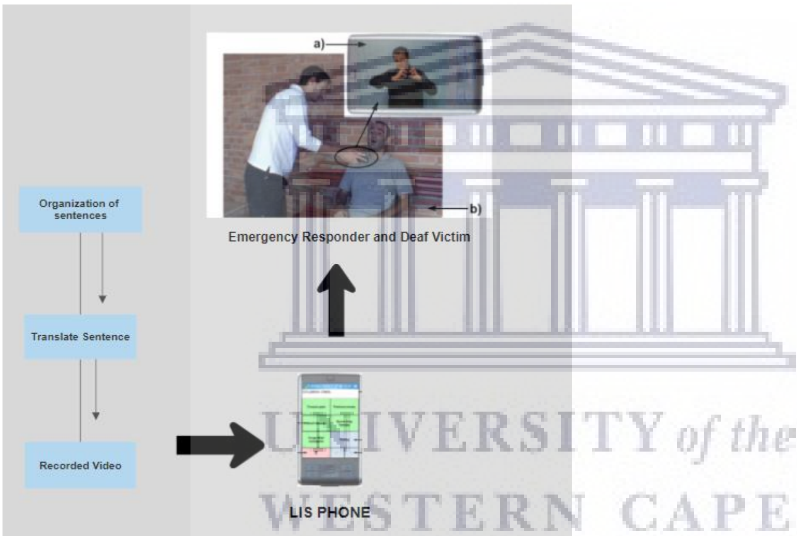
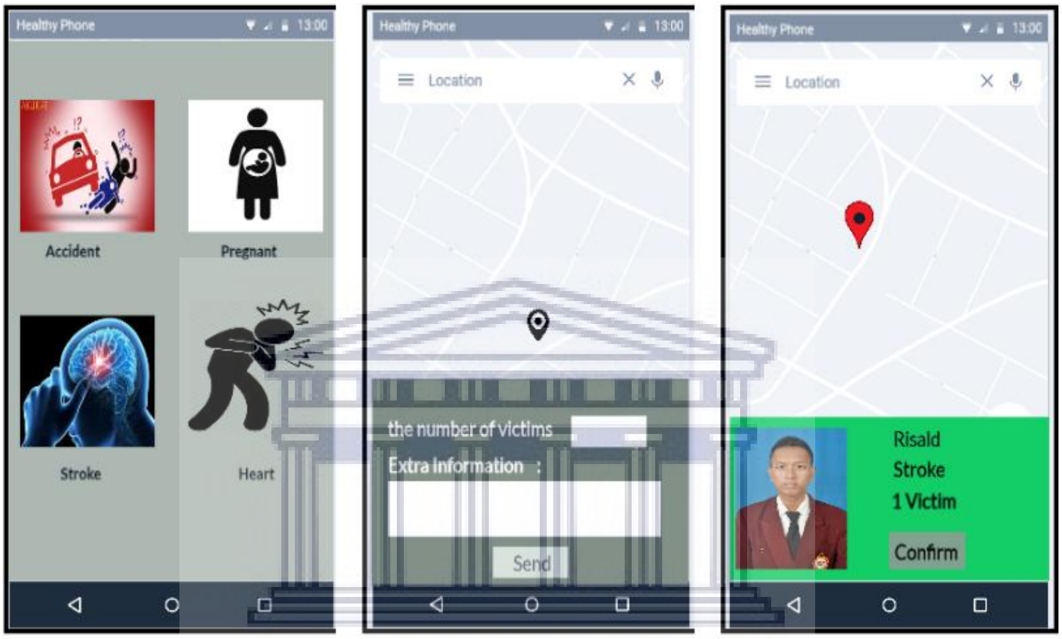


Figure 2-5 LIS phone structure

The system applied the Italian emergency medical service from acquiring the EMS questions to giving the instructions, and descriptions of activities needed for communication, hierarchically forming sentences for the menus, translating all the sentences in LIS, and recording the videos of the LIS sentences.

Risald *et al. (2018)* proposed an application called Healthy Phone App to provide medical emergency assistance for Deaf people in Indonesia (Risald, Suyoto, and Santoso 2018). The mobile application, Healthy phone app is designed to serve medical emergency purposes for Deaf people during a distress call for help. This system contributes to an existing emergency system for the Deaf people in Indonesia with a more acceptable user interface by identifying the need of characters to be used on the emergency calling application according to a Deaf person's perspective. This study focused on using the User-Centred Design (UCD) method throughout the system development cutting across all system life cycle processes from the analysis, design, and implementation and evaluation stage (Risald, Suyoto, and Santoso 2018). This interface shows the home screen, send location form and confirmation form page.

The result from this study identified that a text-based communication cannot be applied due to the language barrier, reason being that sign language differs from normal English language. The prototype of Healthy Phone app shown in Figure 11 (Risald, Suyoto, and Santoso 2018). The Healthy Phone app concept is like the concept of online taxi booking. In an emergency situations user send request message to the hospital using the app, then message is sent from the app to the closest hospital to the user request location. Clarification of application concept can be seen in Figure (Risald, Suyoto, and Santoso 2018).



(1) (2) (3)

Figure 2-6 Healthy Phone app user interface

Screen (1) is the initial view of the app when a registered user opens the Healthy Phone app. User requesting emergency only need to tap images that match their request type. Screenshot (2) needs users to fill in some data such as the number of victims and other information which is optional. The displayed here location is the automatic location given the user's position. Then the user only clicks "Send" and the request will be sent from the app to the nearby hospital. Screen (3) is the confirmation interface page comprising situation data received by the hospital from the user's location. The hospital agent needs to click the "confirm" button for notification that the hospital has confirm an emergency and is ready for action by conveyance of ambulance and medical equipment necessary (Risald, Suyoto, and Santoso 2018).

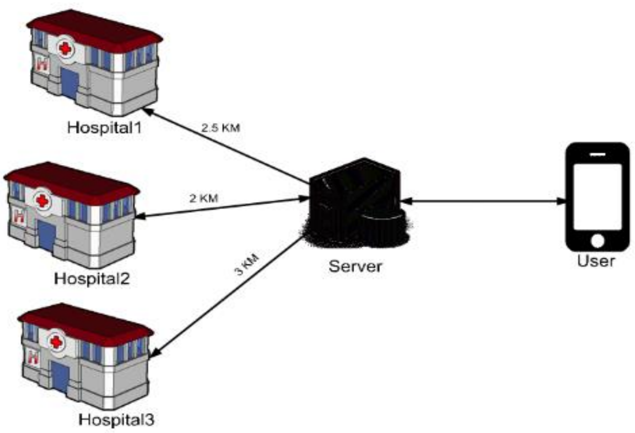


Figure 2-7 Healthy Phone app architecture

This architecture illustrates the flow of messages between the app and the hospital with the server has the message carrier. Users sends request to the hospital and the app picks up the closest hospital location and transfers the user request from the app (Risald, Suyoto, and Santoso 2018).

2.4.2. Existing EMS in South Africa

The existing system in South African and the most used emergency service contacts are 10111, 10177 and 112; all of which are voice orientated and completely unusable by Deaf people. The 10111 emergency contact requires police as the service responder, while 10177 is for ambulance response that involves an incident with human casualties. 112 is an interactive voice response triage system that helps classify an emergency.[4] These emergency systems require providing personal details, incident location, and type of emergency injuries (WesternCape2018Government).[8]

Vodacom South Africa launched an emergency Short Message Service (SMS) for their Deaf customers on the 24th of April 2018.[9] This system uses 080112 for any kind of hearing or speech impaired people who are Vodacom customers. In order to request help during an emergency, the user is required to send an SMS with the keyword 'Help' to 082 112 from an active Vodacom device, other information required in the text are the type of emergency service required, the nature of emergency, and the victim's location where the emergency is happening. The emergency SMS service is free for registered customer and it exclusively cater for Deaf users on the Vodacom prepaid and Top-up/hybrid tariff.[6]

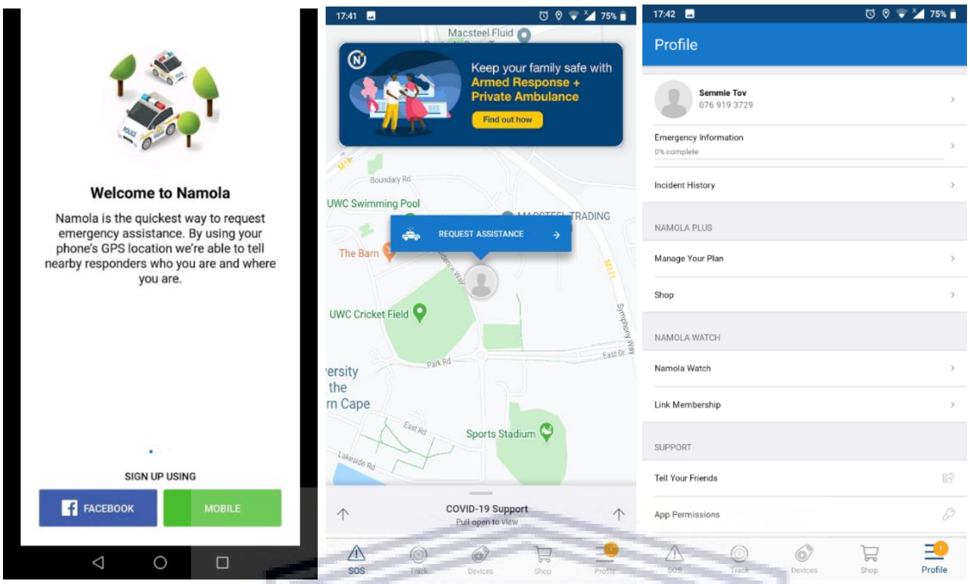
Namola is a new emergency mobile application in South Africa implemented in 2017.[10] It is an Uber-like application for police case emergency service.[10] Working with mobile devices with an enabled GPS for caller location details, Namola users are required to register and create an account that pops up whenever a user calls for emergency. This information is stored to create a record file for users and

[8] Western Cape Government, Emergency Service, 2019. [Online]. Available: https://www.westerncape.gov.za [Accessed: 03- Oct- 2019

[9] Vodacom South Africa, 2019.[Online].Available:https://search.secure.vodacom.co.za/c/serp/vodacom?step=1 [Accessed:03-Oct-2019]

[10] Namola, Monitoring, 2019. [Online]. Available: https://www.namola.com/location-sharing-and-live-tracking [Accessed: 03-Oct- 2019

the details of their accident for future reference to patient treatment. Namola doesn't provide any additional features for Deaf people as it is a voice-based interaction system with the victim during emergency.[10]



(A) (B) (C)

Figure 2-8 Screenshot of Namola app

Screen A is the welcome page of the Namola app which redirects users to the signup up page. It allows user to sign up with an existing Facebook account. Screen B demonstrates the request assistance button which links user to the address on the Google map page. Screen C is the profile page for user details and record of emergency history logged on the Namola app.

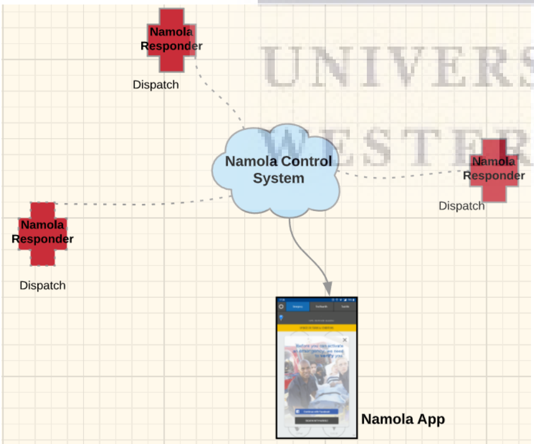


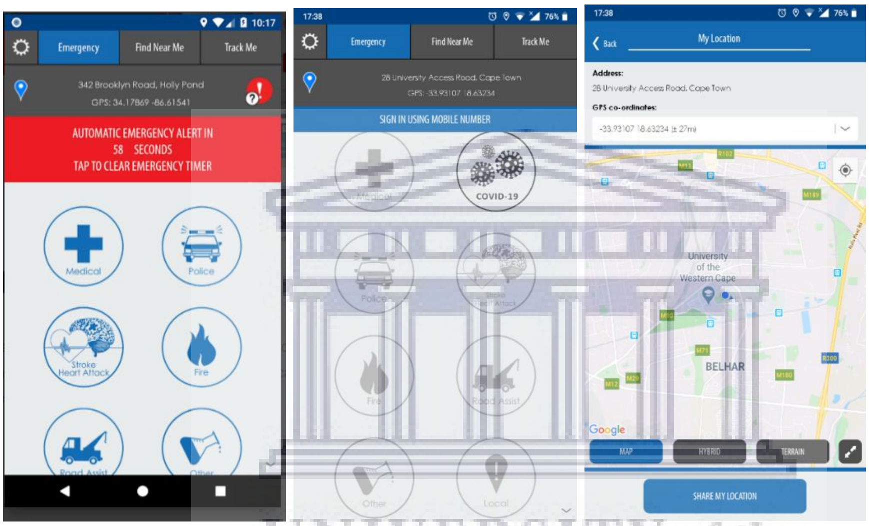
Figure 2-9 Namola architectural display

The Namola app has its control system and other emergency dispatch services (first responders) across the province. When Namola control system receives an emergency call, it picks the user location and searches for the closest emergency dispatch team to forward the details of the emergency for swift assistance.

MySOS is a South African emergency application that partnered with Netcare911, Med-Pages, Arrive-Alive, and Sapaesa[11]. MySOS was established in 2013 by a group of entrepreneurs who identified the need for access to appropriate emergency services in the country and provided a solution which is

[11] MySOS, Panic Button, 2019. [Online]. Available: https://mysos.co.za/store.php [Accessed: 03- Oct- 2019]

MySOS.[12] MySOS app aids users in finding the closest hospitals, pharmacies, dentists, veterinarians, and police stations in a user's nearby area with built-in Google navigation. The MySOS app also includes features like Track Me that automatically alerts emergency contacts.[12] MySOS is very beneficial to tourists, schools, security estates, travellers, and the public in South Africa with no priority for the Deaf people. Although, MySOS doesn't typically involve Deaf people its method can be adapted to a system that can work for Deaf people to serve the same purpose of emergency services.[12] It provides various emergency assistance, to use MySOS user need to activate an emergency on the app, choose nature of emergencies such as fire, medical and roadside assistance, and once an emergency is activated the user's emergency contacts get the details of the person as describe in **Figure 2-9** and **Figure 2-10**.[12] MySOS application is available for Android and iOS users.



(a) (b) (c)

Figure 2-10 Screenshots of MySOS app

MySOS app interface, screen (a) displays the symbols of the services available which takes us to screen (b) which displays user's selected emergency type and screen (c) allows user to set their location. This system provide a simple user interface that could be used by a Deaf person but at the final request stage of MySOS app user need to speak to the first responder to verify the request answer the regular emergency questions.

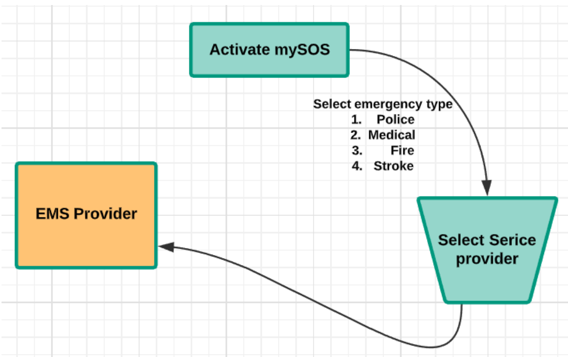
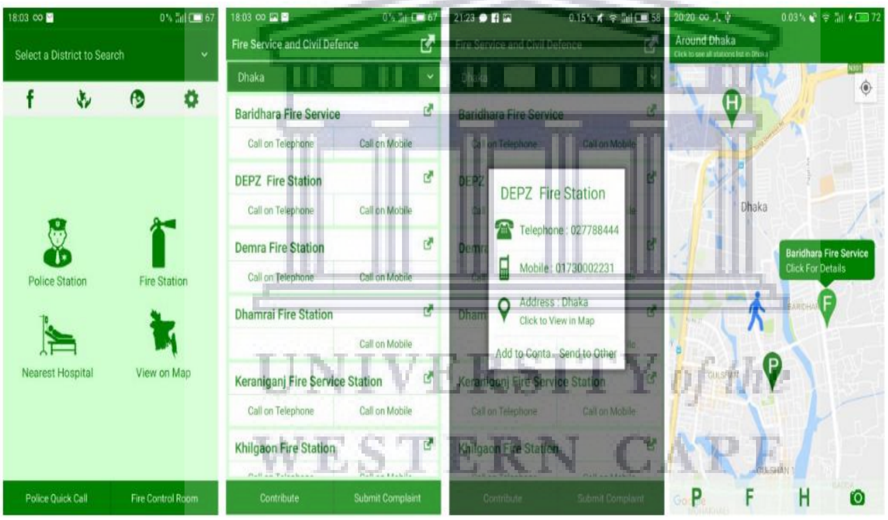


Figure 2-11 Architectural illustration of the MySOS app

The flow of information between the person requesting help to the EMS provider, when a user activates the MySOS app request help, the user selects the type of help needed hence move to select an EMS provider that is close to user's location as appeared on the app for user to call and give more details for help.

In 2018, Hossain *et al.* initiated a 911-like application in Bangladesh termed Bangladesh emergency service (BES) (Hossain, Sharmin, and Ahmed 2018). This system is used to report aggressive behaviour, street fights, harassments, fire-related incidents and for locating the nearest hospital for medical emergencies. It is one of the first mobile-based emergency service aides in Bangladesh utilizing the existing infrastructure and providing automated user location, information, and access to a nearby emergency service provider (Hossain, Sharmin, and Ahmed 2018). BES features provide users with a complete and dynamically up to date contact list of all emergency service provider in Bangladesh with or without internet connection for accessing this information, direction of nearest emergency service providers and view it on interactive google map as shown in figure 16, BES allows users to share contacts, address, and screenshots of emergency service provider with friends on their social media circle. Users are also allowed to make calls to the nearest emergency service provider with the application using a single interaction without storing or memorizing the emergency number (Hossain, Sharmin, and Ahmed 2018).



(A) (B) (C) (D)

Figure 2-12 Bangladesh Emergency Service app user interface design

Screen (A) is a screenshot the home page, made up of four icons to indicate the primary services offered by BES. Screen (B) establish the information of neighbouring fire stations in another screen after tapping the Fire icon. Similar process is applied for Police and Nearest Hospital. Screen (C) shows that tapping each cell will provide information such as mobile number, and address. Whereas tapping the phone icon will help to make a fast call to the corresponding service provider. Screen (D) shows that tapping the map icon will indicate the direction and location of the needed service.

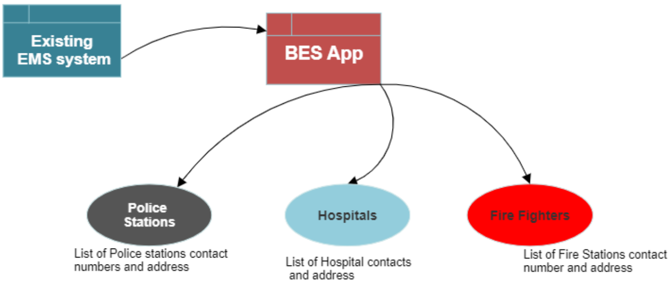


Figure 2-13 Bangladesh Emergency Service system structure

BES app functions are developed to fully operate on its link to an existing emergency system in Bangladesh as the system provides an updated list of all police stations, hospitals and fire fighters contact number and address that is made available to user on the BES app (Hossain, Sharmin, and Ahmed 2018).

Table 2-1 Approaches on providing emergency services to Deaf people.

Description	*Strengths*	*Weakness*
Namola is an emergency calling application in South Africa. It serves police case emergency and uses the mobile phone GPS to detect the user's location	*Since the introduction of Namola it recorded good usage among hearing people, also Namola is able to detect the user's location and dispatch their emergency team to render help.*	*It requires users to give details description of the kind of help needed and other personal information which a Deaf victim at the moment cannot provide because it requires a voice-to-voice communication.*
Mobile application design for a medical emergency for Deaf people using a User-centred Design method. The system is a contribution to an existing system in Indonesia for Deaf citizens to be able to make contact.	A clearly defined Deaf user interface with generally identifiable characters used in a medical emergency.	The text-based aspect of the application was an error due to the different interpretation of signers (language barrier) when calls were placed communication was not coherent.
An application designed for smartphones to allow the medical first responder to browse a collection of emergency related sentences and show the video of the corresponding translation to the Deaf person, in order to give them first treatment.	This application is embedded with a collection of possible questions in Sign language that the first responder may need to ask the Deaf user.	*The designed system to support communication focuses on attending to the victim after they have been alerted for an emergency but not the immediate need for a Deaf person to request for emergency service when they are alone and in need of help.*
A mobile application used in an emergency for communication among first responder and Deaf victim upon arrival at the scene. The mobile application is presented to the Deaf person showing first basic questions that requires a Yes or No response.	*The app was a very useful tool for communication between the first responders and Deaf people. Users were pleased with the application. It tackled the highlighted problem that was mentioned in the problem statement.*	This application does not help Deaf user communicate with the first responder when help is needed it only caters for communication after help arrived.
This is an invention of an assisting device for Deaf and hard of hearing people get help when calling 911 for an emergency.	*Designed mobile device to perform two major function, a normal smart phone and a Deaf or hard of hearing captioning phone depending on the user's preference.*	*Users will need to purchase the device for have access to the captioning feature. This is a major limitation because user may already possess a phone with one function of the two functions the captioning phone is provide. System is not cost effective and depend heavily on user to possess a good texting communication skill*
Bangladesh introduces a 911 like mobile application. The app is used for reporting concerns such as aggressive behaviour, street fight, fire accident & finding the closest hospital for medical emergency. The system employs the existing infrastructures with an additional location feature provided.	*Bangladesh emergency system (BES) gives users an up-to-date contact list of the emergency provider in Bangladesh without an internet connection. One user can share emergency contacts with friends and family. Calls can be made through the application to the nearest emergency service provider without memorizing the contact.*	*All the services made available does not include a feature that can benefit a person with disabilities such as a Deaf person.*

2.5. Adaptation of existing public access emergency systems into a Deaf emergency service

I3 is an emergency call management where calls received from emergency service platforms (ESP) through various communication networks are affiliated with the locations data and recognized on the map server through i3 event protocol, which is visible on the graphical map shown at the operator's position (Biage et al. 2012). The system addresses the next generation of 911, it is an enhanced 911 to an all-internet protocol-based emergency communication system called i3. i3 protocol implicates varieties of emanating networks that could be used to convey calls to a public safety access point, i3 is the first form of the NG911 for the evolution of the North American 911 system (Biage et al. 2012). I3 allows the operator in a position to select a call from the geographical map laid out and an associated responding client enquire the emergency call to be routed by emergency system platform (ESP) to the operator. ESP receives communication from different networks and translates the communication to session initiated protocol (SIP) base communication period and communication workstation, each workstation provides an operator for each call management, identification and dispatch related to the emergency call selected, where the location of the call is assigned to public safety access point (PSAP) is displayed on the map as shown in Figure 2-14(Biage et al. 2012).

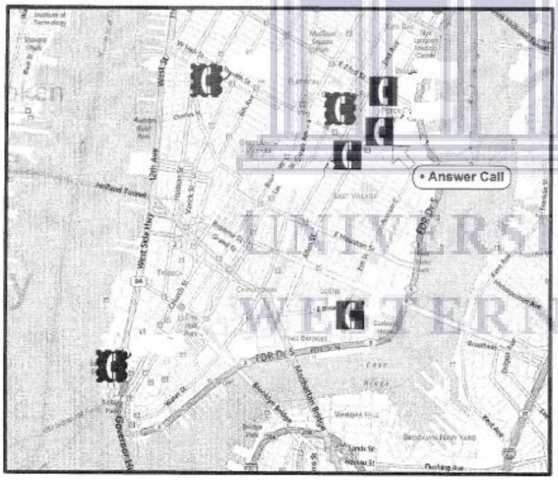


Figure 2-14 A map Interface for call interaction

Multiple emergency incoming calls are displays on the board along with the caller's location at the operator's spot, identifying the status of the call, how long the caller have been waiting, if they have been allocated an operator and the priority of the call can also so noted. Through this graphical interface the operator is able select a call to answer and it will be transferred the operators point (Biage et al. 2012).

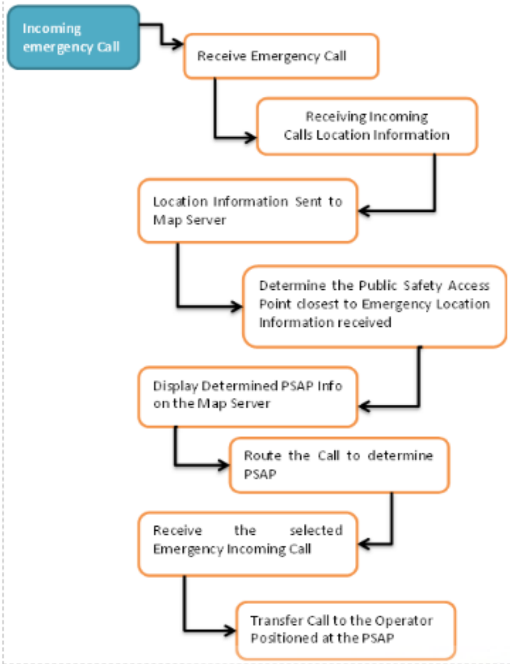


Figure 2-15 Back-end process of i3

Figure 20 illustrates the back-end process of how i3 works, from the incoming call to all network protocols transfer actions done before the final point of answering and getting all location details of the emergency call. i3 uses the map server to determine the user's location for a fast response (Biage et al. 2012).

Similarly, a 911-like system was designed for partially Deaf people called 911 call assistance for the assisted device user. This invention relates to communication tools for Deaf people who need assistance especially to concepts related to 911 emergency calls system for delivering captioning services to serve communication device users (Robert et al. 2014). Phones were designed to provide captioning for Deaf people such that when a hearing person is communicating with a Deaf person, the speech from the hearing person goes on while it is transmitted to a remote relay to produce a text translation on the Deaf user's device. The mobile phones have been made available to be used as normal mobile devices without the captioning depending on user's preference.

When captioning is automatically turned on, an emergency call is initiated, the processor is likewise programmed to offer some type of indication to an assisted user that the captioning button has been automatically turned on. The caption selection button specifies automated captioning as displayed in Figure 2-16. The purpose of these mobile phones is for users who are hard of hearing and therefore want to use the caption option some time but maybe not always (Robert et al. 2014). This device can be used as regular phones or captioned phones and are particularly useful where one or more non-assisted users live with an assisted user and may need or desire a captioning (Robert et al. 2014). The flow of data between assisted user device (Deaf) and a hearing person is shown in Figure 2-17.

Figure 2-16 The captioning keyboard screen

A text is provided through the display Screen when captioning button is on. It displays bold letters to specify upon launch of an emergency call. When a white light illuminate at the back of the caption button it means that captioning is off, when the light that illume is green this indicate that captioning has automatically been turned on, and a red light specify that caption button is turned off (Robert et al. 2014).

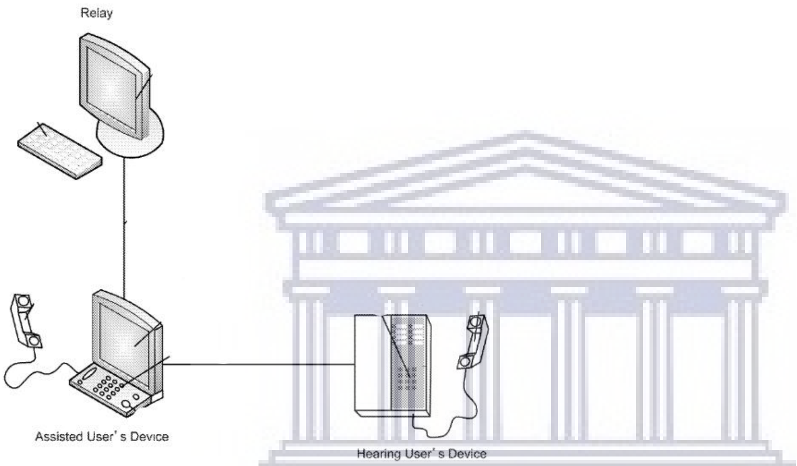


Figure 2-17 Architecture diagram of the Assisted User Device

At the relay, a hearing user's voice messages are transcribed into text and text is transmitted back to the assisted user's device through a third communication link and the transliterated text is presented to the assisted user display (Robert et al. 2014).

The United States in 2015 introduced a System and method for location management and support for voice over internet protocol (VoIP) device, this system processes calls in a VoIP network using a private identifier (PRID) method for receiving calls at a server (Khan, Qui, and Dalley 2015a). IP enables communication provider to be able to support 911 emergency call, such that when a user dials 911, the telecommunication carrier is obliged to be able to process and determine the geographical location of the caller, in other to send the dispatching team to the location. The classification of the caller's location is based on the private identifier and then the system transfers the call to the public safety answering point (PSAP) with a return call from a number linked to the private identifier (Khan, Qui, and Dalley 2015a). This system may utilize five possible server interfaces, each designed for its own purposes as showed in Figure 2-18.

This system describes how the data is transmitted in an emergency where the IP device pushes all the information needed to the central system through VoIP, including the location. VoIP with emergency services for an internet protocol (IP) device comprises, keeping a first roaming service designator linked with a first public user identifier, the first roaming service designator show whether the internet protocol device is permitted to access VoIP services in association with the first public user identifier from diverse network locations, to facilitate creating a first call with the IP device (Khan, Qui, and Dalley 2015a). Keeping a second roaming service designator in link with the second public user identifier. To specify if the internet protocol device is allowed to access the VoIP services in connection with the second public user identifier from the dissimilar network locations, the second public user identifier to facilitate establishing a new call with the IP device, where the first and second roaming service designators are configured for different roaming approvals for both the first and second public user identifiers, and storing them in association first public user identifier (Khan, Qui, and Dalley 2015a). Operating mode designator specifies when the IP device is in a postponed manner that confines the IP device to using a subsection of the communication service linked with the service subscription of the device to using 911 service. More description of the tools and method for location management is shown in Figure 2-19.

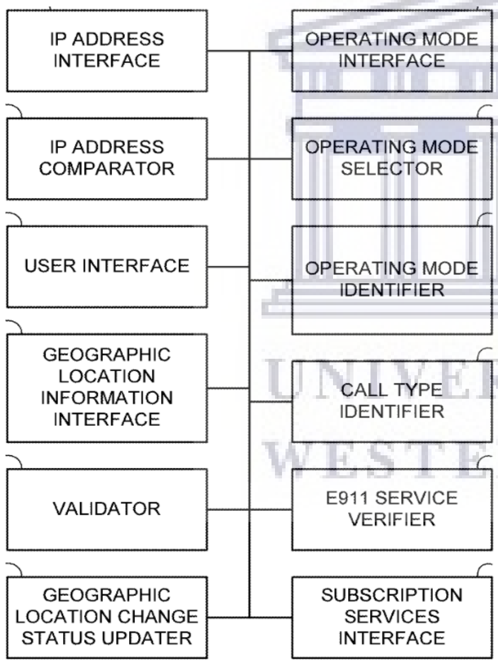


Figure 2-18 Blocked system diagram for E911 service to VoIP device Interface

This shows the interaction among all the fields which may be implemented using a desired combination of hardware, firmware, software and it displays the 5 possible interfaces from IP address interface to the operating mode interface, the user interface, location information interface, and the subscription service interface(Khan, Qui, and Dalley 2015a).

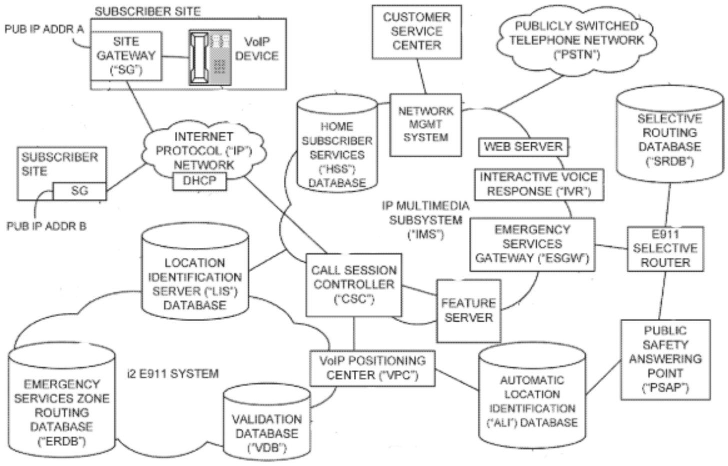


Figure 2-19 Schematic diagram of the network system

The methods associated with Voice over internet protocol (VoIP) to support emergency communication involve determining a geographic location change status associated with the internet protocol device. A message is then presented via the VoIP device based on the geographic location change status requesting a user to confirm whether a registered location associated with the VoIP device is a current location of the VoIP device. If the current and previous IP address differ, the location status is updated to indicate that the location of the device have changed from its previous registered location. The subscriber sites may be residential, or business sites gateway provide user equipment such as computers and VoIP devices network access to network system and be implemented using wire interface network gateways. The internet protocol multimedia (IMS) Subsystem enable different communication technologies work together in delivering an enriched communication to subscribers, IMS is provided with network management system to manage subscriber system. NMS stores data in the Home subscriber service (HSS) database indicating subscriber's features and services. The PSAP corresponds to a particular geographic area, and dispatchers at the PSAP, emergency calls originating from VoIP devices within that geographical area. Dispatchers can dispatch emergency services personnel from a location nearest the geographic location of a 911 caller (Khan, Qui, and Dalley 2015a).

System and methods for automated Personal Emergency Responses (PERS) is an alarm system designed to summon medical personnel in an emergency event (Travis E. 2018). PERS are consistently monitored by a central control centre and with well trained professional staff including medical professionals as an operator at the call centre always made available for PERS subscribers for evaluation of PERS subscribers responds to calls and alerts. PERS users will subscribe to the service for monitoring, in a situation of a sudden ailment, the user triggers the alarm by pressing the button on the subscribed device. This device could be a chain pendant worn around the neck, wristband and/or device carried by users with a wireless transmitter that can be activated during an emergency (Travis E. 2018). When an alarm is triggered, an alert is transmitted to the central monitoring station, where the medical practitioner is then dispatched to the alarm triggered location.

On the contrary, where the central monitoring system is not present, the subscriber's device is programmed to contact friends and family or local emergency responders (Travis E. 2018). There exist other visible forms of an idea such as: a computer-implemented for the purpose of responding to PERS alarm events and a configured response server that allows two-way communication and transmission of data among more than one party and the subscriber's device.

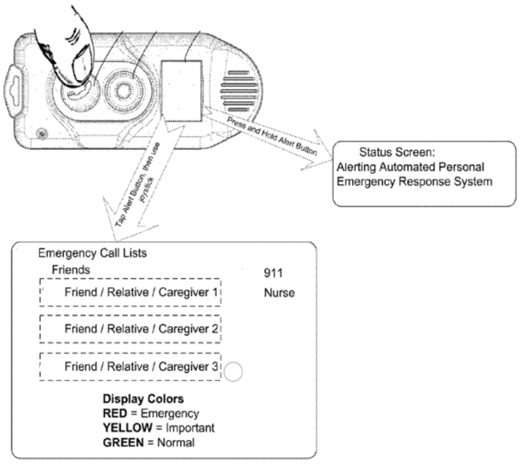


Figure 2-20 Description of the Personal Emergency Response system (PERs) interface

Representing an embodiment of user interface commands accessible to users of the exemplary device, upon the user pressing and holding the alert button, this device will initiate cellular transmission to the personal emergency response system (PERs), to establish a two-way communication between parties to the telecentre and the subscriber device. A status screen will be displayed upon the alert button being held down, informing the user that the subscriber device is Alerting Automated Personal Emergency Response System. When the alert button is released an Emergency Call List be displayed and the number of pre-programmed telephone numbers for a phone call from the subscriber device limited (Travis E. 2018).

This system employs the method used in the some similar approaches, location based management for emergency services done in the United State (Khan, Qui, and Dalley 2015b). Adopting this method, a Deaf person uses the application to push an emergency message through a registered smart phone from the database alongside the destination details and pushed to the nearest emergency service provider. Location and details of the caller are received and pulled from the back end. Healthy phone application developed a system using a user centred Design approach methodology. The emergency app provides Deaf users with an easy to navigate user interface including the user's location details of the nearest hospital identified by the user on application (Risald, Suyoto, and Santoso 2018). Table 2-2 presents the

Table 2-2 Approaches on linking new and proposed systems to existing EMS systems.

Description	Strengths	Weakness
This system introduced system on enhancement of the existing 911 emergency system to an Internet Protocol-based emergency communication system called i3. This system integrates calls from the	I3 introduced an additional feature for feature to the existing 911 which is retrieving and sending the location data and determining the closest public access point. The introduced system is an emergency call management system	This system involves Voice to voice conversation, although the location of the victim can be detected there is a need for call initiation and stating the kind of emergency needed. Therefore,

emergency service system platform with the location information and is identified on the map server through i3.		it is not a suitable system for a lone Deaf person calling for help.
An iOS custom keyboard for Deaf people can use to communicate back and forth with an emergency call centre via SMS texting.	Provide text-based first aid instruction, allows user to customize their message before through selections from options available on the app's interface. It can be used upon the arrival of the emergency first responders to acknowledge some Yes/No questions.	This system involves Voice to voice conversation, although the location of the victim can be detected there is a need for call initiation and stating the kind of emergency needed. Therefore, it is not a suitable system for a lone Deaf person calling for help.
This is an invention of an assisting device for Deaf and hard of hearing people get help when calling 911 for an emergency.	Designed mobile device to perform two major function, a normal smart phone and a Deaf or hard of hearing captioning phone depending on the user's preference.	Users will need to purchase the device for have access to the captioning feature. This is a major limitation because user may already possess a phone with one function of the two functions the captioning phone is provide. System is not cost effective and depend heavily on user to possess a good texting communication skill.
This system focuses on the location management and support for VoIP. The system uses a four-server interface, each with its designed purpose. It uses the structure of an existing system for emergency service	Makes the data transmission process done when a call is initiated for emergency request very easy to be transferred to the emergency central system	The system still requires voice exchange conversation when help request is pushed to the emergency centre.
This is an alarm system designed to summon medical emergency personnel. This device for this system could be any device with a wireless transmitter that can be activated during an emergency. The system is consistently monitored by professionals including medical practitioners	In cases where the central monitoring system is not present, the device is programmed to contact family and friends. Portability of the device and the user does not have to initiate a call, this could be work for deaf people in an emergency.	As much the system considered the option of reaching out to family and friends of the victim, it does not resolve the need for medical attention which is the purpose of the device. This system is very expensive to build and maintain.

2.6. Summary

This chapter discussed structure and features on existing works from general EMS approach to the Deaf EMS system approach. SignSupport for emergency app is adopting several methods from literature reviewed in Table 2-2 above, given all the limitations our proposed system intends to find a way to overcome them. The overall goal of SignSupport for emergency research is to investigate the needs of users who are highly at risk for a system that will serve them in requesting for emergency independently. Universal design give emphasis to the need to accommodate all possible users when developing a system. The next chapter explains the methods that will be used to guide the research processes and development of the SignSupport emergency app.

3. Methodology

This chapter deals with the research approach used to investigate the research questions and explains the research methodology adopted for this project. Section 3.1 unpacks the research questions, Section

3.2 discloses the methods used to examine the research questions, Section 3.3explains how to apply the methods identified in Section 3.2; Section 3.4describes the design process; Section 3.5 discusses the ethical considerations involving all participants, especially the vulnerable Deaf participants; and finally, Section 3.6 summarises the chapter and leads to the results in the following chapter.

3.1. Research questions

Considering mobile technology as the major and accepted tool in the world and for Deaf people, a mobile device application will be the preferred choice for an achievable solution.

1. How can an EMS be provided to a Deaf person in need of urgent rescue attention?
2. What can be done to craft a bridge between a mobile interface for Deaf People and a standard hearing EMS contact centre?

3.1.1. Research question 1: an EMS for Deaf people

In most cases of emergencies involving Deaf persons, communication with an emergency service first responder is challenging due to the communication barrier; and this hinders required cases from getting the needed attention. To provide an effective means of communication for emergency support for Deaf people, SignSupport for emergency is a smartphone application developed to assist Deaf people during emergencies. This application is Deaf-centric with an interface designed with icons and videos from Deaf signers. SignSupport for emergency app is built to be used on the Android platform to share a Deaf user's emergency request with a Deaf contact centre, which can then provide for easy integration into an existing EMS provider system.

3.1.2. Research question 2: connecting to an existing EMS.

SignSupport for emergency app features include using the Deaf user's mobile GPS to detect the incident's location, which is forwarded alongside the help request and the nature of emergency. SignSupport for Emergency also provides a medical history section for Deaf patients to fill in allergies and a list of their emergency contact details. This information can be pushed to the contact centre agent receiving the patient's emergency request. The aim is to automatically provide such information to the EMS contact centre that would otherwise be extracted by a conversation with the caller.

3.2. Methods

Methods are specific processes for completing data collection during research. Data collection and analysis is done using different kinds of research methods and research techniques. In this section, we will discuss the methods employed by the process of prototype development and testing.

3.2.1. Co-design and participatory research methodology

Co-design methodology involves multiple entities or bodies when academic and community members work together on projects from the planning phase to the design phase. Co-design thus generates a meaningful diverse and affluent learning experience for all the entities involved; and can contribute to social and cultural regeneration of the community. Participation is a community oriented and engaging procedure since it unites isolated individuals around common problems; approves their encounters as the establishment for understanding and basic reflection; presents the information and encounters of external practitioners as additional data; and contextualizes what have recently felt like individual problems and shortcomings by connecting them to development actions (Dearden and Rizvi 2008).

Participatory design is a process by which people, especially disadvantaged people, influence decisions that affect them as opposed to one where decisions are imposed on them by hierarchical outside agencies (Dearden and Rizvi 2008). Co-design amplifies knowledge exchanges between researchers, professionals, and the communities, it is therefore an integration of life learning. Co-design is a creativity of designers and non-designers working together in the design process (Kankainen et al. 2012). Co-design and participatory design ideas involve the user in its design process for a more effective and accepted outcome. These designs are human-centred (Yalman and Yavuzcan 2015); users are seen as a partner, not as a passive object of study; and it is 'designing with users' notion instead of 'designing for users' into a practice in education field (Yalman and Yavuzcan 2015). In other words, co-design and participatory design can be summarized as:

- ❖ Breaking down institutional and organizational isolation through involvement that brings change.
- ❖ Conducting a collaborative research partnership between researcher and participants.
- ❖ Giving all participants an emancipative and transformative sense of achievement.
- ❖ Allowing a collective of diverse of people to share knowledge, skills, and expertise, encouraging the circulation of knowledge development.
- ❖ Encouraging technology transfer to people in need, which is often essential for projects to have long-lasting impact (Dearden and Rizvi 2008).
- ❖ Creating a comfortable and reliable work relationship between the researcher and all participants involved.
- ❖ Inspiring a culture of self-help and an obligation among the people to the development of their own communities (Dearden and Rizvi 2008).
- ❖ All the while, researchers must follow the ethical guidelines that do not compromise the participants' rights throughout the duration of the research process (Goodyear-Smith, Jackson, and Greenhalgh 2015).

Casali (2013) suggest that researchers adopt tools such as idea repository and straw-man-concept to leverage the knowledge of both participatory and co-design methods. Individuals also learn and strengthen their belief in their abilities and resources, as well as further develop their skills in collecting, analysing, and utilizing information.

Idea repository prioritizes the list of features coming from users and then blends with other kinds of research and data points; and this was all synthesized to come up with an initial complete idea (Casali 2013).

Straw-man-concept is using the feedback gotten from the community to create a first design that reaches the initial objective (Casali 2013). This design idea would be sketch of the complete idea in a low-level detailed design; and then the design commences its further iterative phases.

According to Bowen (2013) a steering group was established for the UK National health service (NHS) to oversee a project on incidence of chronic health conditions and subsequent need for self-care, to achieve an effective design of healthcare services, the need of a collaboration among managers and patient representatives is important (Bowen et al. 2013). Co-design and participatory services design methodology was used to develop a better understanding, participants in the project took part in semi-structured interviews as the method adopted for reflecting on their involvement with the project. Most participant reviews were positive as they discuss the value they perceived in story-sharing, emotional mapping which displays an efficient collaboration between service users and service providers and recognising areas for enhancement by focusing on experience (Bowen et al. 2013).

In this research, the researcher followed a similar approach to Bowen et al. (2013) in implementing co-design and participatory design methodology, we prioritized the participant (Deaf community) idea and formed a working relationship among other stakeholders (Experts, WCP and design researcher). The initial idea for this research was obtained at a meeting with DCCT, where we had a discussion with a view to understanding the major problems facing DPOs. We were interested in understanding their experience and perspective before embarking on the research. The meeting yielded the SignSupport for emergency app idea and we adopted co-design and participatory design methodology such as the use of a focus-group, questionnaires, and semi-structured interviews as a means of identifying major features and revising our own thoughts and reflection. Hence, we came up with the first basic design of the SignSupport for emergency app from the group session feedback.

3.2.2. Qualitative methods

Qualitative research is an approach that allows us to examine people's experience with a specific set of methods such as interviews, questionnaires, observations and focus groups (Langford 2012). This method allows us to identify issues from a study participant's perspective and understand their interpretations and meaning of events. Qualitative research methodology understands and epitomizes rather than predicts. It is a study that combines the methods and techniques of observing patterns, attributes, document and meaning of human experience (Tessarolo et al. 2019). The purpose of using multiple research instruments is to understand different phenomena. The data collection methods used herein are presented below:

Focus group methods are like interview methods but it involves a group of people in a discussion. Focus group interview is described as a scientific qualitative research method which has remained extensively useful in academic spaces, e.g. in social and behavioural science, for over 80 years (Redmond and Curtis 2009). It is frequently used to support quantitative studies as a data source. During focus group meeting, participants can communicate with other participants in a comfortable way. In this study, one of the questions asked was on how can rescue services be provided for the Deaf community and the responses from this question lead to the design of SignSupport for emergency app. We formed a focus group of 12 participants who were chosen from the Deaf community based on the scenarios we already developed.

Our focal characteristics were users who are comfortable with mobile technology and phones but not expert users. We also have a member who is very curious about technology and learning programming. A representative from the DPO was the moderator for the focus group sessions, this representative is a SASL interpreter who is a member of the community and was chosen because of their years of expertise in working with Deaf people and their skills at managing communication with similar focus groups while making sure the entire meeting is on track. Video recordings and photographs of the sessions were taken for data collection during the meetings to aid shared understanding and the vulnerability of the participants were taken into consideration. See section 3.5 for further discussion.

Observation: In this study, observation was used to create an understanding, to provide a better platform to later review information and possible differences between what people say and their reaction to it, to familiarise we with the activities of the community, to gather data on how users interacted with new ideas in the community, and to discover things that people may not wish to reveal in questionnaires or something they may not have thought of mentioning. Different types of tools such as field notes and pictures were taken to facilitate the observation process. All through the sessions of this study, observation was made on some similarly omitted questions by the participants, an example of this was a question asked on "what would like to do to improve SignSupport for emergency app", and we observe that participants would prefer to talk (sign) about their thoughts rather than write it down. This is discussed in detail in section 4.3.5.

Interviews: When conducting an interview, it is reasonable for the interviewer/researcher to be natural with the agenda, so that the process appears less rehearsed. However, the researchers must possess a data collection techniques such as recording to ensure that comprehensive and representative data is collected (Gill et al. 2008) . More importantly, the ability to listen attentively to what is being said, for participants to be able to recount their experiences without interruptions. We employed a semi-structured interview method which consisted of several key questions that help to identify the areas to be explored, but also allows the interviewer and participant to diverge to pursue an idea in detail. This provides participants with some guidance on what to talk about, which many find helpful (Gill et al. 2008). Semi-structured interviews were a key tool during the entire course of this research, it was used to get in depth details of the participants expectations of the final app and how to improve it. For instance, a question we asked at the first meeting was: "How does a Deaf person want to be serviced in an emergency?" The feedback from this question gave an insight on how SignSupport for emergency will be integrated with Deaf contact centre to an accepted system that can be incorporated into a standard hearing EMS system.

Questionnaires are used to assess participant thoughts from a given self-statement in order to examine endorsement measure of a product (Glass and Arnkoff 1997). Questionnaires can be a closed ended or open-ended question. For this study, both types of questions were applied. Close-ended questions provide a predefined answer option for the participant, it could be a 'yes' or 'no', multi-choice, check box, rating scale or Likert scale. Open-ended questions do not have a predefined answers; participants will supply their answers to be able to express their opinion freely (Maramba, Chatterjee, and Newman 2019). In a similar project, questionnaires were developed to explore the use of assistive technologies, as well as functional electrical stimulation in stroke patients. A cognitive interview technique was used in developing the questionnaire as it is considered a useful method for identifying and correcting problems (Triccas et al. 2016).Finally, the result of this study shows that participants have provided vital insight from exploring interviews and from well-designed questionnaires.

We followed the same methodology for our questionnaire designed to survey how the user interface for SignSupport for emergency app will work. We explored concepts ranging from how many pictorial assets were considered overwhelming, the size of buttons and length of videos. The result provided more clarity on what is better accepted by the Deaf community; about 70% of pictures and less textual content with highly visible headings for easier navigation.

3.2.3. Iterative prototyping

Iterative prototyping fits within a software development life cycle, where developed prototypes are assessed by participants and feedback is given, after which a new prototype will be developed according to the feedback (Adel and Abdullah 2015). This process of re-modification is iterative, it helps in the development of a usable system which gets verified by participants involved in the development for correctional purposes. This method is more reliable than the waterfall model, which goes through with the development until completion and delivers to the intended user (Casali 2013), (Adel and Abdullah 2015). Corrections made at the end of one incremental testing provide a positive result for the next iteration; and the convenience of finding errors earlier is less expensive to fix.

This research adopted iterative prototyping to develop the SignSupport for emergency app, we find it useful to follow the iterative research approach (see Figure 3-1) of Lauren et al. (2017) in creating a requirements prototype for Young Deaf Children (Lauren, Research Online, and Korte Bachelor 2017). In the context of our study, we started from the original idea and iterated four times before we arrived at the final prototype. The first prototype was a very basic design that only offers the user a way to send a request to the EMS provider using WhatsApp as the transport platform. This prototype was subjected to usability testing that suggested that WhatsApp is in the idea transport layer, so the second prototype was designed which removed WhatsApp entirely from the study. A second prototype was designed that uses an API-centric design that will eventually allow the prototype to connect to various EMS provider services. The prototype was widely accepted by the stakeholders but the usability testing on the focus group came back with a major request for new features such as SASL video tutorials which will give a user some first-aid instructions while waiting for the EMS service to arrive on the scene. The research team came up with the scripts for the videos needed for the third prototype while DCCT recorded the videos and gave it to the researcher for editing and modification to suit the prototype under development. Once the third prototype was complete, the stakeholders met again to discuss the prototype and it was decided that the prototype still has a missing part: an emergency contact feature where the user can have a list of already vetted contacts that the EMS provider will contact on their behalf once an emergency occurs. This final prototype was developed, and all the stakeholders and target users agreed during usability testing that it is suited to their needs. The workflow for the study is shown in Figure 3-2.

Figure 3-1 Iterative process model

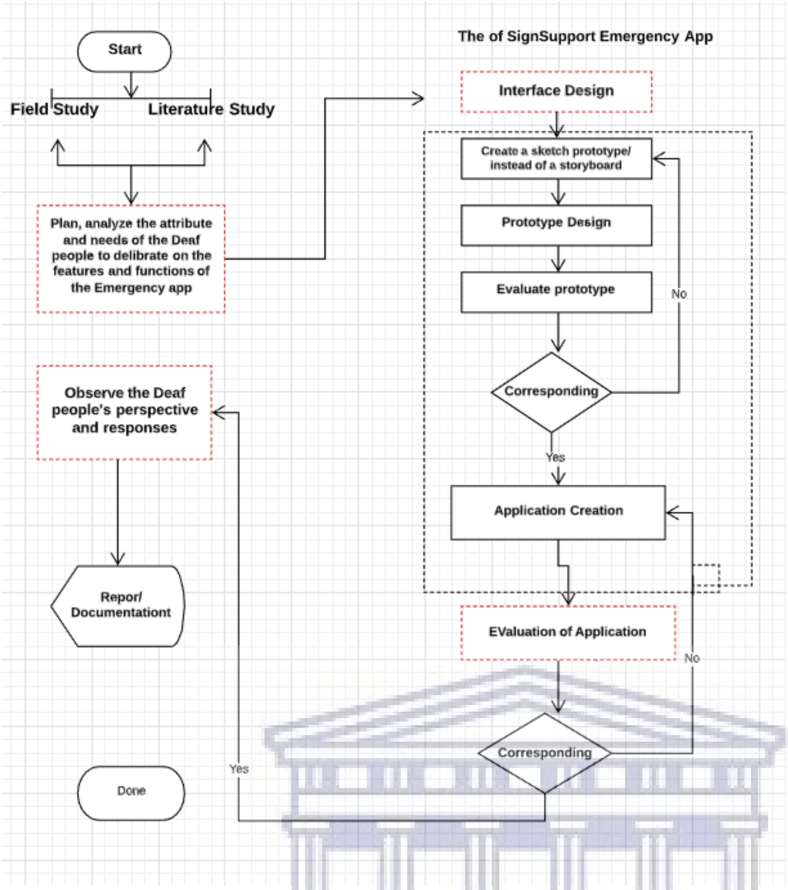


Figure 3-2 SignSupport for emergency research workflow

The Figure illustrates the two phases that began the research process: field study and literature study. The field study was conducted by observing, interviews and focus group meetings. In the field study, participants were made up of 13 Deaf people and 2 hearing persons from the Deaf community, 6 hearing people who represented the Western Cape provincial EMS and acted as our domain experts from the EMS point-of-view, 10 individuals who formed the steering committee for SignSupport, 4 research team members from University of the Western Cape and 1 person who was the product/project manager. The steering committee is made up of both Deaf and hearing people and are our go to source for quick information and advice. The literature study was conducted consulting academic materials at libraries and searching for supporting research literature such as reading different sources from the internet such as articles, thesis, and journals related to the research topic. In addition, questionnaires were also given to the Deaf community members to obtain more supporting data.

3.3. Methods application

This section explains how we applied the above-mentioned methods to the study. Co-design and participatory methods encourage a collaborative research partnership among researchers and stakeholders, see section 3.2.1.

We started the research by setting up an open objective, which was how the SignSupport team can be of help to the Deaf community. Since our primary users and domain experts are the Deaf people, we met with them to discuss the problems they have. At that meeting, we brainstormed over various ideas and those ideas were set to a vote where the emergency app emerged as the outstanding problem facing the community since obviously Deaf people have limited access to the emergency services without help of a third party. The researcher being aware of the co-design methodology strictly kept her role to moderating, directing the focus of discussion, and helping the brainstorming happen. We wanted the idea to be Deaf community aligned. We were careful to keep the conversation on track and be open to new ideas. Once the emergency app idea was identified and prioritised by the community, it was time to bring in another major stakeholder which is Western Cape Provincial EMS Centre (WCP). This stakeholder manages EMS calls that fall within the province. We met with them and learnt about their existing system, showed them our ideas, and discussed how we can integrate our solution into their service.

Finally, it was time to build the user epic. That is, a prioritised list of features that should be included in the proposed app. Then, the researcher did other kinds of research, consulted literature on previous work and data available before coming up with the initial complete idea of how the app will work. This proof-of-concept was shown to the domain experts which are Deaf community stakeholders and the WCP EMS provider. We intended that the design process would be participatory for all users and they were invited to contribute to the design/developmental process. We had several iterations and used a combination of tools like questionnaires, focus groups, semi-structured interviews, and contextual enquiries to get feedback from all stakeholders which were incorporated into the work in an iterative pattern. Involving the users in the research process ensured that the research has the best of both design methodologies, co-design fares better when the researcher shifts to a supporting role and let the design process be community-driven whereas participatory design shines when all stakeholders, especially less privileged users, are involved actively in the design process (Casali 2013). We will discuss the stakeholders and the process in detail in the sections below.

3.3.1. Research team structure

This study was a combination of efforts from various people that include the participants, domain experts, collaborators, and the researcher. This section discusses the details of their involvement and contribution to the research.

Participants (Deaf communities): The Deaf participants come from Deaf communities associated with the following Deaf People's Organisations (DPOs): DeafSA, DCCT, and NID. Over the years, there has been a long-term relationship between these DPOs and the University of the Western Cape, working interdependently on several projects that aim at positive contributions to Deaf people's daily lives. Some of these communities include a few hearing individuals such as interpreters and some experts who specialize in these scenarios. The DPOs helped in facilitating the focus group meetings. In one meeting, the DPOs appointed representatives on a steering committee in discussing the SignSupport projects. They assisted in selecting the Deaf end users to participate during the sessions. They also made the scheduled meetings for the data collection possible and at each session, interpreters were made available.

Domain experts: This study is intended to come up with a working prototype that presents the vision of working in the real world and as such, our solution must fit right within the existing systems. We used co-design and participatory design methods by developing the solution with the domain experts. The primary domain expert for this research is the Steering committee for SignSupport, which is a group of 10 individuals, consisting of stakeholders such as leaders of various Deaf communities, academic researchers from UWC and other representatives. The steering committee was established to create solutions for Deaf people and as such they have years of experience in issues facing a typical Deaf person and can offer advice on ideas that will work or are likely to fail.

Also, the Western Cape Provincial (WCP) EMS centre was a domain expert for this research. They provide services to the Deaf person after an emergency request has been made, WCP EMS offers SignSupport team access to observe their present EMS operation system and how their first responders interact with the callers requesting emergency assistance.

Another domain expert was the project/product manager for the SignSupport project who designed the user epic stories that was used for the user testing scenarios and introduced the team to the WCP EMS and leading us with his work experience from other EMS groups. He facilitated the focus group meetings with the EMS and was also very involved with the DPOs. The domain expert also conveyed the incorporation between the Deaf contact centre system and the SignSupport for emergency App for possible integration to the EMS centre provider.

3.3.2. Limited domain scenarios

These scenarios were noted at the focus group discussion on the most prioritized incidents emergency needed and were prepared using the SignSupport for emergency app in the testing stage:

Police Case Emergency: Generally, in South Africa, when there is an emergency requiring the police, the approach is to call 10111 which is the emergency contact available for the public. A Deaf person in this situation will need assistance from a hearing person to help them make a request call to give them the details of the Deaf person involved in the incident. SignSupport for emergency app will be used to play this scenario by the Deaf users to request help from EMS through the Deaf contact centre and all personal details will be received on the Deaf contact centre platform. Also, the requester's emergency contact will be contacted.

Medical Assistance Emergency: Medical emergency request is one of the most crucial moments when help is needed almost immediately it is requested. We direct the user through the process of requesting help, which is very easy and direct, the Deaf user is then encouraged to make a medical emergency request. The request details and location of the victim is received by the Deaf contact centre agent.

Fire Emergency: Traditionally, it is required to call the Fire fighter squad through the general emergency public contact or call a fire station and explain to them the situation with the address of where help is needed. In the case of a Deaf person requesting help in such method will be difficult.

SignSupport for emergency app firefighter emergency feature will be tested by the users to request help while observing the usability.

SASL Help Tutorials: In some emergency cases, victims might be able to help themselves or assist someone who needs help before the emergency providers arrives at the scene. We believe that if materials that can initiate self-help are made available on an emergency platform, it will be helpful the victim and the emergency service provider. SignSupport for emergency app will of benefit in way that the design includes SASL pre-recorded video tutorials to assist the users.

3.4. Design process

In this section, we discuss the process undertaken to apply the methodologies discussed in earlier sections to develop our prototypes in an iterative process that involved the Deaf participants, the domain experts, and the product manager. Each iteration generally involves seeking the approval of the DPOs and informing them of our intention to carry out an experiment at their premise. Once the approval has been obtained, the researcher and her team visit the community to discuss with the DPO's representative and a focus group session is organised. Each session begins with the distribution of an information sheet which educates the participants about the aims of app, how it was developed and how the participants will contribute to the project. It also informed them that their contribution was voluntary, and that all information collected would be treated confidentially. A SASL interpreter, which is usually provided by the DPO, is readily available to interpret the sheet for the Deaf participants. The next stage involves confirming that the participants understand the information sheets and they are ready to participate in the research after which they sign a consent form to witness that they concur to participate in the iteration process. The preliminary stage is capped off with a PowerPoint presentation that describes the stage of the prototype, explaining the app's functionality and what action is expected when performing the testing. After which, the testing starts. Shown below this section is Table 3-1 Encounter table, which describes the duration of the project.

3.4.1. First iteration

The facts acquired from different works of literature on work done in emergency services and the study research question led us to the creation of the first SignSupport emergency app prototype. Our objective is to create a mobile app that can be used by a Deaf person to contact EMS services. As discussed in section 3.2.1, the initial idea for the research was obtained at a round table meeting with the DPOs which was further refined at a focus group session.

The session showed that the expectations of the Deaf communities is an app that uses pictorial assets such as icons and less textual instructions and a clear-cut navigation menu. The product expert was very involved and contributed to the overall direction of the prototype. We also used domain experts from the DPOs and WCP EMS to articulate ideas gotten from the Deaf community fleshing out the basic features of the prototype to better align with the needs of the users. The initial focus is to design a complete low fidelity mock-up for deeper feedback and a better design which can then be analysed before transforming it to a high fidelity design that captures all the details needed (Casali 2013). This low fidelity design prototype was a quick sketch using pen and paper. Our aim was identifying the key user flow from initial opening of the app to sending a request to the EMS. After getting feedback from the product-expert, this design was converted to a high-fidelity design using Justinmind. Justinmind is an UI/UX tool that is used for mocking and prototyping web and mobile apps. Although it is a paid service, we used the free tier for our prototyping work.

Sampling This iteration involved 6 Deaf participants and 1 interpreter from the DCCT. The interpreter is an employee of the organization whose task is to assist and empower other Deaf people. The selected participants were appointed by the chairperson of the Deaf community based on our research needs which is people with basic knowledge of mobile applications and are comfortable using mobile phones. The participants have been through similar exercises in the past years, which makes the information session familiar to them. We are convinced that this group of selected participants are the best for the process from prior general conversations and with recommendations from other employees and members of the organization. The interpreter was present throughout the session to help with translation from the English language to SASL between the researcher and the participants.

Table 3-1 Encounter table from the first meeting with Deaf Community to the Final testing

Iteration	Size	Date	Location	Duration	Type	Details
x	10	08/03/19	DCCT	3Hrs	Meeting	First meeting on discussion of various challenges of the Deaf community. This was the beginning of Emergency service for Deaf people's
x	5	27/06/19	WCP EMS Centre	2Hrs	Contextual enquiry	Went to work with the EMS on ideas about integration
x	4	28/06/19	DCCT	2Hrs	Studio work	Discussion on first-aid tutorial script and recording Sign language video.
1	6	21/05/19	DCCT	2Hrs	Testing	Tested the initial idea for viability
2	8	17/07/19	DCCT	3Hrs	Testing	Testing of the second prototype
3	6	23/09/19	WCP EMS Centre	2Hrs	Testing	Testing the prototype with the EMS centre
4	9	08/11/19	DCCT	3Hrs	Testing	Testing of the final prototype of Sign Support for emergency app.

Testing Procedure The testing session was to check the features of the SignSupport for emergency app for usability. The goal of usability testing is to get the target users of the emergency app to complete tasks to measure the ease of use and whether they are appeased with the system. This involves checking the technique of requesting emergency assistance from the designed prototype. Testing these features will give an overview of the system functionality and an insight into what needs to be improved. The procedure for achieving this was primarily divided into three stages: training, testing, and feedback.

The training stage started with an introduction to the research and its objective. Next is introducing the first basic prototype to the participants. The prototype was installed on the researcher's mobile phone who then demonstrated the features and the user flow. Afterwards, the participants were then handed the mobile phone and were asked to use the app.

During the test, participants used the app to simulate various emergency scenarios randomly and they were observed by the researcher as they interacted with the prototype. After the tests were completed the researcher carried out a semi-structured interview with each of the participants with the aid of the interpreter. Some of the questions are: "What do you like about the app?", "How can we improve the app?"; "Is there a feature that you wanted and didn't see?". Data collected from this experiment is discussed in section 4.1.5.

3.4.2. Second iteration

The second iteration started with a visit to the WCP EMS where the research team met with the management of the emergency services for a contextual enquiry into how the EMS carries out its activities on a day-to-day basis which included observing various activities such as receiving emergency requests call, triaging those calls into different categories, and sending the request to the appropriate first responders. The team also specifically asked why the EMS is not servicing the Deaf community and discovered that it was due to the lack of infrastructure and sufficient funding. Then, the researcher and her collaborator spent the entire day at the EMS shadowing the workers in a bid to learn more about how they handled their jobs and how such processes will be replicated in the prototype and system architecture. At the end of the contextual enquiry, the research team, consisting of the research supervisor, the product manager, research collaborator and the researcher met with the technical team of the WCP EMS to brainstorm on how the research can improve the existing system and facilitate sending emergency request to the EMS from the SignSupport for emergency app prototype. An option was presented that involves setting up a dedicated help desk with specially trained call centre agents at the EMS to handle emergency requests that come from the app.

The Deaf community already has an ongoing research project called the Deaf Contact Centre which is a relay service built to accommodate other similar projects currently in use by the Deaf community to effectively communicate with services that are originally designed for hearing people. This relay service is meant to coordinate and service all the projects currently under development for the Deaf community such as the Pharmacy app and Diabetes app. The research team had further consultations with the Deaf community and the EMS, and it was decided that the Deaf contact centre which is already in active development is a suitable solution and it will aid the pace of the research. Also, the Deaf community will greatly benefit from using the Deaf contact centre as the service can evolve independently of other external services that they may be connected to now or in the future.

The next step was a major redesign of the user interface based on the feedback obtained from the testing of the first prototype. The design tool was changed based on some identified limitations of the Justinmind software such as not having the ability to create more complex components, so Adobe XD was chosen as a replacement. The basic skeleton of the app was maintained which was improved with the addition of more vibrant colours and icons to make it more appealing to Deaf users who are majorly visual learners (Marschark et al. 2013). This prototype also improved features like categorization of emergency requests by adding relevant icons and colours to depict each emergency: medical, fire and police (law enforcement). Furthermore, WhatsApp was integrated into the prototype through a paid third-party service called Chat API to send emergency requests to the Deaf contact centre. Chat API was used because WhatsApp does not allow direct integration into its services. The addition of WhatsApp gave the Deaf users the ability to chat with the Deaf contact centre and send their real-time location and possibly send pictures of the emergency and videos.

The main purpose of this iteration is to determine how effective it is as a tool for a Deaf person to contact the EMS service. We concentrated on how the Deaf user can make a request during emergency, give the EMS their location and personal and other pertinent details and the ease at which they get help. The Deaf user was encouraged to give suggestions on improvements and how we can make the prototype better.

Sampling: The participants for this iteration are both hearing (60%) and Deaf participants (40%). The selected hearing participants were chosen based on close working relationships with the Deaf communities and their understanding of the communication and other needs of Deaf people. The selected Deaf participants included some of the participants from the first iteration and some new Deaf members who will be interacting with the prototype for the first time. These participants were selected based on their experience in working with similar solutions by the Deaf community chairperson. All our participants except the hearing users are prospective users of the app and therefore they are the best candidates to conduct the tests.

Testing Procedure: This session again began with the researcher introducing the objective of the research and the work done so far. Then, the prototype was shown to the participants and the researcher simulated an emergency where she requested for help using one of the scenarios. The participants were then encouraged to use the prototypes, which have been installed on a few smartphones for that specific purpose. The smartphones were manufactured by Xiaomi communications, the model is RedMi 2 and running the android platform using the version 8. These phones with the prototypes already installed were handed to the participants and who were tasked with replicating the scenarios for the actual usability testing. Participants are observed while using the prototype, as the researcher documents problems and confusion they encountered (Holzinger 2005), (Maramba, Chatterjee, and Newman 2019). If similar problems occur, recommendations will be made to correct the issues. Participants were encouraged to think out loud while using the app: what they are currently doing, how they expected the app to respond, what they expect at the next screen and if they think a response is out of place after carrying out an action. After the testing session, the researcher carried out semi-structured interviews with the participants individually using a SASL interpreter provided by the DCCT. The most important questions used during the interview were:

- How would you describe your overall experience with the prototype?
- What did you like the most about using this prototype?
- Do you think it is something you can use effectively during emergencies?
- What did you like the least?
- What, if anything, surprised you about the experience?
- What, if anything, caused you frustration?

The data collected from this experiment include adding features such as Ability to seek help for a friend, wants more icons and less text and videos should have closed captioning. This is further discussed in section 4.2.5.

3.4.3. Third iteration

The third iteration followed an entirely different approach from the two previous iterations where we concentrated on the Deaf people as the end users whereas this iteration majorly focused on domain experts. The product manager arranged a meeting with the WCP EMS team which gave us the opportunity to get them to test the app as usability testers. We evaluated the SignSupport for emergency app as a solid technical solution for the research questions. The aims of this evaluation are; "Check the integration of the app into the current emergency system", "To get recommendations on how we can improve the emergency app", "Confirm the ease of use on the SignSupport for emergency app" and "Understand how the domain expert's (emergency provider) view the SignSupport for emergency app". This experiment consists of three parts, which are the sampling, procedure, and data collection.

Furthermore, the domain expert knows all that is required of a person requesting an emergency service, such as the standard questions needed to assist the victim. For example, when the first responder takes a request from a hearing person, they request the name, address and what type of help is required. This is not possible with a Deaf person, as s/he speaks a different language from the first responder. However, the first responder needs all these details to be able to process the request, and the situation becomes difficult for both parties but more for the Deaf person who needs the service. This is a major reason why this iteration concentrates on the emergency service provider (hearing domain expert).

Sampling: A purposive sampling is used for this iteration with different participants. This iteration was evaluated with the domain experts among which were 7 Western Cape Provincial EMS executives and first responder's team, a fellow researcher that designed and developed the Deaf Contact Centre and the product manager. The WCP EMS representatives were chosen by the branch manager and they are team leaders from different sections in the EMS centre. The fellow researcher from the university research team was chosen because he is an expert on encoding emergency requests and sending it to the EMS and the product manager who is an expert solutions architect who understands how all the individual parts fit together within the system. The session was conducted in Afrikaans and the fellow researcher, who is an Afrikaans speaking person, interpreted for the rest of the team.

Testing procedure: This procedure consists of a training and testing phase. In the training stage, there was a formal presentation which recapped the functionalities of the SignSupport for emergency app and the changes that have been made to the prototype since the researcher last met with the domain experts. This is done for better understanding of the app although the participant group are professionals and very experienced in this field. It must be noted that consent was gotten verbally and not documented as practised in other prototype testing sessions. Afterwards, we begin a try-out session of the app. The product manager moderated this session using acceptance tests and criteria that were already created by him for this purpose. The testing at this phase was majorly without the researcher's assistance. The participants were given the prototypes which are in the testing phones and instructed to make emergency requests based on the scenarios already explained to them, although the research is on hand to answer questions, clarify any confusion and any solve difficulties encountered during the exercise.

We also carried out integration testing, where we exposed the prototype to all components within the emergency system. We evaluated the emergency request sent from the SignSupport for emergency app to the Deaf Contact Centre for better encoding and formatting, load testing the mobile phones for performance related issues and using a computer to simulate a live EMS centre where emergencies are responded to in real-time.

Data Collection: Notes were taken during this experiment and participants were observed during the exercise process. A post-testing group session was held with all participants after the testing phase was over. Below are the questions and highlighted points raised during this session.

- What is unique for you in the SignSupport for emergency app?
- What would you like to change?
- Does the app provide sufficient data for a first responder to sufficiently gauge the appropriate response in an emergency?
- Would you recommend this app incorporation to your present EMS system?
- What are your thoughts on the first-aid video section of the App?

These questions are asked to ensure that the purpose of the SignSupport for Emergency app is understood and that it could be an acceptable and useful tool for the EMS providers and the Deaf community. The feedback is summarized, analysed, and discussed in section 4.3.5.

3.4.4. Fourth iteration

We evaluate the final improved prototype of the SignSupport for emergency app for usability and performance testing. This prototype contains changes and features that originated from the co-design and participation of all stakeholders throughout the research: The Deaf community, the domain experts and product manager. Our aims here are to: "Confirm the ease of use of the SignSupport for emergency app prototype", "Verify that the final prototype meets user's expectations", "To get the participants general remarks of the SignSupport for emergency app" and "To get recommendations for future improvement of the SignSupport for emergency app". This testing stage consists of the sampling, testing procedure and data collection.

Sampling: The participants for this iteration are the Deaf community members that were part of the testing phase from the first iteration. Two new participants also joined for this session and the interpreter who works for the community who had started with us from the beginning of this project. This experiment is divided into three scenarios with a similar user epic as the previous iteration, to demonstrate an emergency scenario using the SignSupport for emergency app.

Testing Procedure: In the training stage, we started with an introductory presentation that informed the group about the project: its aims and objectives. This was done to keep the new participants updated and prepared for this experiment. The participants were provided a consent form to sign as an indication that they agree to participate in this exercise. Thereafter the researcher describes the use of each features on the SignSupport for emergency app, by updating their profile (personal profile, medical history, and emergency contact), requesting emergency help (linking to the map then the confirm request page and to the successful request page), the video (if the subtitles were helpful). Next was giving the participant the chance to try out the features that were demonstrated by the researcher.

Data Collection: Pictures, observing the participants, notes were taken during this session as the participants were using the SignSupport for emergency app. At the post-testing stage, a questionnaire session was conducted after the completion of the exercise. Below are the questions from the questionnaire:

- How satisfied are you to describe the user interface?
- How would you describe your navigating experience through the app?
- How satisfied are you with the app responsiveness?
- How efficient were the video content conveyed?
- How satisfied are you with the requesting help process?
- How satisfied is the entire app content?
- How satisfied are you to recommend the app to other Deaf people?

The questionnaire includes an open-ended question that allows the participants to write down their thoughts and suggestions on future improvement of the app.

Some of the suggestions which will be discussed in detail in Section 4 which include: A video call mechanism should be included in the SignSupport for emergency app, A short SASL video describing the app features at the beginning more first-aid SASL videos should be included and rore learning applications are needed for the Deaf community.

3.5. Ethical considerations

This section speaks to the ethical considerations that guide the process of working with human participants, and with vulnerable Deaf participants. We took into consideration the vulnerability of the Deaf people by following the benchmarks developed by Emmanuel (2018) which listed culture and traditions, distribution of knowledge and collaboration and the disclosure of information in culturally and linguistically appropriate formats as the underlying policy for any contact with the community (Emanuel et al. 2018). Presented here are the ethical consideration points on the ethical engagement with vulnerable and non-vulnerable participants alike; and a formal specification of these issues was used to acquire ethical clearance for this research (McKenna and Gray 2018).

3.5.1. Ethical issues addressed by the information sheet and consent form

Consent: Before participating in the project, the participants from the DPOs were told what the project is about before they sign the consent form, having been translated to them in SASL by the interpreter who instructs the use of the information gathered and ensures privacy of personal data from the participant.

Confidentiality: Data collected and recorded in this study will be protected; information gathered from the user will be looked after so that the only people who have access to the data gathered from the interview and questionnaire are the researcher, the supervisor, and the participants.

Information gathered from. The interviews, questionnaire and focus group such as video recordings, pictures and forms will be transcribed.

Use of SASL Interpreter: An interpreter was used to conduct the data collection process and all information gathering from each method such as the focus group, questionnaire, and semi-structured interview with the Deaf participants. The interpreter will be notified that the information he/she is about to hear is confidential and that s/he cannot make use of it and that the participants' privacy must be preserved.

Risk and Benefits: The study is a scenario-based approach, with a designed epic story that illustrates a real emergency scenario. The benefit of this research is to develop SignSupport for emergency app to reduce the issues surrounding emergency services among Deaf people. Deaf participants will be under observation of the researcher while enacting a scenario, they will be expected to interact with the SignSupport for emergency app and make an emergency request to the Deaf contact centre. Another benefit of the data collection process will be under controlled conditions since the research is a co-design and participatory design method of the study, participants are able to give valuable input to the researcher as the researcher learns from the experience of the participant (Goodyear-Smith, Jackson, and Greenhalgh 2015).

3.5.2. Ethical clearance process

The emergency service system application required approval from the University of the Western Cape Faculty Board Research and Ethics Committees and from the University's Senate Research Committee. Senate Research Committee may also make their consultations on ethics questions from outside sources or the University ethics subcommittees before the approval of the project registration and ethics clearance. The rule remains that no project can progress without granting ethical clearance.

3.6. Summary

The primary interest here is to introduce the valued impact of qualitative methods to this research with active participation with both Deaf participants and EMS experts in order to realise an iterative prototyping process (Langford 2012). As we explore the views, experiences and motivations of each participant and domain experts using the different methods adopted: co-design and participatory design methods, by building a comfortable and reliable partnership between the researcher and all participants involved to generate quality data (Gill et al. 2008).

The first interaction was based on introducing the participants, who are the end users of SignSupport for emergency, to the first prototype. The second iteration involves a focus group of both deaf and hearing participants and a major upgrade in design due to feedback from the first experiment and adoption of better development tools. Our third prototype followed a different technique: we worked with the WCP EMS team for usability and the prototype's compatibility with the EMS system. Finally, the last experiment took feedback from all the previous experiments to become the final version of the SignSupport for emergency app. This prototype was evaluated by the end users at the DPOs, and their recommendations were recorded as future work to be done. Questionnaires, semi-structured interviews and focus group sessions were used at each of the stages as a data collection process.

4. Results

The research methodology and application of methods was discussed in the previous chapter. This chapter presents the results of applying those methods in each of the four iterative phases of the SignSupport for emergency app development and usability testing. Usability testing assists in improving the general features of the emergency app and the user interface. There were four cycles which each ended with user evaluation. In each evaluation, participants simulated different emergency scenarios on the prototype while also interacting with other features of the app such as watching first-aid videos, filling in profile information and generally navigating around for usability. Also, the researcher and domain experts carried out the acceptance tests based on a predefined list of activities that the prototype should do at each iteration. The acceptance tests were carried out by the product manager with assistance from the project supervisor and research collaborator and were marked as done once the tests passed before proceeding to the next iteration. Section 4.1 demonstrates the first iteration, section 4.2 explains the second iteration, section 4.3 discusses the third iteration, and finally section 4.4 presents the last iteration. Each iteration is described with the same sub-components consisting of: user requirements, interface design, system architecture, prototype development, results, analysis, and plan for next iteration (except for the last iteration).

4.1. First iteration: Initial idea exploration

The prototype is based on the priorities of the Deaf communities after they described what the application should look like and the expected functionalities. The iteration started with a planning session where the domain experts and the researcher came up with user stories based on the initial idea gotten from the Deaf communities at the first focus group session. It must be noted that this iteration includes a simulation that demonstrates SignSupport key functions and operations and it will only evaluate the app to the point of sending a request. (Casali 2013).

4.1.1. User requirements

The user requirements are gotten from the focus group session where the researcher asked the participants (of course, with the help of a sign language interpreter) some open ended questions with the assistance of the product manager and the research supervisor. The answers gotten from this session are broadly categorised and converted into user stories by the product manager in collaboration with the researcher. The user stories are listed below:

- As a Deaf user, I want to simulate the authentication process so that I can have access to the other functionalities of the app.
- As a Deaf user, I want to simulate sending an emergency request to the EMS.

4.1.2. Interface design

This section describes the features available in the first iteration of the SignSupport for emergency app. This is an app that helps a Deaf user to make an emergency request to the EMS service provider through a mobile phone. The low fidelity version of the interface design was done using the "pen and paper" technique where the researcher drew a basic concept of the app on a storyboard to identify the major elements and user flow, as recommended by Preece et al. (2002). Then, domain experts were invited to help refine the idea before creating hi-fidelity designs using a UI/UX prototyping software. High fidelity mock-ups can be done using a variety of software tools. The research team used Justinmind, a paid UI/UX prototyping tool which also has a free version. The free version was found to be sufficient for our needs, which is designing a basic proof-of-concept with clear-cut user flow. Another benefit of Justinmind is that it is a beginner-friendly tool which has a drag-n-drop functionality where the designer can pick components from a present library and drop it on the design screen.

On the high-fidelity design (see Figure 4-1), a user sees an initial interface that contains a login screen on first load. If the user is already registered, then the user can type in her login credentials: email and password; else, the user can click on a signup button which is linked to the "sign up" screen where the user will register using her email address and password. Upon successful registration, the user is redirected to the login screen where she logs in and gets authorization to use the app. The prototype contains additional screens like the home page where the user sees a welcome message and 4 buttons that depict the different emergency scenarios. When any of these buttons is clicked, the app will load the Request Help screen and populate it with data related to that emergency scenario and retrieve the user's location in real-time using the requesting device's GPS sensor. The Request Help screen provides a form for users to give additional details about the emergency before finally clicking on the "Request Help" button which sends the request to the EMS provider. The interface (again, see Figure 4-1) has 5 main screens which are:

Sign in: SignSupport for emergency app has an authentication feature and the login screen is the first of such pages (see Figure 4-2a). The login screen is divided into 3 sections: the header text, a login form, and a subtext with a link to the sign-up screen.

Sign Up: The sign-up screen uses the same template as the login screen described above. This was purposely done as a consistent layout; which is shown to aid usability and minimise surprises for users.[12] The screen has 3 sections: The header text prominently shows the word "Sign Up" while the

[12] Importance of omnichannel consistency experience, 2016. [Online]. Available: https://www.nngroup.com/articles/omnichannel-consistency/[Accessed: 09- July- 2020]

form has three fields for name, email and password; and finally the screen also has a link to the login screen which users who already have an account can tap to go to that screen.

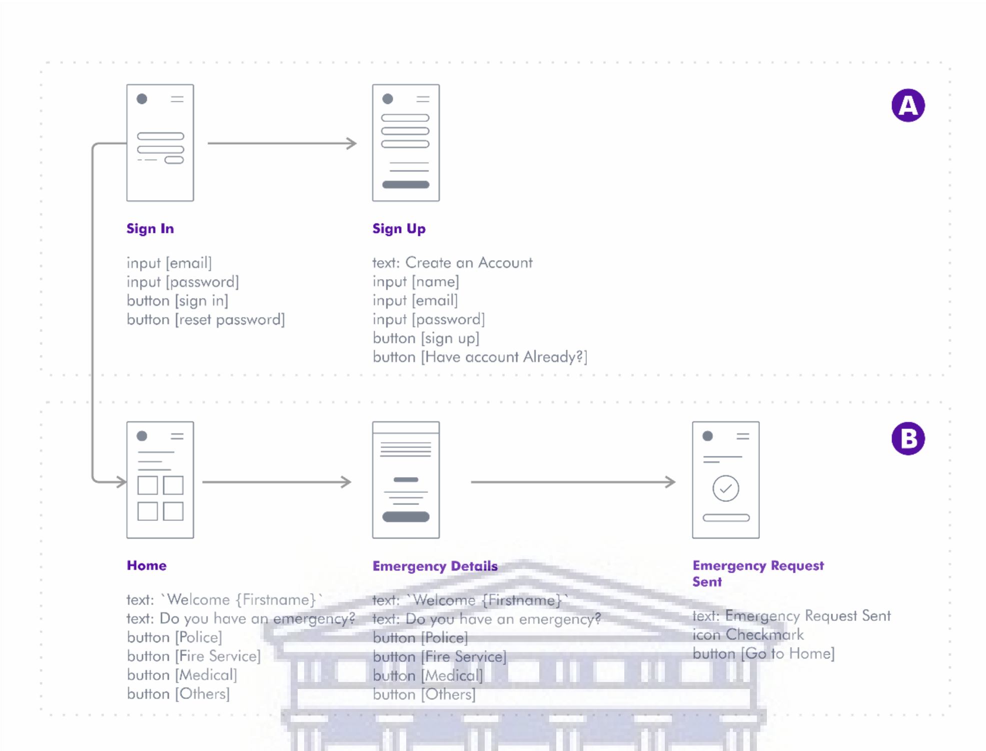


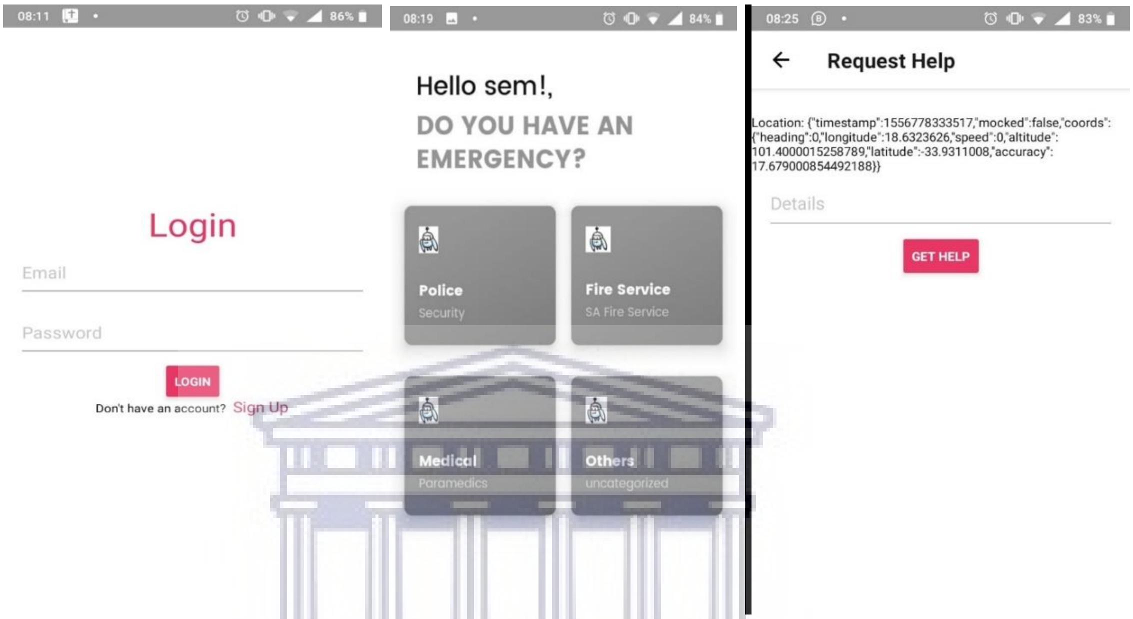
Figure 4-1 User Workflow in the first iteration

The user flow has two processes: A) Authentication flow and B) Emergency request flow.

Home: The home page (see Figure 4-2b) is the main screen on the SignSupport for emergency app and uses another template for its layout. At the top of the screen is a personalised welcome message using the format "Welcome First name", the currently logged-in username. A "Do you have an emergency?" header text is displayed below the welcome message. This is the biggest text on the screen and has the distinction of drawing a user's attention to the purpose of the app. The last section of the app contains four buttons that link to the various emergency scenarios. The buttons are arranged on a 2-x-2 grid and are designed to be big enough for users to tap on them easily under an emergency and with adequate spacing between each button to prevent accidental tapping of another button while under stress.

Emergency Details: A user cannot get to the request help screen directly. The only entry point to the screen is through the home screen after tapping on one of the emergency buttons. The request help screen layout has three sections (see Figure 4-2c). The first section is the default Android heading tab which has a back button and prominently displays the title of the screen. The content of the screen is the location coordinates gotten from the device's GPS sensor and finally, the additional details text where a single free text form field is shown for the user to give more details about the emergency request before tapping on the "Request Help" button.

Request Sent: The request sent screen has only one purpose which is to notify the user that the emergency request has been sent successfully. It also has the default Android navigation heading tab with the screen titled "Request Sent" but without a back button as the researcher doesn't want the user to go back to the "request help" screen immediately after making a request. This was done to prevent making multiple requests within a short time.



(a) (b). (c)

Figure 4-2 Screenshots of the first user interface design Prototype

4.1.3. System architecture

This prototype has a simple architecture with two software components: the mobile app and the database. This iteration was mostly concerned about showing that the project idea can work and simulating the process up to the point of sending a request to the EMS; and the architecture reflects that idea. The next iteration will elaborate on this by exploring the ability to get the request to an EMS provider.

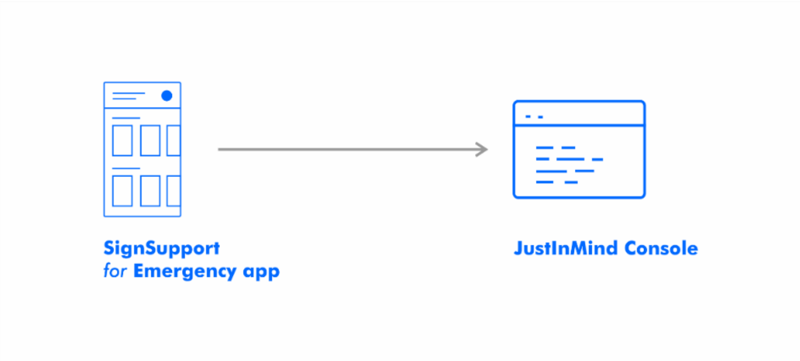


Figure 4-3 System Architecture for first iteration.

The architecture is a simple model where the prototype connects to the JustInMind Server remotely to store and retrieve data.

4.1.4. Prototype development

The prototype was built using Justinmind. The same software used for the mock-up design and it made the prototype development process seamless. Justinmind has a feature where the mock-up design can be exported as an interactive prototype. There are two options when exporting: iOS (formerly iPhone Operating System) or in APK (Android Package Kit) format. Once the export was downloaded, it was installed on a testing device, which in this case was the researcher's mobile phone. The mobile phone used is a Nokia 5 running Android version 9. Figure 4-2 presents screenshots of the SignSupport for emergency app after installation into the mobile phone and being used.

4.1.5. Results

Most of the participants, from a total of 5, successfully registered on the app as a new user. Only one struggled with the registration process and was unable to go beyond this section. The reason for this bug was never discovered as the prototype was a 'black box' and the researcher did not have access to its internal implementation. The participants who successfully registered were able to use the emergency app without any problem. They simulated the various scenarios and were also able to request help on their respective emergencies. The testing was done one after the other on the researcher's mobile phone, as this was a proof-of-concept, to evaluate the feasibility of the idea. The feedback gotten from this evaluation and the usability testing is analysed and categorized according to user flow, as discussed below.

Authentication flow: Regarding the process of authenticating on the prototype, all the participants understood the authentication process and how they should move from page to page on both the login and sign-up screen. However, the researcher noticed while observing the participants that they repeatedly clicked on the same button because the prototype did not give feedback while the authentication process is ongoing, e.g. when a participant taps the login button, there is no feedback from the prototype, so the participant assumes that the button needs to be clicked again. Also, validation of the login and signup forms should be done to eliminate email addresses that are obviously incorrect. The participants also suggested that the app should have more visual elements to make it more appealing to users. In the words of a participant, "the prototype is too bland".

Emergency request flow: This deals with the three screens: Home, Request Help and Request Sent. All five participants were able to simulate emergencies and request help without difficulty due to the simplicity of the interface. On the home screen, they rapidly identified the functions of each of the four buttons and clicked on them depending on the emergency scenarios which led them to the Request Help screen where they gave additional details before proceeding to the Request Sent screen. The participants were mostly concerned about the lack of colour in differentiating each of the buttons for the emergencies on the home screen. They recommended that the buttons should use icons or images that reinforce what the emergency scenario is. Also, on the Request Help screen, all the participants suggested that a map should be included on the page so they can visually confirm that the GPS coordinate shown on the app is the same as the location where they are. Another suggestion that came up was the inclusion of a profile page so that users can pre-fill some of the details rather than repeating it in the additional details form while making a help request. Additional feedback gotten from the domain experts is that Deaf users should have the ability to send video and pictures that describe their emergencies.

Other features: During the semi-structured interviews after the testing phase, the participants suggested that the prototype should have first-aid videos recorded in SASL that the Deaf user can watch while waiting for first responders to arrive. This suggestion mirrored the real world where agents at the Emergency Call Centre talk hearing callers through how to give first aid during emergencies.

Table 4-1 below shows a summary of the participants' responses and suggestions. Each Deaf participant is tagged using a letter of the alphabet and the letters range from P1 to P6 while the domain experts are represented with D1, D2 and D3. The participant's column shows the participants that made or agreed with an assertion while the responses and suggestions column is self-explanatory.

Table 4-1 Iteration 1 suggestions from co-designers

Participants	Suggestion
Researcher	There is no feedback on long running processes such as when the user taps on the login button which instinctively makes the user tap the button again.
D1	Validation of the login and signup forms should be done. This will filter out obvious incorrect data such as bad email formats and special characters in name.
P1, P4, P5, P7	The participants also suggested that the app should have more visual elements to make it more appealing to users. In the words of a participant, "the prototype is too bland"
P1 - P5	The participants were concerned about the sparse use of colours and icons especially in the emergency buttons. They recommended that the buttons should use icons or images that reinforce what the emergency scenario is.
P1 -P7	All the participants suggested that a map should be included on the "Request Help" screen so that the GPS coordinate can be visually confirmed

P1, P3	Create a profile page so that users can pre-fill some of the details rather than repeating it in the additional details form while making a help request.
D1 - D3	Another feedback gotten from the domain experts is that Deaf users should have the ability to send video and pictures that describe their emergencies.
P4, P6, P7	The participants suggested that the prototype should have first-aid videos recorded in SASL that the Deaf user can watch while waiting for first responders to arrive.

4.1.6. Analysis

The result of this iteration shows that the interface is user-friendly, but it needs more features and details for a Deaf person who is requesting help during an emergency. This analysis is based on the responses from the 6 Deaf participants present at the focus group feedback session. The participants could not visually verify that the location being shown on the screen is correct because it displays longitude and latitude coordinates rather than a map. Also, the participants want the app to be more visually appealing with the addition of more icons on major sections of the emergency app. Moreover, they want first-aid videos recorded in SASL to help while they wait for first responders to arrive at the scene. Furthermore, a profile that captures the user information before an emergency will reduce the time wasted in typing additional details before requesting help.

Finally, more mobile phones are needed for testing purposes. One of the limitations of using just one phone was that at the general group presentation, the Deaf users showed a lot of interest and seemed to understand the process and what was expected of them. However, the testing phase was one after the other, and the participants complained about the slow testing process and forgot some of the instructions. So, the researcher needed to start explaining the process to most of the participants again when it was their turn to test the app. Hence, the need for an adequate plan (and more phones) for the next iteration.

4.1.7. Plan for next iteration

In the next iteration, testing should be done at a faster rate to limit wasting participants' time and show more respect for their time. Optimally, each participant should be provided a mobile phone so they can all test the app at the same time. However, the researcher has access to a limited number of testing devices and may have to batch the usability testing based on the number of participants in the next iteration. We believe that this will contribute towards a better understanding of how to improve the app and understand the users' needs. It follows that if the users are given enough time to use the prototype and carry out the testing action plan, then they can give more valuable and insightful feedback.

4.2. Second iteration: Refining the idea and connecting to the Deaf contact centre.

In this section, we discuss the second iteration of the SignSupport for emergency app and the improvements to the app based on the feedback obtained during the first iteration. The first iteration established that the proof-of-concept will work, and the next step is expanding the prototype to send actual emergency requests to a Deaf contact centre which then independently processes those requests before forwarding them to the EMS providers for appropriate action. As discussed in Section 3.4.2, the research team met with the domain experts at the WCP EMS to determine how to send emergency requests to the EMS. However, the EMS provider does not have the facility to receive requests directly from the prototype and the Deaf contact centre was considered as a viable relay service to bridge this gap. The Deaf contact centre is a WhatsApp based system which necessitates the integration of WhatsApp into the system architecture to handle sending/receiving messages to/from the Deaf contact centre. This integration of WhatsApp led to the domain experts recommending that the app should have a feature where Deaf users can connect manually to the Deaf contact centre using WhatsApp which will also give them the ability to send pictures, videos and even make video calls with the Deaf contact centre.

The testing phase for this iteration has a total of 8 participants: 3 Deaf participants from the previous iteration, 3 new Deaf participants and another 2 hearing participants from the Deaf community who helped this researcher to clarify feedbacks from the previous iteration. The added hearing participants are people who have worked closely with the Deaf communities and understand the communication, technical and social needs of the Deaf people. This expertise will be useful in creating the first-aid videos, developing the system architecture, and integrating a specialised relay service called the Deaf contact centre which is the bridge between the prototype and the EMS provider. Note as described in Section 1.6, the Deaf contact centre was built by another master's student in the research group.

4.2.1. User requirements

Based on the feedback obtained from the previous iteration, the product manager and the researcher came up with a revised list of user requirements for this iteration:

- As a Deaf user, I want to send an emergency request so that I can get help.
- As a Deaf user, I want to verify my location so that the first responders can get to the scene.
- As a Deaf user, I want to render first-aid help while waiting for the first responders to arrive.
- As a Deaf user, I want to send emergency requests manually through WhatsApp during special circumstances.
- As a Deaf user, I want to provide information to the call centre agent via mechanisms I already use to communicate such as WhatsApp video or image messages.

4.2.2. Interface design

This prototype includes better UI design, basic profile page, a rudimentary video player, first-aid videos in SASL and incorporation of WhatsApp to communicate with the Deaf contact centre (to be described in Section 4.2.3). These new improvements are the results of recommendations gotten from the previous iteration and advice of the domain experts.

The researcher abandoned Justinmind and chose to use Adobe XD, a UI/UX design and collaboration tool, for the UI design of this iteration and henceforth. This decision was made because Justinmind has a limited capacity when creating prototypes that are data-driven and collaborative in nature. In this instance, the research team needs a tool where the researcher can collaborate with other stakeholders and the Deaf participants when creating the designs by sharing a link where the collaborators can comment on the designs and work with the researcher.

In the latest high-fidelity design, additional colours were added to the screens as recommended by participants. The login and sign-up screens were not modified as the Deaf participants are satisfied with the screens from the first iteration. Also, a bottom navigation was introduced and added on all the screens. Bottom navigation on mobile apps acts as a shortcut which users can use to quickly navigate from one screen to another. It is used for top-level destinations that need to be accessible from anywhere in the app. The bottom navigation for this iteration has three tabs: The first tab is Home which always returns the user back to the home screen. The Manual Request tab allows the user to connect to the Deaf contact centre manually using the user's personal WhatsApp. The final tab is Profile that links to the profile screen". The list below describes the new screens and any redesign of screens previously introduced in the first iteration.

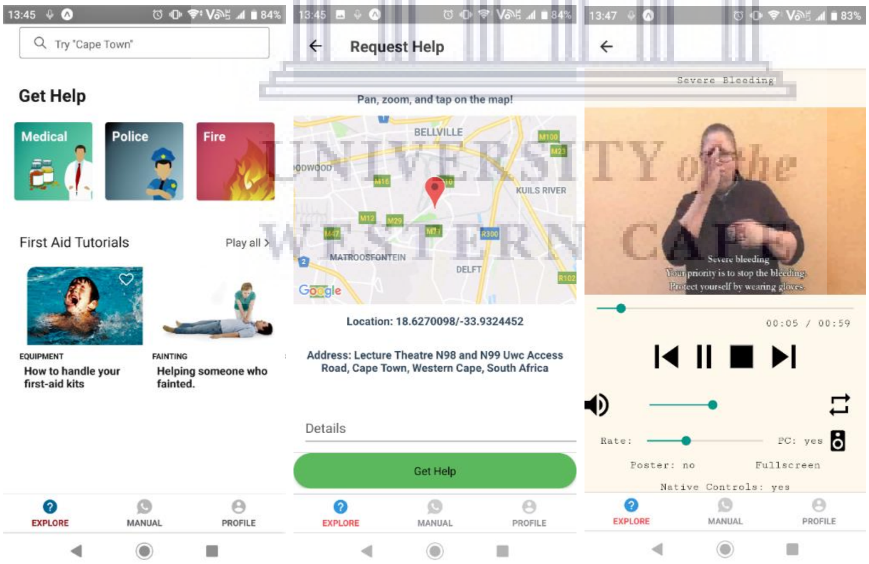
Home: This screen was entirely redesigned to become more visually appealing with the use of more images and colours. The new design is divided into two sections: Get Help and First-Aid Tutorials. The Get Help section contains the Medical, Police and Fire emergency request buttons. The researcher, in discussion with the product manager, decided to remove "others" from the categories of emergency scenarios as the EMS providers only offer emergency help in those three categories at the moment. The emergency buttons were designed to be as visible as possible and use images and colours to reinforce each emergency scenario that is linked to that button. For instance, the fire button used an image of a fire and a red background to depict danger. The second section has a header called First Aid Tutorial which describes the section and has a list of videos in SASL that the users can watch. There is also a "play all" button in this section that will redirect to the video screen and play all the videos embedded within the app in alphabetical order.

Request Help: Once a user clicks any of the emergency request buttons on the home screen, they are redirected to the Request Help screen where a map with the requester's location is displayed on the screen. This section also shows the GPS coordinates, as with the first iteration, along with the address of that location. The design also retained the additional details area where the user can pass along more information about the emergency before finally sending it to the Deaf contact centre using the green "Get Help" button which is just below the additional details.

Profile: The profile screen is a generic screen with links to two forms: Personal profile and Medical history details, which are to be filled by the Deaf user and stored in the database for retrieval during emergencies. The personal profile form fields for first name, last name, birthday and sex while the medical history form contains a free text field where the user can fill in details such as medical preconditions and allergies to drugs and food.

Request Help Manually: The screen has a header "Use WhatsApp Directly?" with additional text description that informs the user in detail about what the step entails. Once, the user clicks on the button, SignSupport for emergency app will open the WhatsApp app installed on the user's phone, automatically open a text chat with the Deaf contact centre's number, fill it with a text message that says, "Help Needed - I am connecting manually" and use the device's GPS sensor to provide the user's location which is rendered on a map before sending it to the Deaf contact centre (see Figure 4-4).

First Aid Self-Help Videos: The video screen contains a list of pre-recorded first-aid tutorials recorded in SASL. The Deaf users can use these to assist themselves or help someone during an emergency before the first responders arrive at the scene; or in a case where self-care would be enough to support the end user. This screen displays the video title and a minimal video player with controls such as return to previous video, pause/play, stop and skip to next video. The video player also has volume control and can play a video in full screen mode.



(a) (b) (c)

Figure 4-4 Screenshot of the second design of SignSupport for emergency prototype.

(a) The Get Help screen is the initial screen that a user sees. The screen is divided in to two categories: get emergency help ad First-aid tutorials. (b) The Request Help screen loads a map to help the user mark their location accurately and give any additional details that can help first responders. (c) Shows a sample of the first-aid tutorials being played. This application is built using JavaScript and React-native which uses the web application protocol, this will allow the videos to be kept when watched and only reload when a new version is found.

4.2.3. System architecture

The system architecture has vastly changed from the first iteration (see Figure 4-5 below). We have added more components like the first-aid videos, WhatsApp integration and connectivity to the Deaf contact centre. The prototype will not be sending requests directly to the EMS provider because the system currently being run by the EMS provider is a semi-manual process where call centre agents pick up emergency calls and triage according to urgency before relaying such requests to the appropriate channel which then transfers the request to the nearest first responders.

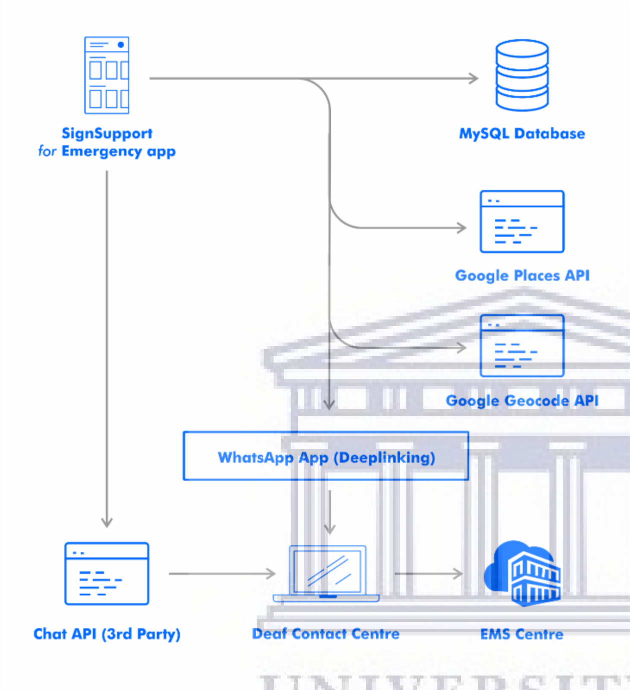


Figure 4-5 System Architecture for second iteration.

The prototype is linked to a MySQL database to store user details and other data needed for optimal functioning. The prototype also connects to internal API services such as the Deep linking API which opens WhatsApp on the user's device when the "Request Emergency Help" button is tapped. The prototype also relies on third party APIs such as Google Places API, Google Geocode API to get the user's current location while Chat API is used to encode the request and sent to the Deaf Contact Centre.

Finally, all emergency requests are routed to the EMS centre via the Deaf Contact Centre.

The Deaf contact centre: Asemi-automated component like the SignSupport for emergency app depicted in Figure 4-5 needs some specially trained Deaf contact agents who can receive the requests and respond to them. While this project was ongoing, a research collaborator started a research project to create a specialised contact centre for Deaf people which came to be known as the Deaf contact centre. That project aims to provide a contact centre for all apps currently in use and under development by the Deaf community; and when fully implemented the Deaf community will hire specially trained contact agents to cater for the needs of Deaf users. The advantage of such a Deaf contact centre is that the Deaf people will be in direct control of the project and it can evolve rapidly according to their needs without waiting for third parties to implement such changes. At the time of the second iteration, the Deaf contact centre uses a WhatsApp business account to manage all requests sent to it. The prototype sends an emergency request to the Deaf contact centre which is then processed and forwarded to the EMS. Once the Deaf contact centre receives the request, it responds with an automated message and an HTTP server response code of 200 which shows that the request has been sent successfully and the Deaf contact centre will take care of making sure the EMS provider gets the request and takes appropriate action on it. The details of the internal workings of the Deaf Contact Centre are outside the scope of this work and it was handled by another researcher.

WhatsApp and Chat API: WhatsApp became a component of the system due to two reasons: 1) encoding and sending a request to the Deaf contact centre and 2) giving the Deaf user the ability to communicate directly with the Deaf contact centre using WhatsApp. Unfortunately, WhatsApp doesn't have a publicly available API for integrating their services to our prototype or the Deaf contact centre. So, the researcher used a third-party gateway called Chat API that solves this fundamental problem. Chat API is WhatsApp API gateway service for sending and receiving messages, notifications, files, and location data with a simple integration protocol using REST API. The gateway exposes different routes for each of these tasks and sends the request to the server which eventually forwards it to the WhatsApp account used by the Deaf contact centre.

Database: The database is an essential component in the system, we store all user data in the database. The database is a MySQL instance that is stored in the cloud using Heroku. Heroku is a Platform as a Service (PaaS) cloud provider that is based on a managed container system which enables a simple process for installing and deploying modern apps. Once the database is instantiated on Heroku and configured, it supplies an URL link which is used to connect with the database securely using a username and password combination.

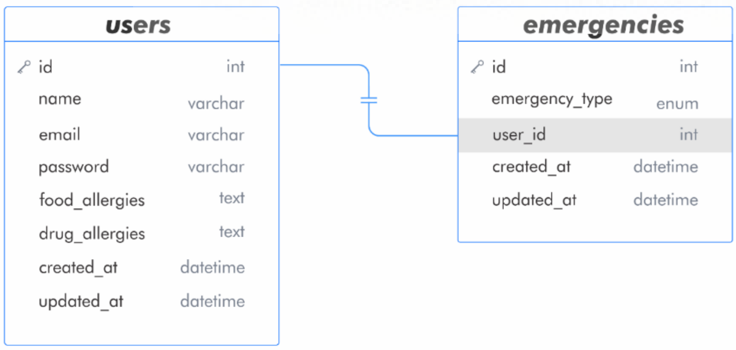


Figure 4-6 Database Schema

The database schema is a simple one-to-many (1:n) relationship between the users and emergencies table. This users table contains the user details and it has a foreign key (user_id) set on the emergencies table where all emergencies are stored.

Mobile app: All the other components of the system are directly linked to the SignSupport for emergency app. The mobile app connects to WhatsApp through Chat API to send messages and other content to the Deaf contact centre. It also uses the Android deep linking feature to expose the

WhatsApp installed on the user's device as an override to send requests manually to the Deaf contact centre. Another connection that the prototype has is the database. Once the mobile app captures the user data, it is sent to/ retrieved from the database.

4.2.4. Prototype development

The first prototype of SignSupport was generated using the Justinmind export function. However, that prototype was a black box as the researcher did not have access to its internal implementation or its source code. A bug was discovered during the testing of the first prototype (see Section 4.1.5) for more details and we could not trace the origin. This necessitated a change in development approach where the researcher writes the code for the prototype and modifies it as needed.

The methodology used for this project demand a mobile app which enables the prototype to change rapidly in each iteration to match changes in the user requirements while reducing costs and development time. There are many options for building hybrid apps, and they include Ionic, React-native, Xamarin, Flutter and Cordova. The researcher chose React-native due to her experience in using React for building web apps in other projects. React-native, an offshoot of Facebook's React framework for building web apps, is designed for a lean learning curve and to provide a way of building platform independent hybrid apps for a wide variety of platforms and ease code sharing across platforms. This means that while the current prototype is tailored for the Android platform, it can be easily used on iOS and Windows mobile devices without much modification.

The prototype development started with setting up the development environment. This was done by installing a code editor, Visual Studio Code in this case; installing a version source control app – Git; and creating a dedicated development folder on the development machine. We installed React-native and its related dependencies, which was version 0.61.4 at the time of writing, and tested that it is installed perfectly by running the test command "npm run tests". After verifying that the tests passed, we committed the code as the "Initial commit". The researcher used a Test-Driven Development (TDD) approach to test that all the user stories implemented are working as expected. The test suite used for carrying for the TDD tests is Jest, the most popular testing suite in the JavaScript community.[13] Finally, Android Studio was installed in the development environment which gave access to the Android emulator for use to visually test that all the features are working correctly as if the app is already installed on a mobile phone.

Once prototype development is done, the prototype is built and compiled into an APK format using the command: "react-native bundle --platform android --dev false --entry-file index.js --bundle-output android/app/src/main/assets/index.android.bundle". This is a long running process and if all goes

[13] NPM compare https://npmcompare.com/compare/chai,jasmine,jest,karma,mocha

well, after a few minutes, an APK file will be generated and can then be copied and installed on a phone. Since, this APK file is not downloaded from the Google play store, when the app is installed on a testing device, the security settings are disabled to allow an unapproved app to be installed.

The user requirements developed through the user stories suggested that this iteration needs 6 features (as laid out in Section 4.2.1) and how those features were developed is described below.

1. *As a Deaf user, I want to register so I can send emergency requests*: The app presents a signup screen where a new user types in their data: name, email, and password. This data is validated for accuracy by checking that the email supplied matches known email formats and the password has an acceptable entropy value not less than 128 bits. To prevent duplicate registration, the code checks the database to verify that the email is not already in use. If the email was found, an error message is sent back to the app and displayed on the screen that the "Email is already in use"; else, the password is encrypted using bcrypt which is a password-hashing function based on the Blowfish standard. Then, a new account is created with the details stored in the database. Login is achieved when a user types in a correct email and password combination. The app then creates a stateless authentication token, in this case, a JSON Web Token (JWT) token which is stored locally in the Local Storage. Local Storage is a file-based storage system found within browsers and mobile apps that acts as a local database without the need to connect to an external database. Once the user logs in, they have access to all other screens within the app.

2. *As a Deaf user, I want to verify my location so that the first responders can get to the scene*: To implement the location feature, we need a map component that will render maps in the emergency request screen. Fortunately, maps are a popular feature of modern mobile apps and react-native already has a community-built package for that. We started by installing the package, react-native-maps, and setting it up. React-native-maps needs some configuration before it can work, amongst which is the default mapping service provider to use and the GPS coordinates to mark present location. Google, being the most popular map service provider, is a clear choice. The researcher registered for a Google developer account and got access to the Google developer console where a project, called SignSupport, was created with Google Maps SDK for Android enabled. Finally, an API key was generated as an authorization token which must be attached to the map component so that the map will be rendered when the page loads. The map component also requires the location coordinates which are obtained from the device sensors using the Android Location API. These coordinates are attached to the component and used to mark the user's present location. Also, the Google Geocode API was used to reverse geocode the location coordinates obtained from the device and present them as the present address on the screen. Finally, once the user taps on the send emergency request button, the location data which includes the reversed geocoded address, and the GPS coordinates is encoded and an API

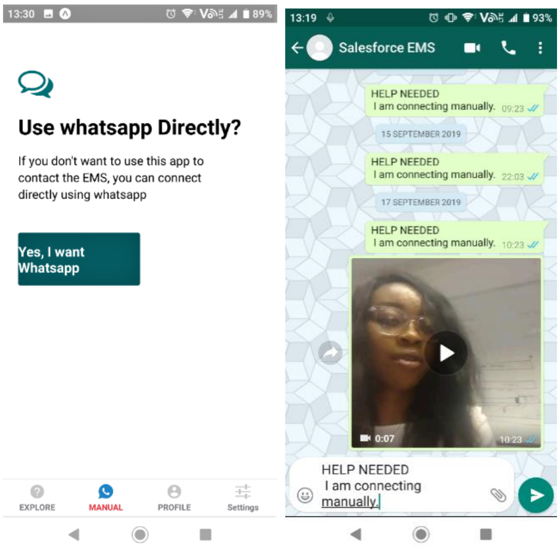
request is sent to Chat API which then sends the request data containing the location to the Deaf contact centre.

3. *As a Deaf user, I want to send an emergency request so that I can get help*: A user can request emergency help by tapping on one of the emergency requests buttons found on the home screen. These buttons have a unique flag, also known as props in the JavaScript framework world, attached to them. The flag uniquely identifies the type of emergency and is sent along with the request header to the emergency request screen. On getting to the emergency request screen, we check for the flag and populate the request according to the type of emergency.

Then, a query is sent to the database to retrieve the user profile details which is then combined with the emergency request details and additional data such as the location which was obtained from the map component earlier implemented. In the case, where the profile has not been filled, an alert notifies the user to fill the details. The data is then encoded into a message format that was agreed on previously with the Deaf contact centre which states that each major data item should have three consecutive asterisks - *** inserted at the ending of each item and the end. The three consecutive asterisks were chosen as a delimiter because it is extremely rare to see that in normal English textual usage.

The encoded message is then converted into JavaScript Object Notation (JSON) format and sent through Chat API to the Deaf Contact Centre. To verify that the request has been sent successfully, we confirm that Chat API responds with a status code of 200 else if a 4XX or 5XX series response is gotten then, the emergency request wasn't sent successfully, and the Deaf user will be notified to try again. See Section 4.2.3 for a discussion of the Deaf Contact Centre.

4. *As a Deaf User, I want to send emergency requests manually through WhatsApp during special circumstances*: Android and other mobile platforms have the concept of deep linking where you can create an URL like link called a deep link which can be clicked to open an app already installed on that device. In our case, the deep link will open the WhatsApp app already installed on the user's device or if WhatsApp is not installed already, it navigates to the Google play store where the user can download WhatsApp and start requesting help manually. The prototype has an agreement with the Deaf contact centre on how manual messages will be sent. The first line of any manual help request must begin with ***HELP NEEDED - I AM REQUESTING HELP MANUALLY***. Once a user clicks on the request help manually button, this first line is sent automatically after the WhatsApp app is opened then control is handed over to the user who will send other custom messages according to the type of emergency. Below is the screenshot that explains the process.



(a) (b)

Figure 4-7 Screen shot of the manual connection to WhatsApp

Screenshot (a) shows the screen that appears when a user clicks on connect manually with the Deaf contact centre through WhatsApp. Screenshot (b) displays the encoded messages and the type of message that can be sent.

5. *As a Deaf user, I want to render first-aid help while waiting for the first responders to arrive*: We discovered that a very good way to add this feature is to provide first aid videos recorded in SASL within the app which the Deaf users can watch either beforehand or during an emergency and follow the instructions in those videos. The researcher discussed with the domain experts from the EMS and consulted a first-aid manual published by St. John's Ambulance Organization of London and then came up with a short list of the following topics which are good candidates to be included as videos. The topics are: First-aid kits, Asthma, Severe bleeding, and Stroke, Fainting, Drowning, Resuscitation (CPR).

The next step was writing a short script of not more than 3 minutes that clearly explains each step. These scripts were written by the researcher and approved by the product manager and project supervisor. The scripts were handed to DCCT who engaged a Deaf person to record the video. It was important to use a Deaf person in recording these videos because a Deaf person offers more clarity in their hand movement and signing. The researcher got the videos back and did some pre-processing activities on it like compressing the video files size and converting it into the MPEG-4 format which is the default Android format. These videos are needed to be always available on the app and most do not use a lot of internet bandwidth. It was decided that the video should be directly embedded within the app to make it always available to the users and not consume bandwidth whenever the user is viewing it.

The video screen was created using the Android Video API through the react-native-video package. The package was installed and gave the researcher programmatic access to the Video API. This allows her to embed a video player within the app with basic controls. The video player accepts some properties such as the source which is the location of the video, and a volume prop that controls how loud the video should be; but it was not used in this case. We also had access to some control such as go to the previous video which loads the previous video on our list of videos or a next video. Finally, we set the video size to occupy 90% of the width of the screen in a 4:3 aspect ratio.

6. *As a Deaf User, I want to provide details of myself beforehand so that I can send emergency requests faster*: The profile screen is a primitive screen that contains a form with the following fields: first name, last name, date of birth, address, and gender. The fields are validated for accuracy using common validation methods like:

- ❖ The first name and last name must be string with not less than 3 alphanumeric characters and less than 24 characters.
- ❖ the date of birth must be in the ISO 8601 standard: YYYY-MM-DD
- ❖ Address is free form and unfortunately could not be validated for accuracy but there is a string limit of 255 characters which is imposed by the database.
- ❖ Gender is a select box field and has only three options (Female, Male and Others) which the user can pick from.

After the form is filled and validated, the app stores the data into the database where it will be retrieved when sending an emergency request or the user wants to update the profile.

4.2.5. Results

The result of this iteration shows that it is better accepted by the participants. A total of 8 participants were involved in the testing and they all registered on the app successfully without any difficulty or confusion. Participants were able to register and login on the app then randomly simulate emergency scenarios to send emergency requests to the Deaf contact centre. They were also able to manually request help using the WhatsApp feature and fill the profile form. The usability testing suggested that the addition of colours and icons really improved the usability of the app. The participants' feedback for this session is discussed in the subsections below.

General features: The participants liked the addition of the bottom navigation bar on all the major screens. Three Deaf participants who were present during the first iteration said they found it easier to navigate from one screen to another rather than "repeatedly tapping the back button", while the other participants have no complaints. Also, the use of more icons and colour to establish a visual hierarchy and separation between elements on the screens also found widespread acceptance. The participants could easily recognise a group of contents that are related; for instance, the video section on the home screen was recognised as being different from the emergency request section.

Authentication Flow: A major feedback on the authentication flow from the previous iteration is the lack of visual cues when a long running process like login or registration is being done on the database. This caused the participants to repeatedly hit the same button as observed by the researcher in the testing phase. This iteration eliminated the issue by adding notification bars and loaders to notify users that a button has been pressed and the action is currently ongoing. Participants found this also found the validation feature useful as they are shown an error message when the email they inputted cannot be validated or they typed in an incorrect email/password combination. At the end of the testing phase, there was no feedback for improvement of this flow. All participants were satisfied.

Emergency Request Flow: All participants understood the use of the different emergency buttons and what they each represented on the interface. Participants were very satisfied with the design of the emergency button on the home screen. They also mentioned how pleased they were with the background and button colours in the Request Help screen and how a map of their location shows up before they send the request. This function was accepted and the participants feel assured that with a few clicks they are able to request help. However, one of the participants mentioned that the images on the emergency button could be changed to an actual police officer on the police emergency button and a real image of a doctor or nurse on the medical emergency button. She said this will give the app more realness and look similar to other hearing people's applications such as exercise apps on the Google Play Store.

Self-Care Video Flow: All the participants were pleased with the first aid videos and also seeing one of their colleagues in the videos was very interesting and well accepted by them. Two of the participants recommend that closed captioning should be added to the SASL videos and they classified this recommendation as very important. They illustrated a case where the Deaf victim is incapacitated with a hearing person and the hearing person needs to use the video instruction to assist before help arrives. The first aid videos will not be useful to the hearing person without the subtitles.

Profile Flow: The participants describe the profile screen as a good improvement of the app. They like the fact that the information requested by the profile screen is generic to a particular emergency scenario and can be easily accessed by authorized persons such as medical professionals and police officers to provide help.

The results specify that a participant wants further improvement on the emergency icons but other participants disagree as they like the icons as it is. Another area of improvement is adding closed captioning to the first-aid tutorial videos to make it useful for a hearing user. Participants mentioned these suggestions (discussed in **Table 4-2**) during the feedback session, when they were asked the question regarding the features to include or remove from the app. These features will be added to the SignSupport for emergency app and will be evaluated for usability in the next iteration.

Table 4-2 Iteration 2 recommended features and enthusiasm from co-designers

Participants	Feedback and Suggestions
P2	The images on the emergency button could be changed to an actual police officer on the police emergency button and a real image of a doctor or nurse on the medical emergency button. She said this will give the app more realness and look similar to other hearing people's applications
P1, P3	Closed captioning should be added to the SASL videos and they classified this recommendation as very important. They illustrated a case where the Deaf victim is incapacitated with a hearing person and the hearing person needs to use the video instruction to assist before help arrives. The first aid videos will not be useful to the hearing person without the subtitles.

4.2.6. Analysis

Six domain experts were asked to give their reviews after the testing is over through a focus group session where a semi-structured interview is carried out. The aim of this session is to check the acceptance and understanding of the system from an expert point of view.

According to the above result of this iteration, SignSupport for emergency app was able to satisfy the first research question stated in chapter 3 of this project thoroughly but the second research question was only partially answered as the prototype was able to send emergency requests to the EMS provider but this was buggy; and the prototype and Deaf contact centre isn't ready to be integrated into an existing EMS system based on the feedback gotten from the testing with the WCP EMS domain experts. The interface design of the emergency app seems to have been standardised as participants didn't mention any major changes or corrections required, except for a few that were suggested to be removed.

4.2.7. Planning for the next iteration

Thus far, the feedback has been positive as the SignSupport for emergency app is being tested and improved from one iteration to the next. The next step is to make a major change to system architecture by removing WhatsApp from the system and its associated complexities. The researcher will work closely with the collaborator who will be implementing the same changes on the Deaf contact centre to develop a contract on how to send the emergency request using a REST API without many changes to the data encoding. The researcher will develop a method of implementing these changes while trying to keep the interface design the same. The next iteration will present the final prototype of the SignSupport for emergency app.

4.3. Third iteration: Evaluate the prototype with WCP EMS

The SignSupport for Emergency app has gone through 2 iterations where the research team collaboratively worked with the stakeholders, domain experts and the Deaf community to develop a prototype that answers the research questions. At the end of the second iteration, the prototype was able to send emergency requests to the relay service called the Deaf Contact Centre which then forwards the request to the appropriate EMS provider. In addition, users have access to first-aid videos recorded in SASL to provide self-care assistance while waiting for the first responders to arrive at the emergency scene. The results from the last iteration shows that the stakeholders and the Deaf users are satisfied with the prototype as it is currently, this prompted the research team to shift focus to the other user which are the EMS providers. This iteration will work more closely with the domain experts from the EMS providers to evaluate the prototype for possible integration into their existing system.

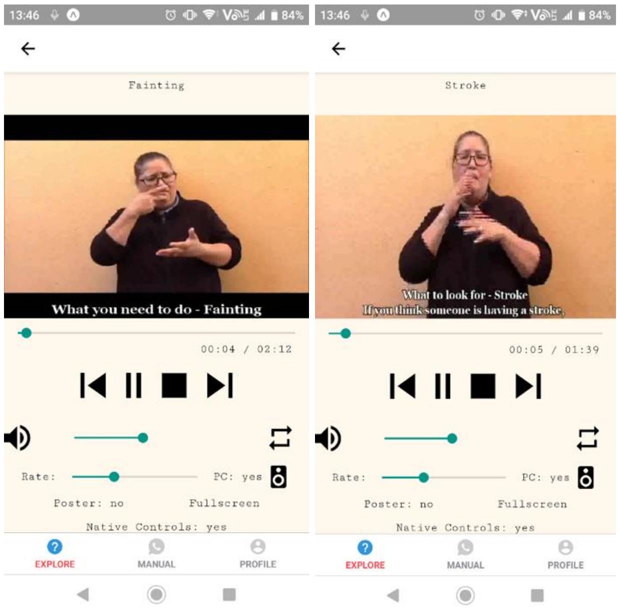
The group of 7 domain experts from the WCP EMS are hearing professionals who worked closely with the researcher and the collaborator to address the system architecture needs of the prototype and Deaf contact centre (which was built by the collaborator). The team worked together to test all the features of the prototype including the video subtitle which was newly added to this iteration. During the testing phase, we specifically tested emergency request flow from the prototype via the Deaf contact centre before arriving at the EMS with intent to determine if the emergency request sent to the EMS provider contains enough information to be actionable. Additionally, the secondary goal is to verify that the prototype and Deaf contact centre met the basic requirements of possible integration into an existing emergency service system and how it can improve their workflow.

4.3.1. User requirements

The user requirement for this iteration is a single task based on the result of the usability testing of the second iteration which suggested that videos should have closed captioning to make it more inclusive and useful for users that don't understand SASL. (See section 4.2.5 Second iteration result). The user story is stated as thus: "As a hearing user, I want to understand the first aid tutorials through subtitles".

4.3.2. Interface design

The user interface remains the same. The video subtitles are embedded directly into the video tutorials as shown in figure 4-3 below. The process is described in the prototype development section below.



(a) *(b)*

Figure 4-8 Screenshot of the Improved User interface Video section

4.3.3. System architecture

The system architecture remains the same from the second iteration.

4.3.4. Prototype development

SignSupport for emergency app had a minor change in the prototyping process where closed captioning was added to the workflow. To implement the closed captioning, the researcher needs to answer this question: "How can closed captioning be included without much modification to the prototype?" Traditionally, closed captioning can be static or dynamic depending on the technical resources available. The static method which is the easiest entails using a specialized software to create text overlays on segments of the videos that corresponds to the audio or sign language whereas the dynamic method which is usually used when catering for different languages create a stream of text in a special format, such as the srt format, that is graduated in time and played alongside the video using a compatible video player. Implementing the dynamic method is outside the technical capability of this researcher, so the basic method was implemented using a video post-production editing software called PowerDirector 13 which automatically crops a video into a pre-set segment of 5 seconds each. The segments are displayed on a UI interface sequentially with controls where the researcher added a white text in the segment and positioned the text at the bottom of the video. Some segments like when the Deaf signer took a long break may not have a text overlay because no words were signed in that segment. The video segments were merged in a sequential order and previewed before a new video was exported. The newly created videos were then watched by one of the Deaf domain experts from the DCCT to confirm that the closed caption perfectly matched the hand actions. The old videos were then replaced with the new closed-captioned video and the prototype was rebuilt and installed on the testing devices.

4.3.5. Results

The results of this iteration are categorized into 2 sections which are the usability testing of the prototype's User Interface and evaluating the emergency request data flow from the prototype via the Deaf contact centre to the EMS provider. The result will also discuss the Deaf contact centre in contrast to the previous iterations because it serves a significant role, as a relay service, in getting the emergency requests from the prototype to the EMS.

SignSupport for Emergency app: Interface Design

Emergency request Flow: All the domain experts were able to simulate the 3 different emergency scenarios and request help successfully. One of the domain experts noted that the text of the medical emergency button should be changed to "Medical Assistance" as opposed to "Medical" as the labels have different meanings. The domain experts were content with the functions and clear self-descriptive buttons which was reiterated by their pleasant remarks and observations. A domain expert pointed out that the prototype does not have a feature where a Deaf user can explicitly seek help for a third-party. The domain expert went ahead narrate an accident scenario where the Deaf user is the only conscious person at the scene. Such Deaf users need a way to notify the Emergency service that help is being sought for other people.

First Aid Self-Help Videos: The research team paid particular attention to the domain experts while they use this section as we are interested in how they interact with the newly introduced closed captioning on the videos. The domain experts showed great interest in the videos and they mentioned that one of the problems facing first responders is the lack of first-aid training amongst the general population and that the videos will give some of the necessary support in the crucial minutes before the first responders arrive at the emergency scene. Five of the domain experts acknowledged that the videos were very informative and that the subtitles made it beneficial to both Deaf and hearing people. Another of the domain experts who heads the medical response team volunteered to write more self-help video scripts so that more videos can be produced and added to the prototype.

User Profile: The profile screen was deemed to be a very important part of the SignSupport for emergency app as it gives the first responders information about the victim which is a priority as the responders might not understand SASL when they arrive at the scene so getting additional information might be difficult. The domain experts noticed some significant information like allergies to drugs and food and insurance information was not included in the medical form. They worked with the researcher to develop a detailed medical form that will be sufficient for their needs during an emergency. See (**Appendix E: User Profile**) for a full list of information required in the profile form.

General Features: There was a consensus that the inclusion of the bottom navigation bar was a good feature as it allows users to get to each section quite fast. A domain expert mentioned that he likes how this adheres to the "3-clicks rules" which says that a user must be able to get from one section to another within 3 clicks. The domain experts did not accept the manual connection to WhatsApp feature very well. While testing this feature, two domain experts simultaneously tried to make a video call to report an emergency but only one call could connect while the other call was put on "call waiting". This is a limitation of using a single WhatsApp number and it is unacceptable as the Average Wait Time (AWT) of an inbound call will depend directly on the length of the total calls divided by the number of calls picked.

$$AWT = \text{length of all calls} / \text{number of calls}$$

The above problem cannot be alleviated by adding more call agents to the Deaf contact centre to pick more video calls as WhatsApp does not have the specialised features needed by a relay service such as the Deaf contact centre. The domain experts advised that the manual connection feature should be removed entirely from the research and a possible alternative to replace WhatsApp was discussed. The group discussed options and arrived at WebRTC being a viable alternative for this research.

4.4. Evaluation of the Emergency Request flow across the system

The second part of the testing phase is evaluating the emergency request flow from the app through the Deaf contact centre before arriving at the EMS provider's system. This involves a thorough discussion of the system architecture of the SignSupport for emergency app and the Deaf contact centre. The researcher and her collaborator gave an oral presentation with hand-drawn diagrams to explain how the emergency request data was encoded and sent through chat API before arriving at the Deaf contact centre as discussed in (section 4.2.4) prototype development. While the Deaf contact centre is not part of this research, it is intricately linked to it as the other side of the coin to answer the research question on crafting a bridge between a mobile interface and a standard hearing EMS contact centre.

The domain experts were against using WhatsApp to send emergency requests to the Deaf contact centre and were also thoroughly against the Deaf contact centre being a WhatsApp account. They pointed out that WhatsApp does not have the features to serve as a core contact centre especially for special needs users. Also, the use of Chat-API complicates the system architecture which will make it more difficult to maintain in the future as the system is tightly coupled. They recommended that WhatsApp should be completely removed from both components and a replacement that possibly uses REST API should be implemented due to its flexibility and proven efficiency of API-centric apps. The evaluation confirms the aim of the SignSupport for emergency app is understood by an existing EMS provider and the goal is to empower Deaf people with the same emergency service as hearing people. The responses from the focus group meeting are summarized in Table 4-3 below.

To avoid confusion, each participant is tagged with a code from D1 to D6 and they are linked to responses or suggestions that they agreed with.

Table 4-3 Iteration 2 Recommendation Table

Participants	Suggestion
A-F	All participants agreed that the WhatsApp breakout is a good idea and it should be removed before the prototype is integrated with the existing system at the EMS. They suggested that a web technology such as WebRTC will be a good alternative to replace this especially in regards to making video calls.
A-F **A,C**	The profile page is very important as it provides the EMS with information to serve Deaf users better during emergencies. The profile page requires an update of some core information like food and drug allergies and insurance information.
A-F	All the participants agreed that the SignSupport for Emergency app implementation in addition to the Deaf contact centre will increase the efficiency of the EMS servicing capacity and will bring a whole new experience to the Deaf community.
B,D,E,F	Most of the domain experts agreed that the first aid tutorial videos will make a better informed Deaf community and will be crucial in reducing risks of death before the EMS first responder arrives at the scene.
F	There is a risk of accidental request and a double opt-in feature will reduce this risk by making users confirm a request before it is sent.
A,C	A Deaf user will sometimes be in a situation where they need to request help for a third-party. The ability to request help for a third party will make a huge difference in how the EMS respond to requests.
A-F	All the domain experts are satisfied with the UI of the prototype, they found it to be easy to use and the primary actions are easily visible on the page. They also noted that a Deaf user does not need to be trained before they can use the prototype as all actions are reinforced by text, colour and icons.
C,D	These domain experts suggested that the researcher and collaborator should explore the option of using USSD to send emergency requests in situations where the Deaf user does not have access to internet data which will make it difficult to use the prototype.
A,C	The domain experts explored the possibility of sending emergency requests with low data usage but this have already been implemented by the researcher by embedding the first-aid tutorial videos directly into the app rather than storing them in a remote server and forcing the user to use their internet bandwidth to watch them at every time.

4.4.1. Analysis

The 6 domain experts were asked to give their reviews after the testing is over through a focus group session where a semi-structured interview is carried out. The aim of this session is to check the acceptance and understanding of the system from an expert point of view.

According to the above result of this iteration, SignSupport for emergency app was able to satisfy the first research question stated in chapter 3 of this project thoroughly but the second research question was only partially answered as the prototype was able to send emergency requests to the EMS provider but this was buggy and the prototype and Deaf contact centre isn't ready to be integrated into an existing EMS system based on the feedback gotten from the testing with the WCP EMS domain experts. The interface design of the emergency app seems to have been standardised as participants did not mention any major changes or corrections required, except for a few that were suggested to be removed.

4.4.2. Plan for next iteration

Thus far, the feedback has been positive as the SignSupport for emergency app is being tested and improved from one iteration to the next. The next step is to make a major change to system architecture by removing WhatsApp from the system and its associated complexities. The researcher will work closely with the collaborator who will be implementing the same changes on the Deaf contact centre to develop a contract on how to send the emergency request using a REST API without many changes to the data encoding. The researcher will develop a method of implementing these changes while trying to keep the interface design the same. The next iteration will present the final prototype of the SignSupport for emergency app.

4.5. Fourth iteration: Final prototype

At this phase we present the final improved prototype of the SignSupport for emergency app according to all the recommended changes suggested by the Deaf participants and the domain experts, we then conclude this final phase with a questionnaire at the Deaf community with the Deaf participants. The steps of using the SignSupport for emergency app was summarized. We also present the workflow of the research from the planning stage to the final prototype.

The fourth iteration is the final iteration for this research work. Throughout the research, the researcher has worked with the Deaf community, domain experts and the research team to develop a collaborative solution that empowers Deaf users and give them access to the emergency services using an app installed on a mobile phone. The prototype has been iteratively improved over the course of the previous iteration and this final iteration will further improve the prototype. The focus of this iteration will be implementing the recommendations obtained at the last evaluation and testing session with the domain experts at the WCP EMS and focusing on the participant's satisfaction while seeking to know if the emergency app is empowering.

The last iteration ended with an evaluation of the third prototype with the domain experts at the WCP EMS. The feedback obtained shows that the system architecture needs to be redesigned and further simplified. There were some unanswered questions such as what alternatives techniques can be used to replace the video call and instant messaging features that WhatsApp offers which was the reason it was chosen initially. Further review with the research team and domain experts suggests that WebRTC will be a good option but due to time limitation, it will not be implemented in this iteration and will be considered as future work.

This iteration contains major changes to both the User Interface and the System Architecture and in extension the prototype. Based on the feedback from the Deaf community that suggested that while the app is satisfactory and serves their needs, they want a User Interface that feels "wordy" to paraphrase one of the participants the researcher redesigned the app interface. WhatsApp and its associated paraphernalia were removed from the system architecture and replaced with a REST API that connects all the other retained third-party APIs and the database. The basic structure of the prototype remained the same. The suggestions and feedback obtained in the testing were treated as future work. The testing maintained the same format as the previous iteration.

This phase started with a notification to the DCCT that the researcher is ready for a review and testing. At this phase we present the final improved prototype of the SignSupport for emergency app according to all the recommended changes suggested by the Deaf participants and the domain experts, we then conclude this final phase with a questionnaire at the Deaf community with the Deaf participants. The steps of using the SignSupport for emergency app was summarized. We also present the workflow of the research from the planning stage to the final prototype.

4.5.1. User requirements

The user requirement for this iteration was based on the feedback gotten from the WCP EMS domain experts which are:

- As a Deaf user, I want my family members to informed about the situation by centre agent.
- As a Deaf user, I want to request help for a third party.
- As a Deaf user, I want a double opt-in feature to prevent accidental requests.
- As a Deaf User, I want to give a comprehensive Personal and Medical detail so that the EMS can give me adequate help.

4.5.2. Interface design

The User Interface features a major upgrade due to user's feedback. The redesign started with the creation of a base colour scheme that will drive the entire design. The colours are divided into 3 categories Main, accent, and neutrals. The main colours as the name implies are used on the screens to draw attention to major elements while the accent colours are used to highlight important information. The neutrals are white, grey and black. See Figure 4-9 Welcome Screen.

In this design, the bottom navigation bar was retained as it found a wide acceptance amongst the participant, but the number of tabs was increased to four. The bottom navigation tabs are Home tab that takes the user to the Home screen, Emergency tab for requesting emergency help, Video tab that gives quick access to the videos and Profile tab where the user can access their profile, update it and set up emergency contacts.

The following section discusses the redesign based on recommendations from the preceding iterations, including the features that were suggested. There are also two additional screens for double opt-in where the Deaf user must confirm an emergency request before it is sent to the Deaf contact centre and an emergency contact screen where the Deaf user can preselect a maximum of three contacts who will be notified by the Deaf contact centre in the case of an emergency. The WCP EMS supplied additional fields that should be in the profile form, so forms have been updated. Each of the screens are discussed in detail below:

Sign Up: The sign-up screen retains all the major elements of the previous prototype such as the name, email, and password fields. The form inputs were improved to be much more visible while the screen's background colour was changed to the main colour.

Login: This screen is also like the previous iteration, the SignSupport logo was made a bit bigger than previously to make it easily identifiable and a "Welcome Back" header was added below the logo. The login form used a neutral white background as a contrast from the rest of the screen and contains the email and password form inputs. Also, the screen has links to the "Sign Up" and "Forgot Password" screens.

Forgot Password: Forgetting passwords is a common feature of web/mobile technology and a user needs a way to reset their password when such happens. The "forgot password screen" is the user interface where the user can type in their email and submit it for a chance to reset their password. The screen shares the same template with the sign up and login screens above. It also uses the main colour as a background and has a link to the login screen.

Complete Profile: The complete profile screen is a new addition. And it is loaded immediately after a successful sign up to prompt the user to fill in his details. The top section duplicates the home screen and has a personalized welcome message. The next section has the SignSupport logo, the header text - Complete Your Profile and additional text that explains why this is important. The screen also has a button that links to the profile section and another one that the user can tap to skip the process.

Home: The home screen incorporates all the elements from the 3rd iteration with further enhancements. The top section contains a personalized welcome message and the user's avatar. The first aid tutorials section was further improved by making the videos thumbnails and the text descriptions within their containers bigger which makes the videos easier to identify. The emergency request section also implemented a participant' feedback from the second iteration about the inclusion of real imagery rather than icons. **Figure 4-11**(a) presents the new home screen.

Emergency Request: The emergency request screen retained most of the elements of the third iteration. The user's location was relocated to the top of the screen with the associated GPS coordinates and the main address was highlighted and directly beneath the address a map of the location is shown. The additional details field was modified to a select list of possible details such as bleeding, unconscious, heart attack etc. The options in this list were supplied by the EMS. Also, a toggle button is included where the user can indicate that the request is for a third party before eventually sending the request.

Confirm Request: This is a new screen that was designed to act as a double opt-in mechanism and prevent emergency requests. It was a major requirement of the EMS whose main purpose is reducing the instance of accidental requests that can take valuable time away from emergency workers. The screen has a countdown timer that counts from 10 to 0 during which the user must tap on the continue button else the request will be cancelled. There is also an option to cancel the request manually if the user chooses to do that.

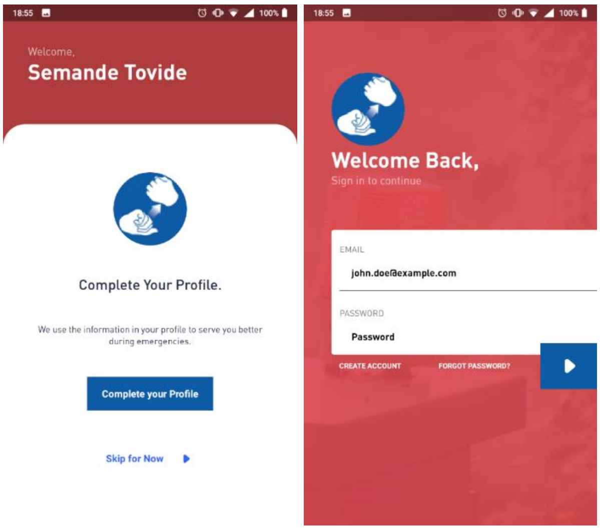
Emergency Sent: The emergency sent screen is a new screen that uses the accent colour green to signify success. It was designed to give the user feedback and reiterate the details of the next steps after the request has been sent.

Profile: The Profile section consists of 4 screens. The main profile screen contains a list that links to the three forms under the profile section. Each of these screens all share the same basic template which has a

- ❖ Personal Data: The personal details screen contains a form where the user can input or edit their personal data such as first name, last name, age, and other pertinent details that the EMS needs to service the Deaf user. **Appendix E: User Profile** contains a full list of the details captured in the form.

- ❖ Medical Details: The medial details screen looks like the personal details screen mentioned above. In this case, the form captures medical information such as the Deaf user's insurance information, drug and food allergies etc. The full list is presented in **Appendix E: User Profile**
- ❖ Emergency Contacts: The emergency contacts display a scrollable list of all contacts stored on the users of which the user can select a maximum of 3 contacts which will then be stored in the database for future reference. The prototype development section discussed the process in detail.

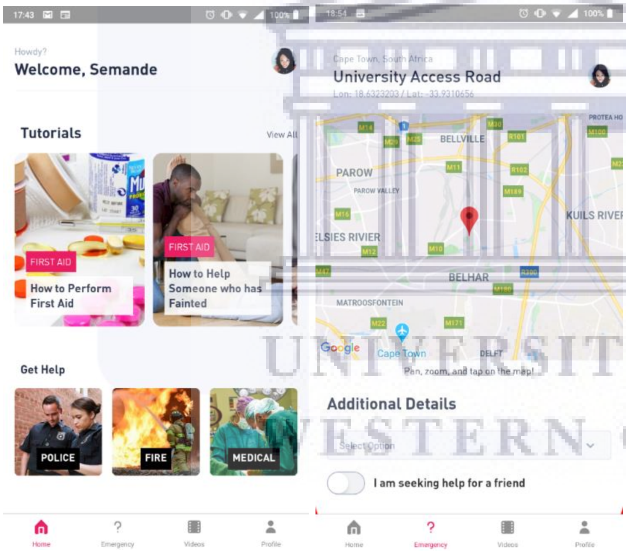
Note, the video screen wasn't changed. It maintained the same form from the third iteration and further improvement to its interface was considered as future work.



(a) (b)

Figure 4-9 Welcome Screen

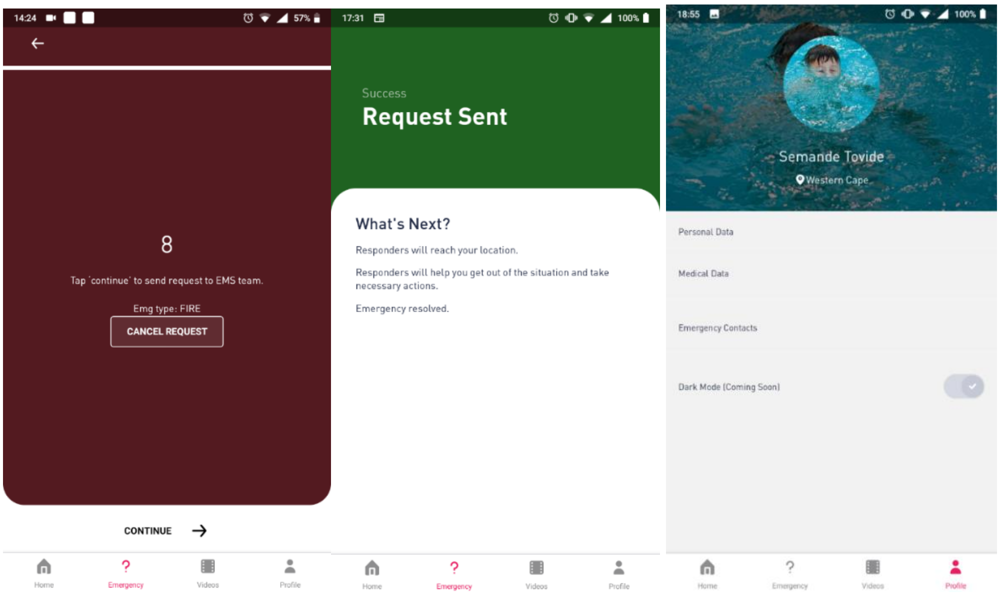
The sign-up page for first time users of SignSupport emergency app to become an account owner, next time the user wants to access the app, they will already be logged in since their previous details are already stored.



(a) (b)

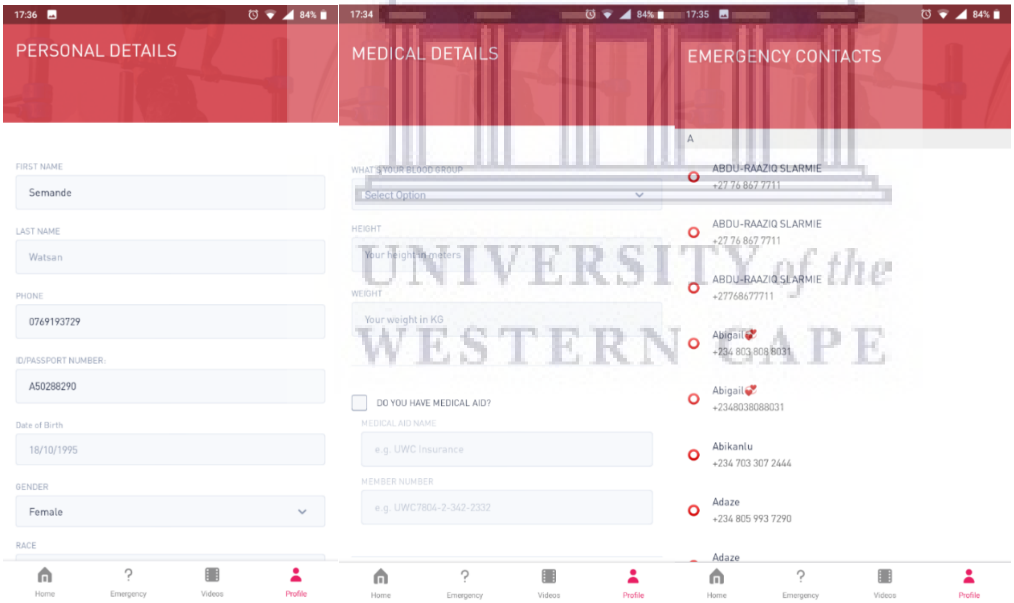
Figure 4-10 Home Screen and Request Help Map Screen

Screen (a) presents all the features on the home screen of the emergency app with clear icons for effortless access user interaction with the application interface. Screen (b) shows a map description of a user requesting help from the EMS provider system, user's location details and the user personal profile details will be sent.



a *b* *c*

Figure 4-11 Screenshot of the improved Request confirmation and successful page
This screenshot (a) demonstrates the request confirmation message from user when requesting for helps to avoid false call, screenshot (b) is the confirmation for a successful request and screenshot (c) displays the various sections on the profile screen.



(a) (b) (c)

Figure 4-12 Screenshot of the improved Profile Page of SignSupport emergency page
Figure (a) above shows the user personal details screen, figure (b) displays the user medical details screen such as food allergies and figure (c) shows where users are allowed to type in their emergency contact and can be updated with more information such as select number from their phone contact.

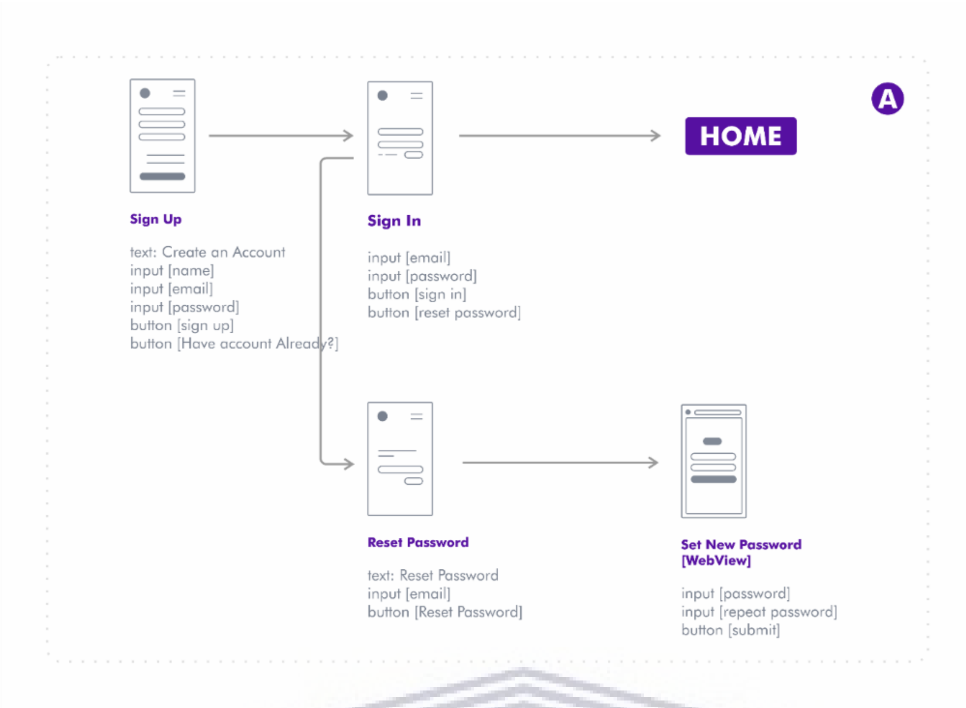


Figure 4-13 Workflow Diagram A – Authentication Flow

The Authentication flow is the initial screen flow that an unauthenticated user sees. The initial screen is the Sign In screen with button that links to Sign Up and Reset Password. Both Sign Up and Sign In screen will eventually lead to the Home Screen. The Reset Password screen will lead to a WebView screen within the browser where a valid user can reset the password and then go back to the Sign In screen.

Figure 4-14 Workflow Diagram B – Emergency Request Flow

The emergency request screen starts from the Home screen where the user is presented with various components such as "Emergency Request". On clicking on the Emergency Request button, the Emergency Request screen is presented which leads to the Confirm Emergency Request screen and finally a confirmation is shown of the Emergency Request Sent screen

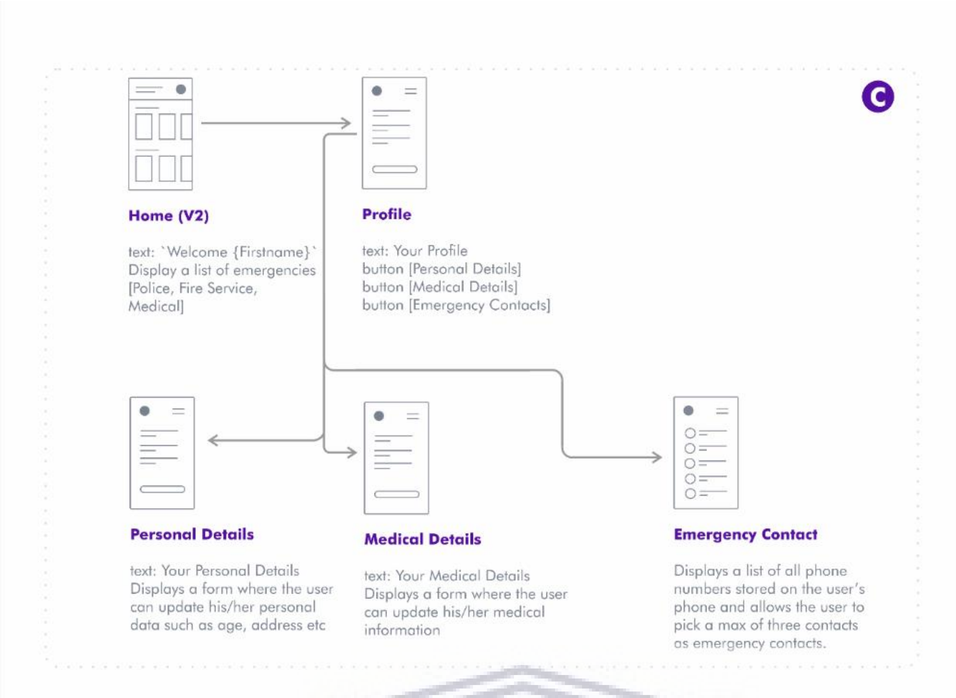


Figure 4-15 Workflow Diagram C

4.5.3. System architecture

The system architecture in this iteration is vastly different from what was obtained in the third iteration. The previous architecture was evaluated by the domain experts at the WCP EMS and found to be too complex and cumbersome and they recommended that it should be simplified by removing all components that relate to WhatsApp and possibly replace those components with WebRTC. The suggestion was implemented, and WhatsApp was replaced by a REST API which is used by the SignSupport for emergency app to connect to all other components including the Deaf Contact Centre and third-party APIs such as Google Places and Google Reverse Geocode API which are used to load a map of the user location and convert the GPS coordinates to an address, respectively. The section below will discuss each component of the system architecture.

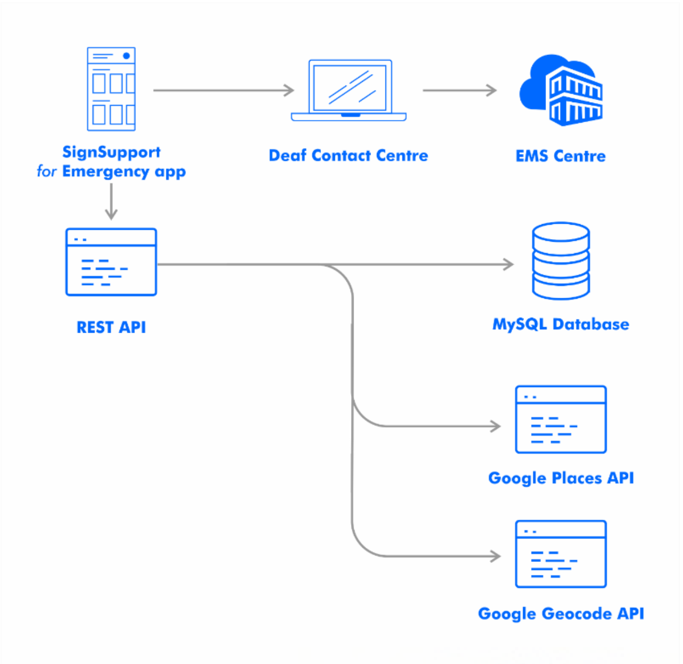


Figure 4-16 System Architecture for Final Iteration
The system architecture for the final iteration is distinctly different from the earlier iterations. The REST API was introduced to serve as our signle source of truth and prevent the app from directly connecting to different services. The REST API connects to the database and calls all external 3rd party APIs. The prototype directly connects to the Deaf Contact Centre when sending emergency requests which is then sent to the EMS centre.

REST API: A REST API, which was formally defined by Roy Field, a special application program interface that uses Representational State Transfer and it offers 3 main advantages that is very useful for this research: Client-Server Separation, Uniform Interface, and Statelessness. REST APIs compared to SOAP and monolith design patterns are useful in projects where requirements are fluid, and a separation of concerns is important. Another added benefit is the ability to expand and add other features easily to the app without a major change to the software architecture. The REST API encodes all requests in JSON (JavaScript Object Notation) before they are sent through the HTTP server to the Deaf Contact Centre. **Figure 4-16** presents the new system architecture.

Mobile App: The mobile app connects to the REST API and receives/transmit data through it. The app is not no longer connected directly to the database or any of the third-party APIs. The benefits of this API-centric approach include separation of the presentation logic (GUI) from the business logic as the mobile app can focus on displaying data to the user while the logical operations are carried out on the REST API. Another benefit is that the app can change independently of the other components because it isn't tightly coupled to them anymore.

Database: The database remains largely unchanged, it is a MySQL instance on Heroku, however the database schema undergoes some core changes as presented in **Figure 4-17**below. Additional tables such as user_profile, user_medical_data and user_emergency_contacts were created to store the profile data that will be introduced by the latest update to the profile section. Finally, each of the newly created tables have a user_id field which is a foreign key that links to the user table.

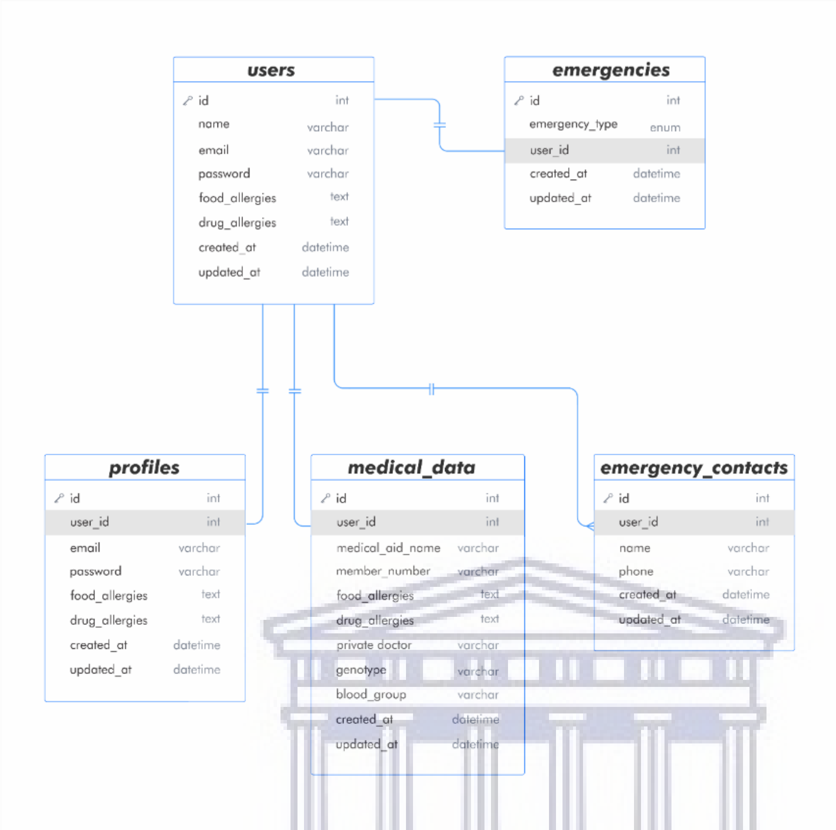


Figure 4-17 Database Schema for Iteration four

Deaf Contact Centre: The Deaf contact centre on its part also changed. The feedback and recommendation from the domain experts and the WCP EMS also applied to the Deaf contact centre as it also used WhatsApp as it major component in receiving emergency requests from the SignSupport for Emergency app and forwarding such messages to the appropriate EMS provider. It must be recalled that the Deaf contact centre isn't built to respond to requests from the SignSupport for emergency app only, its main purpose is to serve as a relay for all the specialized apps that are currently in development for the Deaf community such as this research and apps that have been completed and in use. The research collaborator who worked on the Deaf contact centre replaced WhatsApp with a set of intricate components that work together to triage all incoming requests to the Deaf contact centre. The process, in the case of the SignSupport for emergency app, basically involves a webhook created with Zapier that receives automated messages sent by the REST API using a POST request. Zapier identifies the request as coming from the emergency app based on the webhook address and then creates a record in Salesforce and sends a notification alert to any available agent. The Deaf contact centre agent then processes the request and sends it to the EMS.

4.5.4. Prototype development

The prototype development pipeline remained the same as the process designed in the second iteration although it was slightly improved in the third iteration with the introduction of software tools for adding closed-captioning to the first-aid tutorial videos. The development activities were done in two stages which are REST API development and Prototype Modification. The section below describes the process in detail:

REST API Development: The REST API is implemented with NodeJS which is a JavaScript runtime environment built on the Chromium V8 engine. There are several advantages in using NodeJS for the REST API which includes using the same language for both the app and the REST API. Also, NodeJS uses less memory due to its ability to run asynchronous and single-thread processes; it is a lot faster compared to other interpreted languages such as PHP and Python. The development process for the REST API started with updating to the latest long-term support (LTS) version of NodeJS which was v10.17.0 as the time of installation. The next step was to create a project directory called api in the development environment and install a web framework to make the API development process easier and faster. While the ability to create a server directly on NodeJs exists that isn't advisable and usually another framework is installed on NodeJS to create the server. In this case, ExpessJS which is a minimal web framework was installed in the api directory and various routes were created to signify the API endpoints that that prototype will call when it needs to. Some samples of the endpoints for the user resource are listed below:

POST <Server-url>/api/create-account - Create a new user account.

POST <Server-url>/api/login - Login a user.

GET <Server-url>/api/user - Get the authenticated user.

POST <Server-url>/api/reset-password - Reset a user's password.

The business logic for each of the endpoints were then removed from the prototype into the respective endpoint. For instance, the sign-up logic was removed from the sign-up screen and placed in the /api/create-account controller. After all the business logic has been moved, the next step was to step up automated tests using Mocha for the REST API to validate that each endpoint is working according to specification and return the appropriate response. Finally, the REST API was deployed to Heroku using the hobbyist free-tier account just like the database.

4.5.5. Prototype Modification

The prototype retained React-native and its associated packages as the development framework and the code remains largely unchanged (see prototype development iteration 2 where the process was discussed in detail) except removal of WhatsApp related features, the extraction of the business logic into the newly developed REST API and the creation of a design system to create reusable standard components. This new design system saved a lot of development time as the researcher was able to reuse components in various sections of the prototype instead of developing them individually.

The modification of the authentication flow started with the extraction of the business logic from each of the screens to the REST API. Then, each screen was analyzed with a holistic view of extracting components into reusable components. These newly created components were then styled using the Stylesheet component which is supplied by react-native and behaves like CSS which is used to style applications built for the web. The emergency request flow remains almost the same. Just like the authentication flow above, the business logic was extracted into the REST API then, each component was optimized for reusability and styled with the Stylesheet component to match the design system.

As a Deaf user, I want a double opt-in feature to prevent accidental requests: Feedback from the evaluation at the Deaf contact centre was the inclusion of a feature to prevent accidental requests. This was implemented by creating an additional screen called the Request Confirmation screen which has a countdown timer embedded within it. The expectation is that the user will tap a button on the screen to confirm the emergency request within the specified time limit before the REST API then sends the request to the Deaf contact centre and it then redirects to the Request Sent screen. However, if the counter lapses without the request being confirm by the user, then the request is cancelled, and the user will be redirected to the Home screen.

As a Deaf User, I want to reset my password if I ever forget it: This requirement involved the addition of a new screen called the "Forgot Password" screen. In the case where the user has forgotten her password, the screen will send a request containing the user's email to the /api/reset-password endpoint. The REST API then verifies that the email is associated with an account and if found, the app will send an email, with a link embedded within, to her email address to confirm ownership and access to the email address. Once the user clicks on a link, she is redirected to a page where she will create another password and be able to login. In this flow, the clicks on "forgot password" screen and types in her email.

As a Deaf user, I want to request help for a third party: Another new user requirement for this iteration is the ability to request help for a third party. The Emergency Request screen was modified as shown in **Figure 4-10** to include a toggle button that the user can click when requesting help for a third party. The toggle button has a well-defined description, "Get Help for a Friend" and when it is clicked, it will set the "isFriend" variable to true on the request body sent to the REST API. The REST API then uses this variable to modify the emergency request sent to the Deaf contact centre and indicate that the request is for a third party. Note, that for third-party requests the profile information isn't sent to the Deaf contact centre because the information is for the user and not the third party.

As a Deaf user, I want my family members to inform about the situation by centre agent: The WCP EMS suggested that the Deaf user being an already vulnerable person should have a list of contacts that can be contacted during an emergency by the Deaf contact centre. The Deaf community and participants agreed that this was a good suggestion, and it was listed as part of the requirement for this iteration. This feature was implemented by accessing the Contact API that is included as a library in react-native. The Contact API returns a list of contacts stored on the device which is then presented on the Emergency Contact screen. The user can pick up a maximum of three contacts which are then stored in an array before being encoded and sent to the REST API. The REST API then stores this data in the database for retrieval in the future. The user can also update the emergency contacts by returning to the screen and picking another set of contact and clicking the save button. Finally, every time the user makes an emergency request, the REST API will retrieve the emergency contact and combine it with the request payload then send it to the Deaf contact centre which will then extract the numbers and contact those listed.

As a Deaf User, I want to give a comprehensive Personal and Medical detail so that the EMS can give me adequate help: Another feedback from the EMS is that the data collected in the form is inadequate and needed to be updated. They supplied the researcher with a list of all the fields that should be in each section of the profile pages. The full list can be found in **Appendix E: User Profile**. The implementation of this started with the creation of a new table in the database called users_medical for storing the medical data while the users_profile table was altered to accommodate the new fields that will be added to the form. The next step was adding new form fields into each of the screens where the user will type in the details before they are sent to the REST API and finally persisted into the database.

WhatsApp Removal Process: This process started by deleting the Request help Manual screen. Then, the entire code that deals with creating a deep link and connecting to the WhatsApp on the user's device was also removed from the app. Finally, the integration with Chat API was deleted and the code for converting the emergency request into an acceptable format before it is sent to the Deaf contact centre was moved into the REST API. This code is still relevant and will be used by the REST API endpoint to encode emergency requests and send to the Deaf contact centre in the same format as previously used.

4.5.6. Results

The testing was conducted with a total of 9 participants who are the same participants used for testing in the second iteration. This testing is a bit different from all other previous iterations as a questionnaire session was carried out after the testing exercise was over. This result showed that all participants were very satisfied with the new interface design SignSupport for emergency apps although they were disappointed with the removal of WhatsApp because they do not have the ability to make video calls to the Deaf contact centre anymore. They mentioned that this design looks more appealing to the eyes and more like the apps they see and download from the Google play store. Another participant acknowledged both designs are good but if she has the option of picking which one to download, she will pick the latest design, she continued by saying 'not only is it appealing to the eyes it also presents all the features from the previous iterations in a much better form'. The researcher observed that the participants' comments were made with a satisfactory tone behind their voice and were happy that they were able to contribute to the research from the starting phase to the final design. They mentioned satisfaction regarding the help request process, user interface, navigating through the app, the first-aid tutorials videos, and the app responsiveness. Another feedback from the participants, after giving their suggestion on the app, mentioned that the Deaf community needs more learning apps on health and education that could serve the community just like the SignSupport for emergency app. A summary of the participant's responses is presented in **Table 4-4**below:

Table 4-4 Participant Feedback Table

Participants	Feedback and Suggestions
P1 - P9	A video call mechanism should be returned to the SignSupport for emergency app.
P1, P3, P4, P8	On boarding feature where users are educated about the app using short videos in SASL describes the app features at the beginning.
P2, P3	More first-aid SASL videos should be included.
P8	More learning applications are needed for the Deaf community
P9	Ability to use the prototype without internet connection

The shared questionnaire includes open ended questions and provides a space to allow the participants write down their thoughts and suggestions on future improvement of the app. See **Appendix F: Questionnaire** for a copy of the questionnaire.

4.5.7. Analysis

The result of the iteration reveals that the prototype is stable enough for integration into the existing system presently being used by the WCP EMS. Although, this iteration was not tested at the WCP EMS due to the coronavirus pandemic the researcher is confident that it will be accepted by the domain experts as all their recommendations and feedback were incorporated into this iteration.

The analysis of the questionnaire in **Error! Reference source not found.**below shows that t he participants were very satisfied with the prototype. At least 7 of the 9 participants scored the prototype as "Very Satisfied" in each of the questions asked in the questionnaire. The leading question which got a "very satisfied" response from all 9 participants was "**How satisfied are you with the emergency request process?"** while "**How satisfied are you with the app responsiveness?"** and "**How efficiently were the first-aid tutorial video content conveyed?"** were scored as "very satisfied" by 7 participants with the remaining 2 participants responding as "**Somewhat satisfied"** and **"Neither satisfied nor Dissatisfied"** each.

Table 4-5 Questionnaire Analysis

Questions	Very Satisfied	Somewhat satisfied	Neither satisfied nor Dissatisfied	Very dissatisfied	Somewhat Dissatisfied
How satisfied are you to describe the user interface?	8	1			
How would you describe your navigating experience through the app?	8	1			
How satisfied are you with the app responsiveness?	7	1	1		
How efficiently were the first-aid tutorial video content conveyed?	7	1	1		
How satisfied are you with the emergency request process?	9				
How satisfied are you with the entire app content?	8	1			
How satisfied are you to recommend the app to other Deaf people?	8	1			

The participants were disappointed when they realised that the video call and instant messaging feature had been removed and suggested that these features should be returned to the app. The ability to use the SignSupport for emergency app without an internet connection and implementing an on boarding tutorial where the prospective user can learn how to use the app were also suggested by the participants. However, they all agreed that these features are not critical and should be implemented in the future as future work.

4.6. Summary

The implementation of the prototype followed the same collaborative design process established earlier in the previous chapter to develop a prototype that meets the needs of the Deaf community. The prototype was implemented as a cross-platform hybrid app to supports different mobile operating systems–although the testing was done only on the android platform, it will work without much modification on other platforms such as iOS. During development, the prototype went through four iterative processes where the prototype was tested, and the feedback and recommendations obtained were used to improve the prototype at the next iteration. The first iteration was a proof-of-concept to check if the values of the research team, stakeholders like the WCP EMS and the Deaf community are aligned, and they have a shared understanding of the problem. The second iteration took this a step further by adding additional features such as the first-aid tutorials videos which were recorded in SASL to give emergency aid to the Deaf users while waiting for the first responders to arrive. This iteration also integrated WhatsApp which was used to communicate with the Deaf contact centre. The integration of WhatsApp also gave the Deaf users the ability to send emergency requests directly when needed such as video calling or sending pictures of emergencies. The third iteration improved the first-aid tutorial videos feature by including closed captioning on all the videos as suggested by the participants in the previous testing. The iteration took a different approach from testing as compared to the first 2 iterations by testing and evaluating the prototype with the domain experts, who are hearing people, from the Western Cape Provincial EMS.

The final iteration concentrated on getting the feedback from the WCP EMS implemented. WhatsApp and all associated integrations were removed and replaced with a newly created REST API. The REST API encapsulated all the business logic needed to communicate with the database and the Deaf contact centre and become the single source of truth. Finally, the prototype was tested and well accepted at the Deaf community and other stakeholders. The next chapter presents the conclusion of the research work.

5. Conclusion

This research aimed at providing emergency service for Deaf people in different emergency scenarios by building the SignSupport for emergency app with the goal of rendering first aid assistance on a mobile platform. The process of research was governed by co-design and participatory design methodologies using qualitative methods (questionnaires, semi-structured interviews, observations and focus groups) in designing a mobile app for Deaf users (Glass and Arnkoff 1997), (Gill et al. 2008), (Tessarolo et al. 2019). The initial idea for this research was conceived at a meeting of the representatives of the Deaf community of Cape Town (DCCT) with the researcher and other collaborators. The initial question asked was, "How can SignSupport be of help to the Deaf community?" Several ideas were proffered, and the most pressing problem was identified as the communication gap between a Deaf person and the emergency services. Traditionally, emergency and telephony services are majorly focused on hearing people which has necessitated the need to build adapters to connect the Deaf users to those existing services. Some of the existing alternatives in use that give access to emergency services include sending SMS to the EMS, the use of User Assistive Device (UAD), a portable alarm system that transmits to the EMS when activated or a captioning device (Robert et al. 2014), (Travis E. 2018). A common limitation of these techniques includes but not limited to extra expenses in buying the devices. (See

Table 2-1 and Table 2-2 for literature review summary) Our research aims at providing a better alternative by using technology that is readily available to the average Deaf person and a mobile device perfectly fits that requirement. The emergency service systems presently in place across the province and other jurisdictions were examined, the researcher worked closely with the stakeholders, consulted the product manager and literature review during the entire course of this project.

The first iterative process started off with a focus group session where the initial idea obtained from DCCT was discussed, the participants were encouraged to brainstorm on the main user flow needed to build the first prototype and get the basic user workflow for emergency requests mapped out. We categorized emergency requests into 4 broad scenarios which are police, medical, fire and others. This categorization made it easy for operators at the Deaf contact centre to identify the first responders which are then contacted through the EMS provider. The iteration also has a basic user registration feature which allows only authenticated users to make emergency requests.

The second iteration implemented the feedback we got through semi-structured interviews and observations from the first iteration's usability testing. We integrated a paid third-party WhatsApp API that allows the SignSupport for emergency app to send requests to the Deaf contact centre and give users the ability to manually connect with the contact centre and send additional details along with the request. We used a 3rd party API for integrating these functions due to the limitation that WhatsApp doesn't allow embedding core chatting and location features directly into unofficial apps. Other additional features for the second iteration include integrating a google map component so users can pinpoint their location accurately, introduction of first-aids videos in SASL, implementing a basic profile page and general improvement in the UI design.

The third iteration started with the introduction of closed captioning on all first-aid videos used within the app. Furthermore, the researcher worked closely with domain experts from the WCP EMS, collaborators and the product manager to evaluate the prototype's possible integration into the existing system for emergency response in Western Cape. As part of the iteration, the domain experts advised that the ability to seek help for another party is an important feature that should be included in the prototype. Also, during the evaluation, it was discovered that WhatsApp integration complicates the system architecture, therefore another alternative to WhatsApp and manual connection is necessary. Finally, the domain experts from the WCP EMS suggested that the profile page needed more forms to capture user details such as a complete personal profile, medical history, and emergency contacts of the user.

The final iteration of the research presented a prototype that encapsulated the user requirements. All through the project, co-design and participatory design methodologies showed great impact in the research process by involving participants and stakeholders at every step of the iterations. The final developed SignSupport for emergency app gives the Deaf user the ability to request emergency help for herself or others during emergency situations, an updated profile page and addition of emergency contacts who will be notified during emergencies. The prototype also has a double opt-in feature to prevent accidental emergency requests by requiring users to confirm a request within a 10 second window using a countdown timer. Also, taking in the suggestions of the WCP EMS and the product manager, WhatsApp was completely removed from the prototype to make the system architecture easy to integrate into the existing EMS system at a future date.

5.1. Discussion

The main research questions are as follows:

- How can rescue be provided to a Deaf person in need of urgent rescue attention?
- What can be done to craft a bridge between a mobile interface for Deaf People and a standard hearing EMS contact centre?

These questions were then broken into sections, as displayed below:

5.1.1. Research question: EMS for a Deaf person

The methodology utilized in developing the SignSupport for emergency app empowered Deaf people in building a solution for themselves that serves the community well. SignSupport for emergency app was built for ease of use in requesting emergency services and that was achieved by classifying emergencies into different scenarios and incorporation of graphical assets such as icons and buttons to offer a more visual way to use the app (see section 4.5.2 for description of the interface design). The usage of icons is common when building interfaces for visual learners (Marschark et al. 2013). (See section 2.4and section 2.5where a similar design approach was used). The SignSupport for emergency app provides first-aid videos instructions in SASL for users before the first responders arrive at the scene. The scenarios used in the app are flexible enough to accommodate other types of emergencies if needed. Participants involved in our research are selected from diverse experience and vary in degrees of expertise in using mobile technology (See section 3.3.1 discussion of participants) and they were able to use the app without help and make emergency requests simulating various scenarios.

The SignSupport for emergency application provides a profile section on the app, where the users can complete the identification and medical history forms. At the testing sessions, users were told to complete the forms in the profile sections which were personal details, medical history and emergency contact. When a user requests for emergency service, the details already saved in the database are retrieved and sent to the Deaf contact centre including the location of the emergency. All these details are forwarded to the appropriate EMS provider from the Deaf contact centre.

5.1.2. Research question: bridge between Deaf person and contact centre?

The SignSupport for emergency app is built for mobile phones to run on the latest version of the Android platform. The mock-ups for the prototypes are designed on Adobe XD and implemented using React-native. React-native was chosen because of its lean learning curve and ability to build platform independent hybrid apps and share code across the entire project. This means that the current prototype can be easily used on iOS and Windows mobile devices without much modification.

The app doesn't communicate directly with the EMS service providers. It sends a request to an aggregator called the Deaf contact centre which analyses the request before onward forwarding to the appropriate EMS service provider. The SignSupport for emergency app is API centric and, as such, requests from the app to the Deaf contact centre is done through a REST API. The REST API offers the ability to expand and add other features easily to the app without a major change to the system architecture. The REST API is where all our requests are made and encoded in JSON (JavaScript Object Notation) before they are sent to the Deaf Contact Centre. (See discussion in detail in Section 4.5.3 System Architecture)

The Deaf contact centre handles requests from the SignSupport for emergency app. It was built by a collaborator in the research team to handle requests from all projects currently in the works by the SignSupport team under the umbrella of ICT4D. SignSupport is a team of researchers whose main focus is to improve the lives of Deaf people and several projects are being carried out simultaneously amongst which is the emergency app (See section 1.1 for more discussion). The Deaf contact centre is a specialised contact centre that focuses on handling the needs of Deaf users using specialised tools and trained SASL interpreters and operators.

Internally, the contact centre uses Salesforce and Zapier to handle incoming requests. All apps that need to connect to the Deaf contact centre do so using a webbook generated on Zapier to send that request to the contact centre which is then inserted into the Salesforce CRM (see section 4.5.4 for more description). Salesforce will then send a notification which will be shown on the screen of any available operator, who will work on such requests and take appropriate action. In the case of SignSupport for emergency app, such request is analyzed and verified for accuracy before it is forwarded to the appropriate EMS provider. The EMS provider receives the request from the Deaf contact centre and notifies the appropriate first responders which can be police officers closest to the emergency location, paramedics, or the fire service office.

We have managed to answer the two main research questions in the sections above. Providing a viable mobile app that deaf users can easily use to contact emergency services with a few clicks answers the first research question and the inclusion of location, medical history, and emergency contact incorporated into the system answers the second research question.

5.2. Limitations

SignSupport for emergency app shows a great promise as a tool for Deaf users to contact emergency services and bridge the communication gap between a mobile interface and EMS provider, we discovered several limitations in this research.

Sample Size: An important limitation in this work was the sample size. At the first iteration, we had 6 participants, the second iteration had 7 participants. The third iteration, which was carried out with the domain experts from the WCP EMS, had 8 participants and finally the fourth iteration had 10 participants. This showed that each iteration had 10 or less participants during the usability testing and that there might be some features that should have been in the prototype but not discovered or some undiscovered usability issues that did not surface throughout the research.

Limited time and the COVID-19 pandemic: The use of co-design and participatory design methods required months of iterative work and prototyping which made it very limited. The researcher could evaluate the app for more complex functions and performance under stress.

The COVID-19 pandemic started during the final stages of this research work. The pandemic necessitated lockdowns around the world and prevented physical contact between the researcher and participants. The researcher could not carry out more usability testing at other Deaf communities to get suggestions on how to improve the prototype and more features to consider as future work.

5.2.1. Co-design and Participatory Design Methods

One of the best benefits of using co-design and participatory design methods is that it encourages making the research and design process a community effort. Collaborative work with the Deaf users and community yielded a transfer of technology to the Deaf users which will eventually have a lasting impact on their lives and give all participants an emancipative and transformative sense of achievement. The research was able to achieve a comfortable and reliable work relationship between the researcher and all participants involved especially at the Deaf communities wherever she visits to carry out her testing of prototype.

5.2.2. Basic Communication skill in SASL

A well-organized SASL class was offered for individuals and organizations who are willing to learn basic SASL communication skills and for people who will be working with the Deaf communities. The researcher team participated in this learning class and got a certificate of attendance at the end class. The class was held for a period of 3 months which taught the researcher some basic SASL communication skills, improved her understanding of the Deaf culture and social values (see section 3.5 for more details) (Emanuel et al. 2004). The knowledge acquired during the classes yield into improving the approach to the Sign Support for emergency app through mutual respect and understanding between the researcher and the participants.

5.3. Recommendations and Future Work

This section discusses the future recommendations for future features that can be developed for the SignSupport for emergency app. We also considered approaches in conducting research for Deaf people.

5.3.1. Features of SignSupport for Emergency App

The SignSupport for emergency app could be further developed to support a real-time location tracking of the first responders after an emergency request has been made and get a bi-directional communication feature. The real-time communication feature can be implemented using an additional screen after an emergency request has been made where the user receives updates from the Deaf contact centre and can further send additional details if the emergency changes. The real-time component of these new features will help users determine how close help is to them and estimate the arrival time of the first responders. Also, from the responders point-of-view, they can get accurate information if the emergency has improved or deteriorated while enroute to the site and be prepared for it.

Video instructions were found to be very useful in the SignSupport for emergency app and more videos in SASL could be provided within the profile section to aid better user understanding in filling the forms, (see section 4.5 for more details). These videos will be embedded in a modal that shows once a user clicks on an icon connected to the videos.

The current prototype of SignSupport for emergency app cannot work without an internet connection. This makes it virtually impossible to make an emergency request on the app during emergencies.

5.3.2. Testing Codes across platforms.

We plan to further explore testing of SignSupport for emergency app on other platforms such as iOS and Microsoft operating system. In addition to implementing features with a WebRTC connection with the

Deaf Contact Centre and actively track the first responders' location and plot it on the map within the app, we will also be implementing a feature where users can bypass using internet connection and make the emergency request to the Deaf contact centre using Unstructured Supplementary Service Data (USSD) or zero charges negotiation with the Internet Service Providers (ISP) within the province.

5.3.3. Conducting research for Deaf people.

Deaf people are vulnerable people and special guides must be in place when conducting research that uses Deaf people as the research subject (see section3.5). The researcher attended SASL classes for a period of 3 months to acclimate her to the traditions and culture of the Deaf community where she is carrying out her research. This is important in achieving rapport with the Deaf participants. For instance, one of the offensive actions to the Deaf culture is clapping to draw the attention of a Deaf person. Also, the need for consent cannot be overemphasized such as getting consent forms signed before proceeding. All participants were well informed about the data confidentiality and understood what data we are collecting and how their data will be kept safe, utilized and stored or destroyed at the end of the research.

The researcher is required to educate participants on details and their contributions to the research. Important details such as if participants will be paid for their engagement or otherwise and the process of the research must be fully understood by all parties. This necessitates a need to hire SASL interpreters that will communicate with the Deaf participants and make sure they fully understand all information passed across. It is always preferred if the SASL interpreters come from within the Deaf community as SASL, like other languages, has slangs and intricacies that can differ across communities. Hence, participants will be more comfortable working with an interpreter from within the community and will enjoy the experience.

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Appendix A: Deaf participant Information Sheet

1. What is this research project about?

This research aims to design a SignSupport for emergency mobile application for Deaf people in Cape Town, empowering them with the same access to emergency service resources as hearing people. The approach is to use a mobile application to contact standard emergency services on behalf of a Deaf person to a representative.

2. Who is running the project?

   - We are Computer Scientists from the University of the Western Cape.
   - You might know Bill Tucker. He's the project leader.
   - The student responsible for this particular project is Tovide A E Semande. (Semmie)

3. What do we want to achieve?

Create a possible link an existing EMS provider for future implementation.

4. What will we do?

   - We will design and build an application to run on android mobile devices and also available for other mobile Operating system such as iOS and Windows.
   - A Deaf user interface that will be easy to use and accepted by the Deaf community.

5. What do we expect of you?

- We want Deaf people to help design and evaluate this system.
- You will be asked to use the system in a role-play and be interviewed about the system.
- Participation is of your own choice.
- If you agree to participate, we will ask you to sign a consent form.
- You can leave the project at any time without any penalty to you at all.

6. Benefits

   - To address the need of an emergency service for Deaf people.
   - Introduce a possible method to craft a bridge between a mobile interface for Deaf people and a standard hearing based EMS call centre.

7. Risks and difficulties

There is no risk or difficulties in the survey or the experiment. There is no question in the session that will require you to reveal your personal medical history or disease.

8. Withdrawal and confidentiality

9. Dissemination of the study results

All information will be disseminated when the study is completed in the form of several papers at various conferences. Ultimately the rest of the results will be published in a form of a Master's Thesis. Deaf participants will be kept informed via several presentations at DCCT at strategic times of the project life.

....
Signature Date

....
Surname Initials

Appendix B: Consent Form for Deaf Participant

I, ____________________, fully understand the Design of SignSupport for emergency app project and agree to participate. I understand that I can withdraw from the study at any time, and any information collected pertaining to my contribution will be destroyed at once. I also understand that all information that I provide will be kept confidential, and that my identity will not be revealed in any publication resulting from the research unless I choose to give permission. I acknowledge that all information attained in this study or test will be stored on a computer that has a password that is only known by the researcher. Furthermore, all recorded interview media and transcripts will be destroyed after the project is completed. I am also free to withdraw from the project at any time.

I understand that an interpreter will be used for this trial and the information he/she translates will be kept confidential and not repeated.

....

Signature Date

For further information, please do not hesitate to contact:

Principal researcher: A E S Tovide

Dept. of Computer Science

University of the Western Cape

Private Bag X17

Bellville 7535

Email: 3748840@myuwc.ac.za and btucker@uwc.ac.za

Cell: 0769193729

Name:

Signature:

Date:

Appendix C: Consent Form for Interpreter

I, ____________________, fully understand the Design of SignSupport for emergency app project and agree to participate. I understand that I can withdraw from the study at any time, and any information collected pertaining to my contribution will be destroyed at once. I also understand that all information that I provide will be kept confidential, and that my identity will not be revealed in any publication resulting from the research unless I choose to give permission. I acknowledge that all information attained in this study or test will be stored on a computer that has a password that is only known by the researcher. Furthermore, all recorded interview media and transcripts will be destroyed after the project is completed. I am also free to withdraw from the project at any time.

I understand that as an interpreter for the above mentioned project participation trial, the information translated will be kept confidential and not repeated.

....

Signature Date

For further information, please do not hesitate to contact:

Principal researcher: A E S Tovide

Dept. of Computer Science

University of the Western Cape

Private Bag X17

Bellville 7535

Email: 3748840@myuwc.ac.za andbtucker@uwc.ac.za

Cell: 0769193729

Name:

Signature:

Date:

Appendix D: Consent Form for Interpreter

UNIVERSITY of the WESTERN CAPE

OFFICE OF THE DIRECTOR: RESEARCH
RESEARCH AND INNOVATION DIVISION

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24 October 2018

Prof W Tucker, K Williams, J Christans and S Tovide
Computer Science
Faculty of Natural Sciences

Ethics Reference Number: HS18/9/1

Project Title: Information and Communication Technology for Development.

Approval Period: 23 October 2018 – 23 October 2019

I hereby certify that the Humanities and Social Science Research Ethics Committee of the University of the Western Cape approved the methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report in good time for annual renewal.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

PROVISIONAL REC NUMBER - 130416-049

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

Appendix E: User Profile

Registration

A. Username:

B. Select your gender: (I don't know if they will want me to include more than just male and female)

C. Home Address:

D. Phone number:

E. Select your Race:

- Black
- White
- Coloured
- Indian
- Others

A. Select your Religion: Christian, Islam, Hinduism, Judaism, Other religion or No religion

B. Select your Marital Status: Married, Single, Divorced, Widow

C. Date of Birth

D. Do you have Medical Aid? Yes or No

Yes:

- Medical Aid Name
- Member number

A. Do you have any food Allergy? Yes or No

Yes:

- Details of food allergies

B. Do you have any medicine allergy? Yes or No

Yes:

- Details of Medicine allergy

C. Do you have a private Doctor? Yes or No

Yes:

What is your genotype and blood group?

- Doctor's Name
- Doctor's Cell Number (Should be able to select from phone contact)

Any other medical history that should be known? Please give details below.

D. Next of Kin 1

- Name:
- Address:
- Relationship:
- Cell Num: (Should be able to select from phone contact)

E. Next Kin 2

- Name:
- Address:
- Relationship:

Cell Num: (Should be able to select from phone contact)

Appendix F: Questionnaire

Design for Emergency Service System for Deaf People

1. How satisfied are you to describe the user interface?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disappointing Exceptional

2. How would you describe your navigating experience through the app?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disappointing Exceptional

3. How satisfied are you with the app responsiveness?

☐ Yes ☐ No

4. How efficient were the video content conveyed?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disappointing Exceptional

5. How satisfied are you with the requesting help process?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disappointing Exceptional

6. How satisfied is the entire app content?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

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7. How satisfied are you to recommend the app to other Deaf people?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disappointing Exceptional

Appendix G: Turnitin Result

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File size:	8.03M
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Character count:	218,495
Submission date:	02-Oct-2020 04:10PM (UTC+0200)
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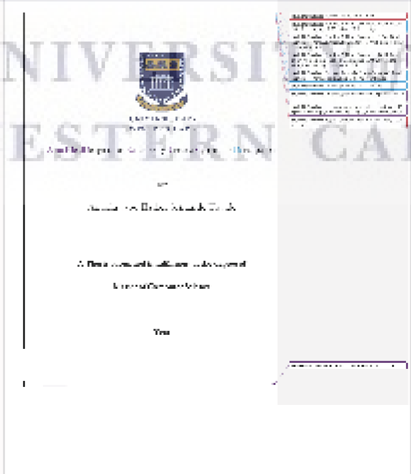

Appendix H: Conference Poster Presentation