NEAR EAST UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF COMPUTER INFORMATION SYSTEM

HELP DEAF AND HARD-OF-HEARING PEOPLE GAIN SOUND AWARENESS THROUGH A MOBILE APPLICATION

Ph.D. THESIS

Hassan Beleid Muamer MOHAMMED

Nicosia
December, 2024

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Supervisor
Prof. Dr. Nadire ÇAVUŞ

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APPROVAL

We specify that we have read the thesis submitted by Hassan Beleid Muamer Mohammed entitled "**Help Deaf and Hard-of-Hearing People Gain Sound Awareness through a Mobile Application**" and that in our combined opinion, it is fully adequate in scope and in quality, as a thesis for the degree of Doctor of Philosophy of Science.

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DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Hassan Beleid Muamer MOHAMMED

26/12/2024

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Hassan Beleid Muamer MOHAMMED

ABSTRACT

Help Deaf and Hard-Of-Hearing People Gain Sound Awareness through a Mobile Application

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People suffering from deafness and those with hard hearing, who are mostly characterized by the inability to speak and hear, are mostly not involved in numerous social considerations, educational attainment, and job opportunities as compared with their counterparts owing to their disorders. It is therefore significant to adopt the newest technology to assist persons with such disabilities in minimizing the communication gap, getting proper education, getting sound awareness, and participating in social activities in society. Smartphones play a vital role in minimizing the burden experienced by people with hearing disabilities through adopting different applications that assist in different ways such as communicational, social, and educational. Mobile apps have numerous advantages for the deaf and hard-of-hearing people (D/HH), including information access and a seamless, personalized user experience. In addition, mobile apps have voice recognition technology, which gives deaf and hard-of-hearing people access to speech. Because of the rare detection sound applications in literature, it was developed a mobile application titled AsEar, that can be used in detecting sound around people with hearing disabilities. It can be used in sending these sounds via different social networks and instant messengers to their close ones in case they do not recognize the sound so that they interpret it for them. This can aid in harmonizing things and ensuring that these people are not segregated from society; more importantly, enrich their reading and writing skills so that their relatives and friends will understand the basic principles of sign language. To evaluate the quality of AsEar mobile application, two different questionnaires have been used: The system usability scale (SUS) and the satisfaction. Also, semi-interviews to get feedback from 63 participants. At the end of these evaluations, the results showed that the developed application is usable and most participants gave positive feedback about the usability. As they reported, the AsEar mobile application encouraged them to communicate. Participants are also happy to involve their relatives and friends in learning sign language. D/HH people can benefit from AsEar mobile application by increasing their awareness of environmental sound, improving communication, and increasing independence, which would increase their well-being.

Keywords: Assistive technology, cloud computing, deaf and hard of hearing, smartphone apps, social networking sites, sound awareness

ÖZET

İşitme Engelli ve İşitme Güçlüğü Çeken İnsanlara Ses Farkındalığı Kazandırmak için Bir Mobil Uygulama

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Aralık, 2024, 136 sayfa

Sağırlık ve işitme engelli kişiler, çoğunlukla konuşma ve duyma yeteneğinden yoksunlukla karakterize edilen kişiler, bozuklukları nedeniyle akranlarına kıyasla çok sayıda sosyal değerlendirme, eğitim düzeyi ve iş fırsatına çoğunlukla dahil edilmezler. Bu nedenle, bu tür engelli kişilerin iletişim boşluğunu en aza indirmelerine, uygun eğitim almalarına, ses farkındalığı kazanmalarına ve toplumdaki sosyal aktivitelere katılmalarına yardımcı olmak için en yeni teknolojiyi benimsemek önemlidir. Akıllı telefonlar, iletişimsel, sosyal ve eğitimsel gibi farklı şekillerde yardımcı olan farklı uygulamaları benimseyerek işitme engelli kişilerin yaşadığı yükü en aza indirmede hayati bir rol oynar. Mobil uygulamalar, bilgi erişimi ve kusursuz, kişiselleştirilmiş bir kullanıcı deneyimi dahil olmak üzere sağır ve işitme engelli kişiler (D/HH) için çok sayıda avantaja sahiptir. Ayrıca, mobil uygulamalar sağır ve işitme engelli kişilere konuşmaya erişim sağlayan ses tanıma teknolojisine sahiptir. Literatürde nadir bulunan ses algılama uygulamaları nedeniyle, işitme engelli kişilerin etrafındaki sesleri algılamada kullanılabilen AsEar isimli mobil uygulaması geliştirilmiştir. Geliştirilen mobil uygulama, etraflarındaki sesleri tanımadıkları takdirde yorumlamaları için yakınlarına farklı sosyal ağlar ve anlık mesajlaşma uygulamaları aracılığıyla göndermek için kullanılabilinir. Ayrıca geliştirilen mobil uygulama sesleri uyumlu hale getirmeye ve bu kişilerin toplumdan ayrılmamasını sağlamaya yardımcı olabilir; daha da önemlisi, akrabalarının ve arkadaşlarının işaret dilinin temel prensiplerini anlamaları için okuma ve yazma becerilerini zenginleştirebilir. AsEar mobil uygulamasının kalitesini değerlendirmek için iki farklı method kullanıldı: Sistem kullanılabilirlik ölçeği (SUS) ve memnuniyet ölçeği. Ayrıca, 63 gönüllü katılımcıdan geri bildirim almak için görüşmeler yapıldı. Bu değerlendirmelerin sonunda elde edilen sonuçlar geliştirilen uygulamanın kullanılabilir olduğunu ve katılımcıların çoğunun kullanılabilirlik hakkında olumlu geri bildirimde bulunduğunu gösterdi. Dahası AsEar mobil uygulaması onları iletişim kurmaya teşvik ettiğini belirttiler. Ayrıca, katılımcılar ayrıca akrabalarını ve arkadaşlarını işaret dilini öğrenmeye dahil etmekten mutluluk duyduklarına vurgu yaptılar. D/HH insanları, çevresel sese ilişkin farkındalıklarını artırarak, iletişimlerini iyileştirerek ve bağımsızlıklarını artırarak AsEar mobil uygulamadan faydalanabilirler. Böylece refahlarının artmasına neden olacağı düşünülmektedir.

Anahtar Kelimeler: Destekleyici teknoloji, bulut bilişim, işitme engelli ve işitme güçlüğü çekenler, akıllı telefon uygulamaları, sosyal ağ siteleri, ses farkındalığı

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LIST OF ABBREVIATIONS

AED:	Acoustic Event Detection
ALDS:	Assistive Listening Device
AR:	Augmented Reality
BaaS:	Back-end as a Service
CB:	Communication Boards
D/HH:	Deaf and Hard of Hearing
EI:	Emotional Intelligence
FaaS:	Functions-as-a-Service
FCM:	Firebase Cloud Messaging
FM:	Frequency Modulation
HCI:	Human-computer interaction
IaaS:	Infrastructure-as-a-Service
LEDs:	Light-Emitting Diodes
MEMS:	Microelectromechanical-System
MIM:	Mobile Instant Messengers
PaaS:	Platform-as- a-Service
PCs:	Personal computers
SaaS:	Software-as-a-Service
SDK:	Software Development Kit
SL:	Sign Language
SMS:	Short message Service
SNR:	Speech to Noise Ratio
SNSs:	Social Networking Sites
TTY:	TeleTYpewriter
XP:	Extreme Programming

CHAPTER I

INTRODUCTION

In this chapter, the provider provides the reader with an overview of the whole thesis, typically including the following key elements: problem statement, research importance, aim, thesis contribution, limitations, project schedule, and thesis overview.

1.1 Background

The ability to hear is a vital part of the human body. It is a necessary sense for effective interpersonal communication. However, the World Health Organization estimates that there are 360 million Deaf and Hard of Hearing (D/HH) people worldwide (328 million adults and 32 million children) (Feigenbaum, 1987). Furthermore, the D/HH have a disproportionately high prevalence among adults aged 65 and up (Deborah, 2021). The D/HH employs a variety of hearing aids, including cochlear implants, sign language, captioning, reading lip movement (speech-reading), and other types of supporting aids, to increase speech and non-speech sound awareness. Despite this, accessible hearing aids only cover around 10% of the global need (Hamed, 2016). As a result, more assisting aids are required (Alkhalifa & Al-Razgan, 2018). In order to keep up with the demands of life, the D/HH must overcome numerous obstacles. Interpersonal connection and understanding without a mediator is one of the challenges they face, which can lead to isolation and frustration. If those around them do not understand sign language, the situation gets even more difficult. Furthermore, they may be ignorant of important nearby sounds such as fire alarms, bells, and car horns, causing them to delay judgments that could put their lives in danger. Furthermore, depending on the skilfulness of the mediator, the requirement for a mediator between a D/HH individual and other people may result in misconceptions and misinterpretation. Furthermore, such discussions frequently involve sensitive material that necessitates the presence of a trusted mediator, who may not always be accessible. Furthermore, there may be times when a D/HH person has to communicate with a hearing person, such as in an emergency or when visiting a doctor, when neither an interpreter nor a layman who understands sign language is present (Gugenheimer, Plaumann & Schaub, 2017). These factors, together with the necessity for language translation, have prompted many people to turn to technology in search of appropriate, accurate, and low-cost solutions, such as those described in (Jones, Hamilton & Petmecky, 2015). Wearable technology, in these circumstances, may prove to be an extremely beneficial tool for all users, particularly the D/HH (Jain et al., 2015). Computer-assisted communication has been utilized to assist the D/HH in their daily lives. Smartphones have proven particularly handy since they combine a camera, sensors, and a display in one device. Various assistive communication apps for the D/HH have been developed (Jain et al., 2015). These applications assist the D/HH in effectively communicating with others. As a result, smartphones have become vital devices for people with D/HH. External devices, such as smartphones or desktop apps, however, require D/HH people to glance at them and move their attention away from conversational partners when auditory warnings or notifications occur (Jain et al., 2015).

Life is full of challenges for disabled people. In order to ease the burden brought about by these challenges, such people need a variety of devices to navigate, communicate, be alert, and align with life requirements. Sound awareness is a problem for Deaf and Hard of Hearing (D/HH) people, which can make it difficult to hear spoken words or an alert sound around them. Knowing the types of sounds surrounding them could be of great importance to them. A mobile application called AsEar, was developed in the study, which detects any sound around the deaf automatically and alerts them about detected sound then they can send detected sound to their friends /family members through social media or instant messenger so they can listen to detected sound and write feedback to deaf and hard of hearing people about detected sound.

1.2 Problem Statement

Hearing aid production worldwide meets less than 10% of global demand and less than 3% of demand in emerging countries (World Health Organization, 2019). Most previous studies (Abbas & Sarfraz, 2018; Manaf & Sulaiman, 2015) focused on one of the purposes, which is the estimation of direction and dangers faced by deaf and hard of hearing people, which equally showed that they participate less in social activity compared with their hearing friends especially on social media. Sound's classification faces a challenge, which represented in store large collecting of sound samples that cannot be accomplished on an individual level. Furthermore, the same sound has many similar shapes (Lu et al., 2009). According to a study done by Bragg et al. (2016), deaf people would rather receive many notifications than miss a notification. Deaf and hard of hearing are less socially active compared to their hearing friends especially on social media (Bragg et al., 2016).

1.3 Research Importance

- Recognize an environmental sound around the deaf.
- Increase social communication with hearing community.
- Making deaf and hard of hearing people to have more sense of belonging in the society
- Make hearing people familiar with sign language.
- Suitable platform for detecting general disasters for example in earthquakes.
- Serve as a united platform for deaf and hard of hearing (to storing all sound forms and it works on all operating systems).
- Increase reading and writing of deaf and hard of hearing people.

1.4 The Aim

The aim of this research is to design a mobile application called AsEar mobile app that is able to do the following:

1. Increase social communication with hearing people
2. Increase reading and writing ability of deaf and hard of hearing people
3. The app detects the sound automatically
4. Teaching hearing people the principles of sign language
5. Store a large number of sounds in cloud storage
6. Store important sounds, like doorbell, horn of car, dog barking, etc. in local database

1.5 Thesis Contribution

The Thesis Contribution aims to eliminate communication barriers between DHH and hearing individuals by increasing the familiarity of hearing people with sign language. In addition, a new data set for sound detected by participants will be created to make DHH more independent.

1.6. Limitations

- The app only works on Android platform.
- D/HH students ages 18 and above.
- The target group does not suffer from any kind of blindness, also target group know the principles of reading and writing.
- Availability of Internet connection to download sounds from cloud computing.
- Mobile limitations such as microphone quality.

1.7 Project Schedule

Project schedule that shows the timeline of delivery of this thesis, starting with finding gaps in the literature until submission of the thesis. As shown in Figure 1.1.

Figure 1.1:

The thesis timeline

	Task	Assigned To	Start	End	Dur	2018	2019	2020	2021	2022	2023	2024
	Phases	Hassan Mohammed	3/20/18	12/26/24	1767.5							
1	Find gap in Literature		3/20/18	10/10/18	146.5							
2	Analysis		10/10/18	5/20/19	159							
3	Designing Framework		3/25/19	4/20/20	281							
4	Systematic Literature Review		5/11/20	10/14/24	1156							
5	Developing Prototype		1/1/20	9/30/20	196							
6	Get Opinin From Experts and DHH		1/1/21	1/1/22	261							
7	Final Design		1/1/22	10/20/22	209							
8	Developing Questionnaire and Interview		11/1/22	3/20/23	100							
9	Evaluation		6/15/23	8/22/23	49							
10	Submit Research Paper		10/17/23	12/26/24	313							
11	Submitting Thesis		12/20/24	12/26/24	5							

1.8 Thesis Overview

The over view of this study as follows:

Chapter One: The first chapter of the thesis provides a topical overview, beginning with a brief introduction to the research project and background information on the thesis. This chapter also includes a background, the research statement, research importance, the aim, contribution, and project schedule.

Chapter Two: This chapter provides an overview of the literature review and theoretical framework. of the recent research on sound detection and gives a deep look at technologies for the deaf and hard-of-hearing and identifies challenges faced by deaf and hard-of-hearing.

Chapter Three: This chapter study methodology, steps to develop AsEar mobile application, data collection, evaluation methods, and data analysis.

Chapter Four: This chapter study results, by presenting screens of the AsEar mobile app after development. Also, show the results of questionnaires and interview.

Chapter Five: This chapter contains the discussion, which gives a detailed explanation of the results.

Chapter Six: This chapter presents the main conclusions and recommendations for developers, D/HH people, and the government. Furthermore, it provides future work.

CHAPTER II

LITERATURE REVIEW

The chapter explains in depth the key concepts that underpin the research. Moreover, this chapter will describe an overview of studies published in the literature related to the current study.

2.1 Theoretical Frameworks

2.1.1 Sound Awareness Needs

The development of effective and efficient technology for sound awareness needs a wide understanding and preferences of people suffering from partial or complete hearing disabilities (Goodman et al., 2020). Different work in the literature have developed various surveys regarding people suffering with deaf and hard of hearing either partially or completely on their interest on sound, indicating a higher interest for urgent as well as safe understanding of various sounds such as sirens, car horn and alarms as well as sounds involve in supporting social interactions such as door knocks and name calls etc. (Blascheck et al.,2019). For example, Mielke and Bruck (2016) conducted a study on smartwatch-based sound awareness that illustrates this trend. The need for understanding sound is equally related to contextual and cultural factors. For instance, deaf and hard of hearing patients that prefer oral communications are more interested in sound awareness than the ones that prefers sing language (Mielke & Bruck, 2016). Findlater et al. (2019) equally conducted a survey on deaf and hard of hearing respondents, the study showed that social context such as relationship between friends and with strangers could have impact on the need for the usage of sound awareness tools. Whereby, most of them showed interest in having filtered sound than getting all the sensed sounds. More also, the need for sound awareness can be relative based on past experience, asking interview, physical location as well as survey respondents regarding being at work, home and or mobile (Findlater et al., 2019). Various researchers and scientists have equally studied the kind of sound characteristics that are desired most, showing that some (urgency, location and identity) are usually vital than others (pitch, duration, volume) (Chen, 2017). Nevertheless, the utility can differ or the method by which the information is conveyed. For instance, at home, location and sound identity can be enough, while guiding indicators are significant when mobile (Harkins et al., 2010).

2.1.2 Sound Awareness Techniques

Mostly sound awareness technologies are categorized into; stationary, handheld/wearable (such as PDA or smartphone). Early research focused more on stationary designs like desktop displays (Kaneko et al., 2013). However, now a days more attention has been shifted to handheld and portable tools ranging from smartphones applications that can be used for environmental sound of for captioning automatically as well as wrist worn for wearable solutions (Ketabdar et al., 2009). The user evaluations for these handheld tools are more especially scarce in single environment (such as the classroom settings) as well as in the lab. Therefore, highlighted the potential of these tools in providing communication skills as well as gives an alert especially to situations that are urgent. They do not probed essential key practical matters on the process that can be employed in managing the complexity of soundscape through various filtering options (Kim et al., 2013).

Furthermore, there is wide range of techniques that can be employed by those with hearing disabilities for sound awareness. Some people with hard hearing ability are not interested in sound, while various approaches and techniques have been developed to attain the need of those that are interested. Most sounds are attributed by visual signals, which the deaf and people with hearing disabilities used to check. More also, some deaf and people with hearing disabilities employs hearing assisting tools as well as cochlear implants in order to enhance their sensing of sound. It can be possible to amplify only a certain sound source by employing the usage of infrared, FM or other wireless streaming devices (Kushalnagar et al., 2014).

The evaluation of these handheld tools were limited to laboratories, whereby the potentials of the tool's lead to communication support as well as alert emergency situations to people with hearing disabilities. Based on the feedback modalities, various researches conducted in the technical literature recommended the combination of vibrational and visual sound information awareness, and this showed the significance of smartwatches. The user evaluation for the prototypes that merge hepatic and visual feedback, though, it has been limited to the application of vibration for secondary modality in order to attract the attention of the visual message, which do not compare various techniques used in merging the two modalities. In contrast, various researchers assess various combination of vibration and visual feedback, which includes the application of tactons for the enhancement of feedback through vibrations (Provvisoria et al., 2021).

There are numerous products that can be employed to detect specific sound, which can equally replace the sound into other kinds of signals. In different homes for deaf and people with hearing disabilities, the phone or doorbell feeds into the light systems, therefore, the lights will flash when anyone rings the bell or call (Matthews et al., 2006). More also, alarm clocks are equally available, which emits loud sounds, vibrations of bright flash light. Many engineering companies such as; Sonic Alert and Harris communication specialize in these kinds of products for people with hearing disabilities. The sound detectors for every sound are equally advertised to the consumers who are equally not struggling with hearing disabilities. For instance, breaking glass and baby monitors detectors are of paramount importance deaf, hard-hearing as well as hearing consumers (Matthews et al., 2006). Advanced and emerging sound detectors are recently introduced into the market, which showed that sound detection is significant in solving various problems (Min et al., 2015). For example, plugs into an outlet that can be listens for carbon monoxide and smoke alarms. When it detects the alarm, it calls the phone of the subscriber and then play the sound recording in order for the user to understand that the alarm has went off, so that he can respond accordingly. Moreover, Audio Analytic sells package of sensors, which are usually installed at home in order to detect certain sound such as window breakage, smoke alarm and baby cry. Therefore, the consumers need to collaborate with the companies to create custom sensor, in which the system can be designed and be used at home (Yuan et al., 2003). Furthermore, many studies have been conducted on wearable vibrotactile techniques without visual displays, which are mostly on sensory substitution of audible messages. Yeung et al., conducted research that involves the transformation of pitch messages into vibro-patterns through a 16-channel tactile using the forearm display. Nevertheless, some factors such as neck worn and waist-mounted that can causes obstruction made most of these tools impractical for daily usage (Yuan et al., 2003).

Figure 2.1:

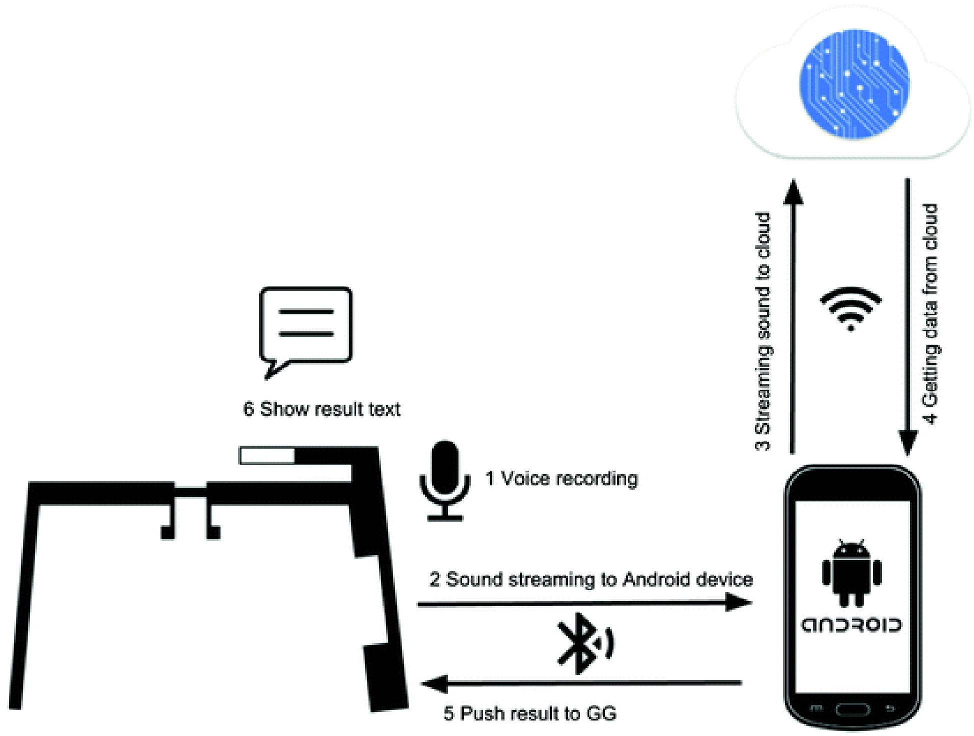
A complete set-up for the use of smartphone application for wizard vibrational and visual feedback following sound events, like phone ringing (Goodman et al., 2020)

2.1.3 Android-Based Application

Recently, there is an important progress in tackling the issues faced by people with hearing disabilities using different technological innovations such as the android-based application, which is considered as a vital component of a developed system (Aktas et al., 2017). Android mobile application is an operating system that was created by Google, using the Linux Kernel and was created majorly for touchscreen mobile phones and tablets. In various studies, a user interface was developed in the android-based applications, which conduct different functions that notify patients suffering with hearing disabilities on alarm conditions. This application is usually developed on App inventor web application (Cheng & Lin, 2012).

Figure 2.2*:*

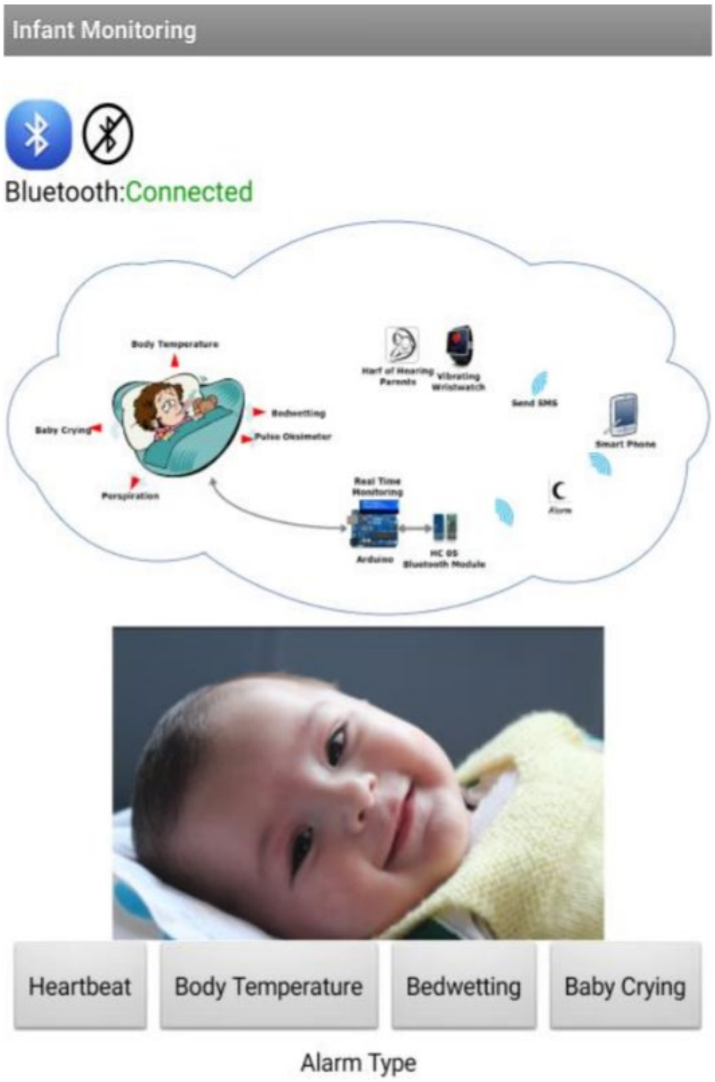
The mechanism by which Android-application work for deaf and people with hearing disabilities (Aktas et al., 2017)



The major importance of this application is that it has the ability of working on almost all Android phones and not only on smartphones. It is equally an open source web application that was initially created by Google and how given by the Massachusetts Institute of Technology (MIT) (Lin et al., 2014). The application generally works by connecting it with Arduino Leonardo board through the Bluetooth module. Whereby whenever the phone receives a sound message from the Arduino, the application will subsequently disseminate an SMS composed of alarm information to the subscribers. More also, the phone will then vibrate and provides an alarm message within short seconds. This kind of application is not only limited to people with hearing disabilities but can equally be used by parents to monitor the sound made by their new born babies. Figure 5 showed the interface of the application subscriber (Mohajerani et al., 2016).

Figure 2.3:

The use of Android-application for detecting infant sounds (Aktas et al., 2017)



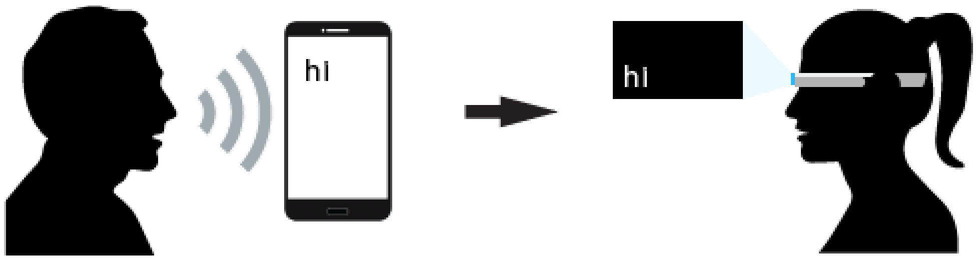
As indicated in Figure 5, the user interface application consists of two buttons, which are attached to the connection of the Bluetooth. In default mode, the Bluetooth showed “Not Connected”. If the blue icon of the Bluetooth button is subsequently clicked, then other active Bluetooth on other devices within the vicinity of the smartphone are found. Immediately the HC-05 Bluetooth module is chosen, the Arduino Leonardo will be connected to the Android phone through the Bluetooth and then a green text color will show showing that it has been connected on the screen (Kumari et al., 2016). When the black-white icon is selected then the Bluetooth will be disconnected by displaying in a red color text on the screen (Wu et al., 2016).

2.1.4 Wearable Device Applications

Many studies in the published technical literature focused more on the provision of various wearable devices like Apple Watch and Google Glass to assist in daily life. In a study, the general overview of the Google Glass was discussed (Alkhalifa & Al-Razgan, 2018). The researchers indicated that Google Glass is well designed to tackle numerous issues in different fields of study such as Augmented Reality, Positioning systems, virtual reality and Human Computer Interaction among others. Google Glass gives an interface tool, which may be operated hands-free and gives sensor that can be used in different forms of gaze and head tracking. The researchers equally found transitions from Android smartphone to the development of Glass software straightforward. Even though, they have mentioned some drawbacks of the Google Glass such as its computational and battery resources are limited as compared with that of the smartphones (Borgia et al., 2014). Thus far, even with these drawbacks, there are numerous applications, which were created to ensure the usage of Google Glass. The authors equally presented and published these applications in universities, medical fields and libraries. There are numerous applications, which are developed in order to assist librarians through Google Glass. One of them is called shelf reading and inventory management, which is aimed in helping librarians in scanning books that are carried by the patrons. In addition, there are many applications used in the area of higher education; among them is the Glassist App, which is developed in assisting faculty members in managing their tasks. It supports the teachers in developing portfolios for every student and subsequently displays the necessary information about them. In general the authors discussed the use of wearable devices in medical sector; For instance, if there’s an emergency, these wearable tools helps the lower staff in dissemination of messages effectively and efficiently to the senior staff, especially if there are not at the vicinity of the situation. Additionally, the Google Glass is now being recognized among people with disabilities, which help them in carrying their daily activities (Gugenheimer, Plaumann, Schaub, et al., 2017).

Figure 2.4:

Dissemination of information to deaf and patients with hearing disabilities using the Google Glass (Alkhalifa & Al-Razgan, 2018)



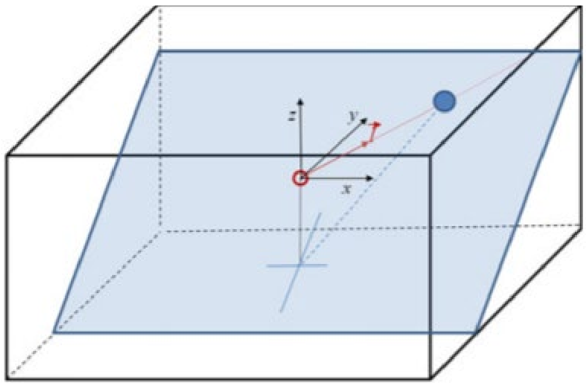
A project was published by the USA patent office on Glass patent. The major motivation of the patent is to employ the usage of the microphones that are situated on the frame of the headband of the Google Glass in order to assist people with difficulty in hearing. Immediately the microphone detects any sound, it will subsequently show a pop-up notification on the Glass. This will composed of the intensity and the direction of the noise (Jain et al., 2015).

2.1.5 Localization of Sound Sources

When the acoustic event is detected, the supplementary information, i.e., the position and direction of the sound source, is dug out from its signal. The localization is generally based on the signal processing received from the multi-channel acoustic vector sensor. The sensor can provide sufficient data that can be used in calculating the direction of the acoustic vector (Rascon & Meza, 2017). Thus, this cannot be sufficient in determining the location of the sound source in an exactly 3-dimensional space, which is due to α and θ (Rascon & Meza, 2017). Therefore, the polar coordinates are known, even though the missing radius (r). The main feature of this proposed technique used in detecting acoustic events in 3D space is to employ the data generated based on the environment's geometry. Let’s assume that the source is positioned close to the floor of the environment. Therefore, the space between the source of the sound and its intensity probe can be estimated. As a result of this, the exact position and direction of the detected sound can be recognized (Huanga et al., 1998).

Figure 2.5:

Demonstration of applied technique that can be used in detecting sound source with acoustic vector sensor (AVS) (Kotus et al., 2014)



2.1.6 Assistive Listening Device

Assistive Listening Device (ALDS) are employed in improving the hearing capacity of patients with different conditions and environments such as airports, places of worship, theaters and classrooms. They allows higher autonomy, lead to alleviation of daily grind and improves the quality of life of individuals (Harkins & Tucker, 2007). Sounds, more especially speech are separated using ALDS to enable a person to be able differentiate it with a background noise as well as to aid in improving, what is considered as the 'Speech To Noise Ratio (SNR)' rather than the 'signal to noise ratio' (Mcinerney, 2013). One of the main aim of using ALDs is to achieve good SNR in different conditions for deaf and people with hearing disabilities. The major setbacks of SNR is distance, reverberation and noise, which represents a triangular SNR issues. The fluency of a signal is reduced if the reverberation and or environmental noise are present. Lower optimal listening in the surrounding has equally been testified to debilitate hearing problems for people with hearing disabilities. It was equally noted that as the distance increases the SNR diminishes, due to the sound intensity is greatly reduces with expanding of the distance. In order to get optimum speech, the distance between the listener and the sound source should not be more than 1.8 meters. It was equally reported in one of the researches that a student listening from a distance of 1.8 meters from the sound source recognition scores of 95% is achieved, while at a distance of 7.3 meters the score is dropped to 60%. The SNR needed by individuals suffering from hearing disability is 15 dB, which can be used in achieving similar level of understanding with other normal people, even though the differences should be considered, which depends on the degree and kind of hearing disability (Lesner, 2014). At different situations, if listening is challenging, the use of ALDs aid in improving SNR in different ways; through reduction of the background noise, minimizing negative influences because of the distance between the signal and the person with hearing deficiencies as well as overcoming low acoustics like reverberation. While using hearing tools, the augmentation of SNR can be attained through directionality (Lesner, 2014). Through taking advantage of spatial separation from the distorted signal from the speech, which occurs because of competing noise and distance. Hence, directionality increases the understanding of speech via the background noise. The directionality is more efficient if the sound source is close as well facing the user with the hearing aid, while the environment does not have much reverberation. This is relative for people using the hearing instruments (Lesner, 2014). Even though, ALDs enhance the access to sound source in the core center of background noise as well the the sound reverberation. Apart from directionality, there are numerous kinds of ALDs that can be used in overcoming the sound triangle of problems; reverberation, distance and sound (Aberdeen & Fereiro, 2015).

A- Types of ALDs

The application of ALDs can be done in different public places such as religious places, classrooms, theaters and market places or using with personal aids such as radio connections, small group activities and telephone (Odelius et al., 2010). They can equally be used as simple devices that can be used in alerting and informing people with hearing disabilities of a baby cry or knock at the door etc. ALDs differs in their internal processing, which ranges from a simple hard-wire microphone amplifier to a complex broadcasting system (Kaufmann et al., 2015). Mostly, a microphone is used in capturing the audio source and then subsequently broadcast it over a wide range of frequency modulation (FM) transmission, induction loop transmission and infrared transmission etc. (Kaufmann et al., 2015).

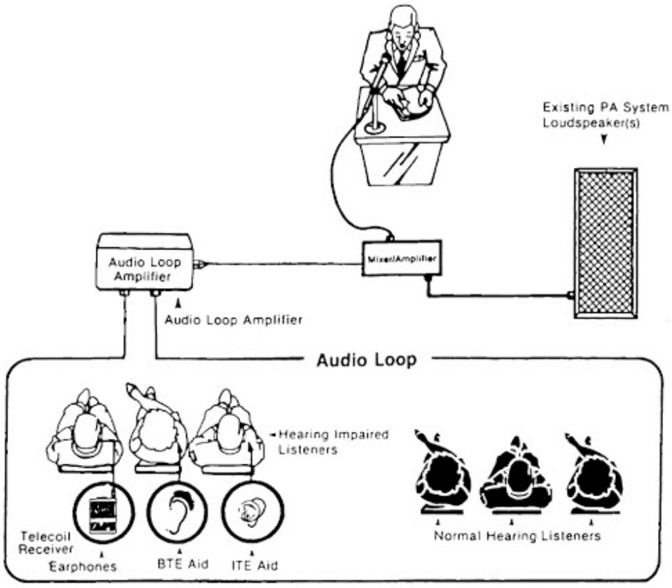
Figure 2.6:

Various types of Assistive Listening Device (ALDs) (Mcinerney, 2013)

- **Hardwire Devices:** ALDs generally needs wires that can be used in connecting them with the receivers, amplifiers, ear-mold, stethoscope earphone and the microphones. If the device is applied as a personal system, the amplifier is minute and can be considered as handheld that can be placed into the pocket (Holmes, Saxon & Kaplan, 2020). Due to this, the device is called "pocket talker" sometimes. More also, it is also known as "box hearing aid," since it equally resembles a little box. In order to minimize the distance between the speaker's source with the microphone, the microphone is sometimes placed on the listeners to be part of the system or even given to the person making the speech (Holmes et al., 2020). Therefore, these tools increases the levels of the sound and minimize the noise in the background for the users, while others have some have directional microphones, which can be placed towards the sound source or the speaker such as audio systems and televisions (Mcinerney, 2013). These devices are targeted for personal use as well as by professionals such as the healthcare providers that provides services to deaf and people with other hearing abnormalities. For usage in the public, the chosen seats are wired with the tools and some kind of receivers such as earphone and headsets can be connected as well (Kaufmann et al., 2015).

Figure 2.7:

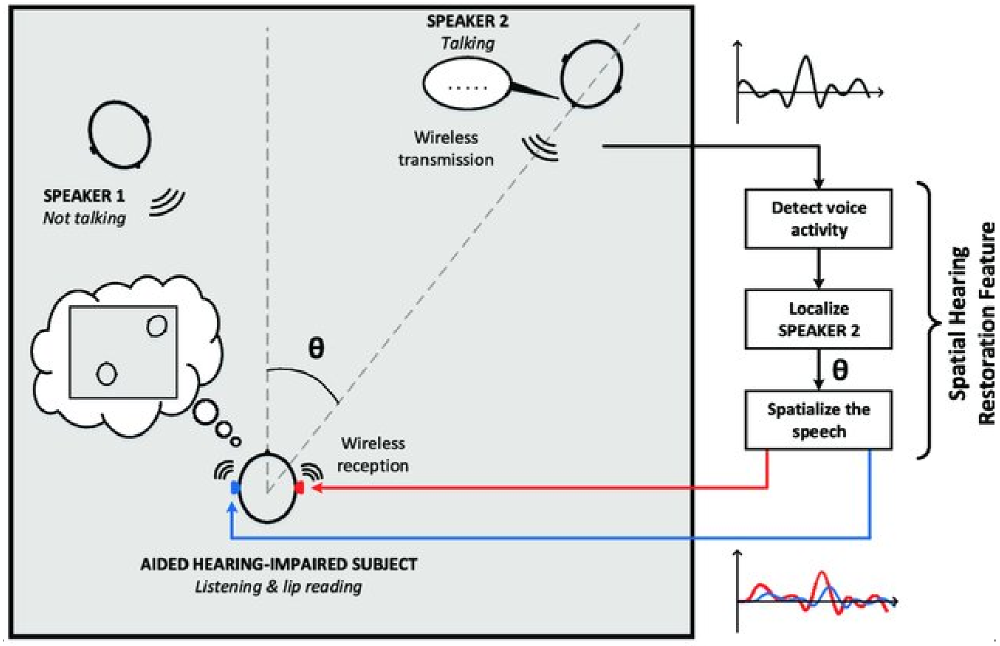
Hardware ware devices connected with ALDS for enhancing sound hearing for both hearing impaired listeners and normal hearing listeners (Kaufmann et al., 2015)



- **FM Sound System:** The wireless FM sound system is responsible for sending auditory information via the FM radio waves through a wireless transmitter directly to a handheld/portable receiver to the subscriber especially a person with hearing disability (Kim & Kim, 2014). These wireless transmitters has the ability of driving the signal from the sound source's microphone or other output of the sound system such as stereos, television and radio. Receivers can equally be installed to the hearing instrument via direct audio input adapters or through telecoil induction or neck-loop (Zanin et al., 2016). FM system may equally be hyphenated with personal cochlear implants through small adaptors or sometimes built them in. This set-up is mostly used in classroom, in which the teacher will wear a miniature microphone that is connected with the transmitter, while the audience wear the receiver, which can be turned to a specific channel or frequency. FM systems has the ability of transmitting signals as higher as 300 feet that can be applied in several places such as religious places and auditorium (Israsena & Dubsok, 2009). Thus, the audience in a single room can listen to different frequencies due to the fact that radio signals has the ability of penetrating walls. Subscribers of FM systems can operate in similar ways and has the ability of using it in helping people with hearing disabilities in face-to-face conversations (Kim & Kim, 2014).

Figure 2.8:

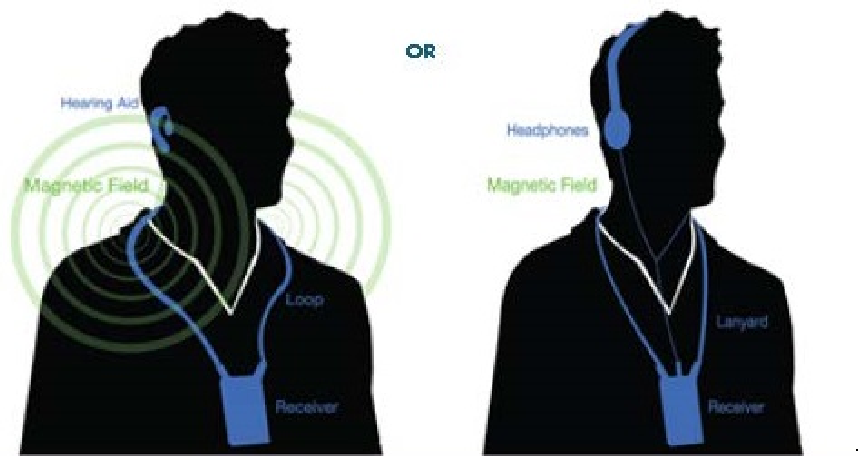
A working principle of FM sound system (Courtois et al., 2018)



- **Infrared Sound System:** The sound is sent from the sound source to the audience through an invisible infrared light waves. Subsequently, a transmitter will then converts the sound to light wave and the beams it to single headset wireless receiver. The receiver will then hooked to the headphones, which can be coupled with different hearing device with telephone switching the decodes of the infrared signal converted into sound. The telecoil is used in converting the signal from the infrared into a magnetic energy. Not like the FM systems or the induction loop, the infrared is prone to natural light due to its weakness, which prevents it from passing to the walls. Hence, infrared should not be employed in an environment consisting of various competing light sources such as strongly lit rooms or outdoors. The infrared provides an advantage that composed of the signal that increases the privacy of the information of the signal, lead to the use of unlimited number of receivers that can be used in providing good sound quality (J. S. Kim & Kim, 2014).

Figure 2.9:

A working principle of Infrared sound system (Kim & Kim, 2014)



- **Telephone Listening Devices:** Various telecommunication and teletypewriters devices have been utilized for years as a message used in messages typing for people with hearing disabilities. Nevertheless, these tools were now considered as old fashion because of the new advancements in technology especially in communication devices such as cellular phones and Personal Computers (PCs). Moreover, other systems uses devices that involves voice recognition software as well as a broad video clips library that depicts sign language, which has the ability of translating the words of signer into text or sometimes to computer based generated speech. It can equally translate the words spoken into text or sign language and vice versa (Kim & Kim, 2014). For people having moderate to mild hearing loss, telephone's captions enable them to perform in a spoken conversation, and provides a transcript of other people's speech below a read-out panel or the screen of a computer as a backup. Additionally, various amplifiers in the telephone such as those specially designed handsets, telephones or portable Snap-On can be used. Some alerting devices, which are visualized and hooked the telephone ringer can be applied in helping a person with hearing disabilities to know when the telephone is ringing. Furthermore, the remote ringer can be kept throughout the house in order to enhance the chances of the person with hearing disability to notice when the phone is ringing (J. S. Kim & Kim, 2014).

Figure 2.10:

Telephone listening devices (Lewis & Downe, 2015)

- **Television:** To watch television, wireless systems such as audio loop systems, infrared and FM can be connected (Kim & Kim, 2014). Moreover, simple amplifiers having headphones or earphones can equally be plugged directly to the television. One of the best options is the used of closed captioning (Pedley et al., 2018). The ability and need for reading the speech greatly increases the understanding on this platform due to the fact that most of the programs consists of background noise or music, which easily interfere with the amplified signal (Pedley et al., 2018).

- **Alert/Alarm System:** Alarm or alerting devices uses vibration, light, sound or a combination of these phenomena in order to allow someone understand the occurrence of a particular event. These devices have the ability of changing the signals of the sounds into wake-up alarms, gentle shaking for clocks, horns, bed vibrators or flashing lights (Kim & Kim, 2014). The visual alerts can monitor a wide range of various household equipment as well as other sounds like telephones, kitchen timers, smoke alarm and doorbells. More so, the remote of the receivers that are placed around the house can equally alert someone from any room in the house (Goodman et al., 2020). Portable vibrating pagers has the ability of monitoring the crying of babies even indicating the condition using a picture to show that the baby is either sleepy, bored or hungry (Jain et al., 2019).

2.1.7 Assistive Technology

Wearable gadgets and technology that are believed to be “assistive” raise significant societal acceptability problems. Wearable gadget acceptability may be represented with relation to conflict among ambitious aspirations (for example, a favourable representation of someone’s personality, usefulness) also undesirable public consequences (Concerns about confidentiality, for example, or disruption) while norms are changing (Hersh and Johnson, 2003). Sexuality, performance, and gadget placement have all been found to influence acceptance. Although these reservations, assistive technology aimed at increasing acceptance might aggravate feelings of isolation among individuals with impairments by accentuating differences and contributing towards disgrace; on the other hand, Bystanders are much more receptive to a worn gadget when they believe it would benefit them (Mielke et al., 2013). Deafness is not considered a handicap in Deaf culture since aural communication is not employed. A design that disregards visual priority and sequencing for mixed communication and alerting would irritate deaf and hearing peers (Ariffin and Faizah, 2010). Issues such as greater social distance by increasing communication friction and increasing the possibility of misinterpreting social and communicative intent can be caused by inappropriate designs. We explore social acceptability in a range of settings, motivated by these complicated issues (Hersh & Johnson, 2003).

- **Smartphones:** The smartphone has become a popular and widely used gadget in recent years. Because of its computing capability and low battery consumption, it provides users the ability to utilize apps that are typically linked utilizing the pc wherever (Alnfiai and Sampali, 2017). It's no surprise that it became a popular gadget for apps that help individuals with impairments. Deaf persons were shown a wide choice of smartphone-based applications. Apps that enable users to utilize their smartphone also as hearing assistant, as a means of assisting interaction with normal individuals in order to communicate in an incident or for sound to text interpretation) (Bitman and John, 2019). Alternatively, it may be used as an audible noise warning that brings awareness when some noise is recognized nearby (Alnfiai & Sampali, 2017).

- *Features of Smartphones:* The camera smartphones composed of a vital value that has the ability of converting and translating sign language into written language and vice versa. More also, the mic is used in capturing the speech or the sound and then subsequently convert them into a means that can be beneficial to people with hearing disabilities (Kholis et al., 2020). Furthermore, it equally has the capability of connecting with the internet via the Wi-Fi and Bluetooth etc. in order to ensure that the smartphones are accessible everywhere (Acosta-Vargas et al., 2019). The ability to couple it with other smart devices, which can be used in transmitting the data between the smartphones and other smart devices. More also, vibration engine, also screen size convenient for the deaf, in addition, mobility of smartphone and size suitable for hand (Chang, 2021).

- **Smartwatch**: One of the significant importance of smartwatches in sound awareness for deaf and people with hearing difficulties is that act as the mainstream devices that has the ability of minimizing stigma as compared with other assistive devices. In this context, smartwatches are usually used for tracking activities as well as receiving notifications when paired with a smartphone. Smartwatches usually interacts with only brief glances, so that visual designs needs to emphasize on space efficiency and glance ability (Shinohara and Wobbrock, 2011). The smartwatch-based applications are generally applied on simple notifications, in which the watch will subsequently vibrates and then the subscriber has the ability of either ignoring or check the alert generated on the screen of the watch to understand the details. Nevertheless, other advanced haptic output equally shows possibilities, in which the wrist has higher perceptual sensitivity to vibrotactile pattern. Nowadays, smartwatches are used as auxiliary haptic display in passive learning and video games (Engström et al., 2005).

In comparison to helpful devices of the past and mobile phone, as an assistive gadget, the wristwatch guarantees considerable advantages to its client. The high incidence of abandonment of assistive technology is one issue (Hou et al., 2019). There are several reasons for leaving a gadget, but one of them is the item's design. In social situations, assistive gadgets are utilized, but they frequently seem odd or have an antiquated creation and don't appear to be orthodox equipment (Alkhalifa & Al-Razgan, 2018). Design as such might draw attention to the user's disability. When this is combined with erroneous beliefs and biases about handicapped persons, social obstacles may emerge. Because of these findings, it is clear that useful technology should be designed in a certain way, which is a critical but frequently overlooked component in its acceptability and utilization (Blascheck et al., 2019). Due of its ubiquitous use, the smartphone is a great platform for the application of assistive technology. Despite the fact that the smartphone has been around for a while, society is still working out social standards for its use. Following social standards is critical for human connection, since failing to do so can cause social interaction to be disrupted (Gugenheimer, Plaumann, Schaub, et al., 2017). For example, while using a smartphone in public is allowed, it is typically frowned upon in public circumstances (Supposedly at a conference) (Blascheck et al., 2019). Because of the widespread usage and acceptability of conventional wristwatches, the smartwatch may be acceptable in circumstances where the smartphone is not (Hou et al., 2019).

Figure 2.11:

Three different smartwatch users for sound awareness (Goodman et al., 2020)

- **Augmented Reality:** Using modern technology to assist individuals with impairments is now highly valued, and significant study is being conducted in this field. The key question is how to integrate and apply these technologies to make them more useful (Kumar & Sharma, 2014). Augmented Reality (AR) is a relatively new technology that has generated a lot of buzz recently. Several researches have demonstrated that virtual reality (VR) and AR can assist persons with impairments. AR allows handicapped individuals to control and organize information and quickly modify it to a chosen form, allowing them to enhance their relationships with others (Gugenheimer et al., 2017).

2.1.8 Deaf and Hard of Hearing People

Children with Deaf and hard of hearing (D/HH) difficulty can face lack of self-confidence among others, feel isolated and abstain from socialization (Hindley et al., 1994). The ability to participate in social activities and decrease in quality of life, are related to being deaf, which eventually result to feeling of abandonment and rejection. Without wonder, D/HH students get picked on by others with normal hearing ability. This leads to risk of depression to the individual (Hindley et al., 1994).

- **Hard of Hearing:** Manual and spoken communication methods are the two primary kinds of communication utilized by hard of hearing and deaf people (Woodhouse et al., 2009). People who are deaf manually generated gestures that are generally perceived through vision in manual means of communication (Tan and Moore, 2008). Sign systems that mirror the English language (such as Signed English), sign systems based on languages other than English (such as American Sign Language), and manual additions to English are the three primary categories of manual techniques (as in Cued Speech). It is believed that these approaches are a viable form of communication among deaf individuals, they do need additional training in the receiving and production of physical signals (Woodhouse et al., 2009). Oral techniques are designed to allow deaf person to communicate with the aid of speech which is orally produced. With numerous from these techniques relying on giving additional information to the clues provided by lipreading. Traditional electroacoustic hearing aids, cochlear implants, auditory brainstem 24 implants, and tactual aids are all examples of oral communication aids. Loss of hearing from minor to severe individuals, generally utilize traditional electroacoustic hearing aids (25-90 dB HL) (Woodhouse et al., 2009).

- **Difficulties Faced by Deaf and Hard of Hearing People:** Individuals with hearing loss may benefit from programs that focus on Emotional Intelligence (EI). Information and communication technology, PCs, sight and sound, and innovation - based interventions could potentially play their part in boosting D/HH children's EI. For the cognitive domain, such treatments have been shown to be beneficial. Barker (2003), for example, used a pc-related lexicon coach in spoken-hard of hearing tutoring to enhance vocabulary learning among D/HH students (Tan and Moore, 2008). Computer games may also be used to inspire as well as appoint pupils. Challenging it can be toward creation of PC based education for pupil with D/HH, according to Giannakos as well as Jaccheri (2014), and it is important to develop in accordance to their demands. Students with D/HH require a particular learning manner or advance while using pcs; however, certain demands are sometimes ignored while in process of design. Pc-related instructional entertainment, for example, seldom concentrate on students who have specific needs, which include D/HH students. Several researches have been conducted in accordance with D/HH student's usage of technology. Such, on the other hand, prefer to focus on subjects other than EI, such as sign language learning, lexicon possession, and tuition coaching and math tutoring (Woodhouse et al., 2009). The major problems faced by people with hearing disabilities can be categorized into:

1. The materials used as hearing aids do not cover the whole world especially the developing and underdeveloped countries (Halim & Abbas, 2015).
2. The reading and understanding of patients with hearing disabilities is poor as compared with that of normal people (Alkhalifa & Al-Razgan, 2018).
3. They equally have problems with perception and understanding (Halim & Abbas, 2015).
4. The use of mediator can be an efficient method for communication, but it major effects is it breaks off their privacy (Singleton et al., 2019).
5. Most of the patients with hearing disabilities have no or little expertise and experience regarding gesture communication (Singleton et al., 2019).
6. One of the major issues faced by people with hearing disabilities is communicating with normal people without the help of mediators (Alkhalifa & Al-Razgan, 2018).

7. Numerous technologies are not accessible by people with hearing disabilities, though they are readily available (Halim & Abbas, 2015).
8. People with hearing disabilities are less interactive with the environmental sounds that can prevents them from hazards. Therefore, they are more prone to danger in case of emergencies and hazards (Alkhalifa & Al-Razgan, 2018).

2.1.9 Sign Language

Sign Language (SL) is the most ordered and structured of the numerous gesture categories in the classifications of expressive arm or hand gestures. Hard of hearing and deaf people use sign language as a primary way of communication (Kim and Kim, 2014). Hard of hearing persons communicate through signals in visual space rather than vocal communication and sound patterns (Jain et al., 2019). SL include not just arm or hand motions, as well as semi signals, which communicate semantic information through facial expressions and different body postures. Pattern matching, computer vision, natural language processing, and linguistics are all involved in sign language recognition research (Jain et al., 2019). Its objective is to create a variety of techniques and approaches for recognizing and comprehending already created signals. Human-Computer Interaction (HCI) in relation to sign language recognition with the goal of the mechanisms is to allow for interactive and useful communication (Yuan et al., 2003). Data capture, Sign language linguistics, Sign language testing, and Sign language technology are all part of this system's interdisciplinary approach (Stinson et al., 2014). A system like this may be used in general places such as lodges, trains, retreats, financial institutions and businesses to help hard of hearing persons discover latest ideas and information while also controlling their emotions (Stinson et al., 2014).

- **Challenges in Gesture Recognition:** Static gesture recognition and dynamic gesture recognition are the two types of hand gesture recognition (Stinson et al., 2014). Static gesture recognition recognizes hand shape and reads the meaning of hand expression; dynamic gesture recognition recognizes and obtains the gesture path in place and instead executes the relevant action obtained from field path characteristics, including when using a projector to display lesson plans, motions with the hands could also be utilized to stop, resume, as well as rotate upward and downward, and so on (Stinson et al., 2014). Traditional gesture detection relied on wearable technology, which allowed users to make some hand motions while wearing special data gloves, the gadget will send the operator's motions and position data to the microcontroller, allowing it to better understand the user's actions as well as habits. Immersion CyberGrasp, a simulation system with several functions gadget comprised with several of the glove's detectors. The virtual items might be moved, grasped also get turned through the glove that has the ability to "reach into the computer" thanks to software mapping (Harish & Poonguzhali, 2015).

2.1.10 Mediator

Mediators should learn about Deaf social norms and be aware of them. Eye contact and body language are two of the most important cultural indicators. With Deaf individuals, eye contact is an essential element of visual communication (Cardoso et al., 2006). It is good for a mediator or hearing participant to maintain eye contact while communicating with a deaf person. As a deaf individual speaks, the most appropriate thing is paying attention not to the interpreter but to that individual. Deaf individuals are more sensitive of body language than hearing people, and they are more likely to spot discrepancies both physically and verbally . Consequently, mediators ought to be mindful to their actual propensities and signals (Conway et al., 2011). In the event, where covering of mouth by the mediator in contemplation or talking, as an example, it might appear to the mind of deaf individual that she is attempting to conceal something. The use of head Nod by a mediator to show listening can be misunderstood as agreement, by so attentive care should be taken during communication gestures. Because Deaf people's actions are generally more group-focused (rather than individual-focused). As many hearing individuals appreciate the secretive character of negotiation also see it to be best for self-rule and secrecy, participant with deafness can be prone of feeling isolated during the process of mediation (Reiman, 2007). Furthermore, a Deaf individual is bound to feel distraught because of the individual-centred intervention measure. As a result, awareness must be in consideration by the mediator to the Deaf individual's batch-centred positioning, which fix him or her in friendly and relational organizations that rise above self-reliance, as well as the worth of reliance above independence in deaf culture. One strategy for accommodating the group-centred approach is the existence of commonly settled-upon outsiders in an underlying intervention meeting (Reiman, 2007).

2.1.11 Social Networking Sites and Mobile Instant Messengers

Social Networking Sites. Deaf individuals may now engage with a larger range of people and maintain worldwide touch thanks to social networking. For example, Breivik (2005) discovered deaf individuals in Norway were utilizing internet and electronic mail to engage frequently with people who can hear as well as building ‘‘multinational" relationships with individuals having deafness issue all over the globe, giving the Deaf society a new transnational character (Kožuh et al., 2015). In Norway, Bakken (2005) looked at the general consequences in relation with Short Message Service (SMS) with terms of person-to-person communication as well as social and etymological confinement. Using the term “socially deaf” to characterize persons who have a “limited ability for communicative contact with others by Bakken, independent of their degree of hearing loss” (p. 163). People who are deaf and those who are hearing may keep from becoming culturally mute when interpreters are available. A normal individual who is unable to sign without an interpreter in an event involving making sign language for deaf persons is socially deaf in that setting (Kožuh et al., 2015). When interacting with another person through a computer or another type of text message, Deaf persons might avoid being socially Deaf in a hearing environment. Communities and networks are formed by more than just being able to interact. In regard to deaf people and deaf culture, Bakken (2005) presents Granovetter's (1973) concept of “weak” and “strong” relationships between individuals. Networks formed by people who are just ‘‘loosely connected”, according to Granovetter, may be extremely strong (Hashim, Safie, & Mukhtar, 2018). Those who have access to a variety of communication channels and relationships with others can exert a significant amount of power. Up to this point, individuals with deafness were generally restricted to personal interactions, as a result, their connections became smaller and more prone to form "great connections" (as Granovetter refers to highly established and personal relationships) among members. Hearing individuals find it easier to maintain relationships with far dispersed acquaintances, Deaf individuals, on the other hand, struggle to interact with Hearing individuals and are more comfortable communicating publicly using TeleTYpewriter (TTY) or fax as People who are deaf who use a TTY are accustomed to doing so. People in a group who communicate have strong bonds with one another on a regular basis establish a comfortable relationship in which one can comprehend the experiences and attitudes of the other. However, being in a closed group has the drawback of being isolated and so out of contact with other person's situations (Hashim, Safie & Mukhtar, 2018).

- **Mobile Instant Messengers:** Communication technologies are swiftly and dramatically altering life and work in today's world. Changes brought about by communication technology will always have a significant influence on all parts of life, particularly how people connect with one another. That circumstance and condition have altered people's lifestyles at all levels (Mutemwa, 2011). Communication technologies are swiftly and dramatically altering life and work in today's world. Changes brought about by communication technology will always have a significant influence on all parts of life, particularly how people connect with one another (Hashim, Safie, and Mukhtar, 2018). That circumstance and condition have altered people's lifestyles at all levels. People have communicated inefficiently and ineffectively in the past, especially for the disabled. On the contrary, there are virtually no barriers to communication between individuals nowadays. Many sophisticated communication technologies have been developed that provide a wide range of functions and services. For example, the most popular gadget used by the majority of people on the planet is the mobile phone. The Short Message Service (SMS) is one of the most well-known mobile phone services. With 2.4 billion active users (or 74% of all mobile phone subscribers) sending and receiving text messages on their phones, this service is the most extensively used data application on the globe (Mutemwa, 2011).

Disabled individuals, on the other hand, are those who are affected by the communication service offered. They are persons who are unable to speak verbally (silent) and who are apprehend (deaf). Typically, these people communicate through a variety of modalities, the most frequent of which being sign language and writing. These two techniques, without a doubt, do not assist them in communicating smoothly with ordinary people. The advent of SMS technology in the previous several decades has greatly aided them in communicating with their family and friends over long distances. However, when it comes to short-distance communication, the issue arises since they typically utilize sign language to communicate. It is the stumbling block since not everyone understands the technique. As a result, a new communication system must be developed that allows them to speak directly with anyone using sign language. Chatting via Bluetooth with a mobile phone is a novel approach that has the ability to translate throughout the conversation process (Power, Power, and Horstmanshof, 2007). It can convert sign language to text and the other way around. Both sides of the software enable sign language and text communication. Furthermore, the application is capable of managing a large number of hosts. It implies that the user can talk using one of three methods: one-to-one (unicast), one-to-many (multicast), or many-to-many (multicast) (broadcast). It is up to the user to decide which method should be used (Mutemwa, 2011).

2.1.12 Cloud Computing

Cloud computing is one of the significant moves used in the world currently in the area of information technology, which is used in businesses to turn a design in order to perform a complex and huge scale processing (El-Gayyar et al., 2013). This process has the ability of incorporating virtual resources, vital information combination, parallel processing, security having a scalable information storage. Cloud computing do not just makes computerization and robotics cost effective to enterprises and people, but equally can provide reduction in their fundamental maintenance cost (Hashem et al., 2015).

A- Service Models of Cloud Computing

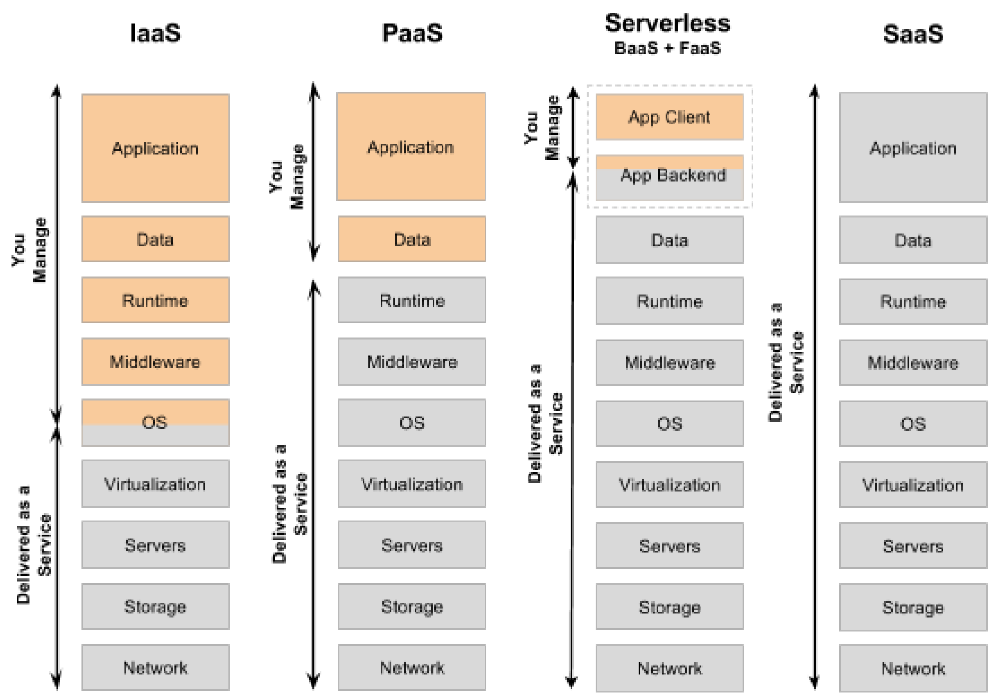
Generally, cloud computing can be categorised into four different classes (El-Gayyar et al., 2013).

- **Infrastructure-as-a-Service (IaaS):** This is the one in which the cloud suppliers disseminates network, computational assets and stockpiling inform of web-based service. This kind of model services relies on the virtual reality technology. The commonest example is the Amazon EC2 (Morsy et al., 2010).

- **Software-as-a-Service (SaaS):** This involves the dissemination of applications that are guested on the frame work of the cloud inform of web based administration to the end user, without the necessary requirements' for introducing the application into the Users PC (El-Gayyar et al., 2013). The model is usually facilitated using IaaS, PaaS or can be directly to the cloud foundation. The commonest example is the SalesForce CRM (Morsy et al., 2010).
- **Platform-as- a-Service (PaaS):** This kind of cloud supplier involves the conveyance of various business benefits, apparatuses, platforms that helps clients to develop their own applications, without the need for any of these bolster or programs instruments on the neighbour machines (El-Gayyar et al., 2013). This Paas can be guested on top of the cloud frameworks or sometimes on top of IaaS type straightforwardly. The commonest example of PaaS are Microsoft Windows and Google Apps. Figure 27 depicts the cloud computing service models (Morsy et al., 2010).

Figure 2.12:

The cloud computing service models



- **Serverless:** The serverless is another form of cloud-computing models that executes a particular action, in which a specific cloud provider will take the responsibility of other servers that run along with computing resource managements (El-Gayyar et al., 2013). In other words, this involve virtual or no physical servers that act as managers, due to the fact that they are automatically installed in the cloud through third party vendors. It composed of wide range of expertise, which are generally classified into two categories; Function as a Service (FaaS) and Back-end as a Service (BaaS) (Morsy et al., 2010).
- **BaaS:** This is significant for mobile application developments, which is equally similar to the SaaS delivery model that allows the change of the server side apparatuses through third party service. The common example is the Google's Firebase1 (Hashem et al., 2015).
- **Back-end as-a-Service (BaaS) and Functions-as-a-Service (FaaS). Backend-as-a-Service:** It has the ability of replacing the server side apparatus using the off-the-shelf services. Baas help developers in outsourcing all the aspects behind a scene of an application, in order for the developers to be able to select and maintain all the applications logics in the frontend. Some of the examples are the hosting, cloud storage, database management and remote authentication system. The commonest type of Baas is Google Firebase (El-Gayyar et al., 2013).

B- Firebase. The high usage of cloud-native, which enables architectural and technological concepts such as microservices and containers in recent time lead to the increasing interest in serverless as computing technique for programming the models and the architecture. In this process, code are used in the cloud as well without controlling the resources by which the code runs (El-Gayyar et al., 2013).

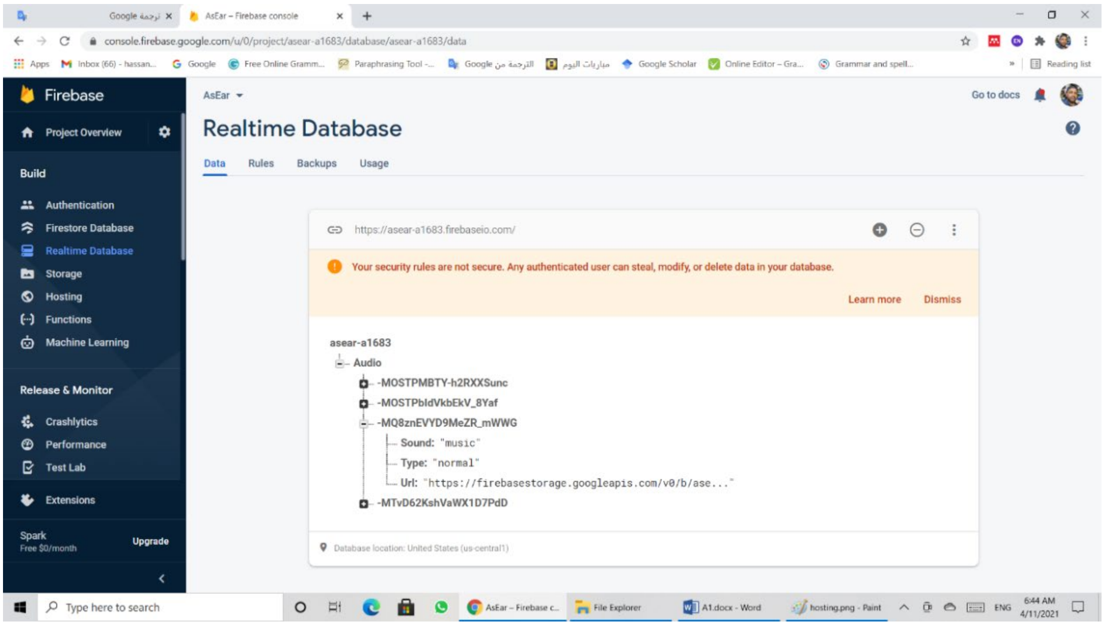
- **Firebase Products:** This gives a simple implementation of Software Development Kit (SDK) that can be used in various devices as well as the web. It can equally be coupled with Baas service models. Due to the fact that the users have the ability of connecting directly to the Baas services. All the resource of services in Firebase are implemented based on demand (Hashem et al., 2015). In this program, it is impossible to change or configure the underlying infrastructure of various services. The Firebase service works on resources of the Cloud Platform of Google, ever since

2014 when Google buy Firebase. The Firebase is only available currently at the centre of the US region (Hashem et al., 2015).

- **Firebase Real-time Database:** The Firebase Real-time Database is considered as a database that stores documents. It is equally regarded as a schema free and cloud-based. The data is mostly saved in JSON tree and data nodes will be synchronize to all the subscribers in realtime. The subscribers uses the Firebase SDK in order to have a direct access with the Realtime Database without the use of any server that connects the two (Deborah, 2021). The Realtime Database has the ability of offering offline capacities via the persistence of the database on the client's desk. Clients utilize a database reference to listen to and write to a specific data node. The Firebase Realtime Database is designed for simple query operations that may be completed fast. Flattening the data structure is recommended since there is a limit to the number of nested layers, and if a parent is queried, all children are also queried. With a set of rules on each data node, data may be protected and verified in the Realtime Database. Indexes can also be built for quicker querying of a certain data node (Deborah, 2021).

Figure 2.13:

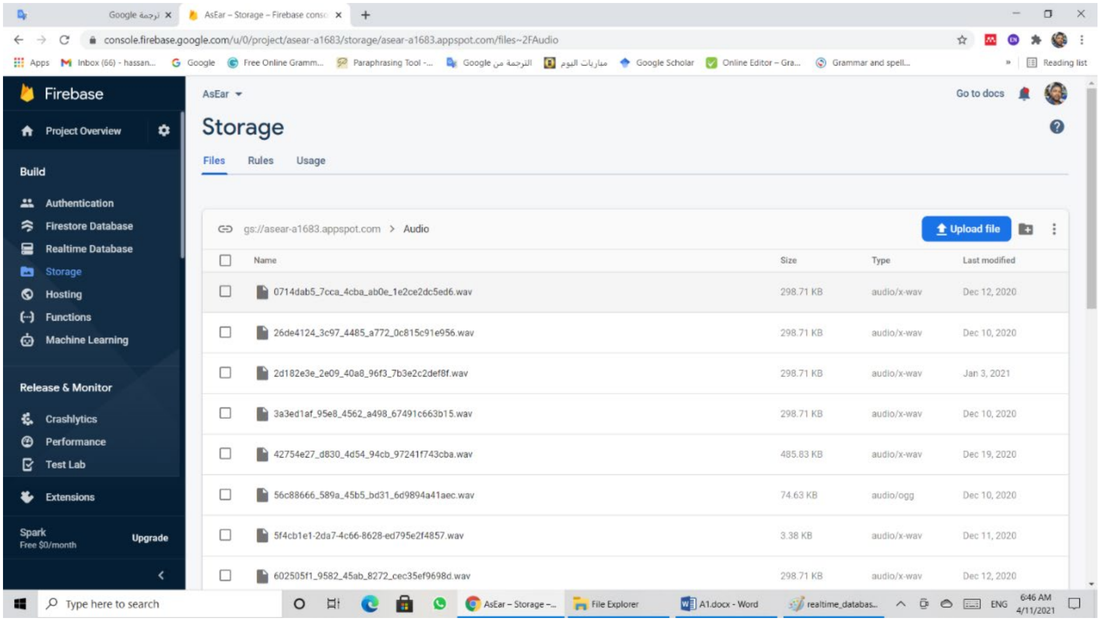
The Firebase Real-time Database designed for simple query operations



- **Firebase Cloud Firestore:** Firebase Cloud Firestore was first released in October 2017 and is still in beta. The Cloud Firestore is a document-model NoSQL database that is the most recent replacement for the Firebase Realtime Database. A collection can be made up of any number of documents. Subcollections can be used to organize collections hierarchically Firebase, 2018a) (Firebase, unlike Realtime Databases, Cloud Firestore allows for more sophisticated and expressive queries. Shallow searches, for example, can only get data at the document level, not the collection or subcollections (Siong, Nasir and Salleh, 2021). A Cloud Firestore database instance should also handle more concurrent connections than a Real-time Database instance, and Cloud Firestore is expected to be accessible in different locations following the testing period.

Figure 2.14:

Architecture of a Cloud Firestore database

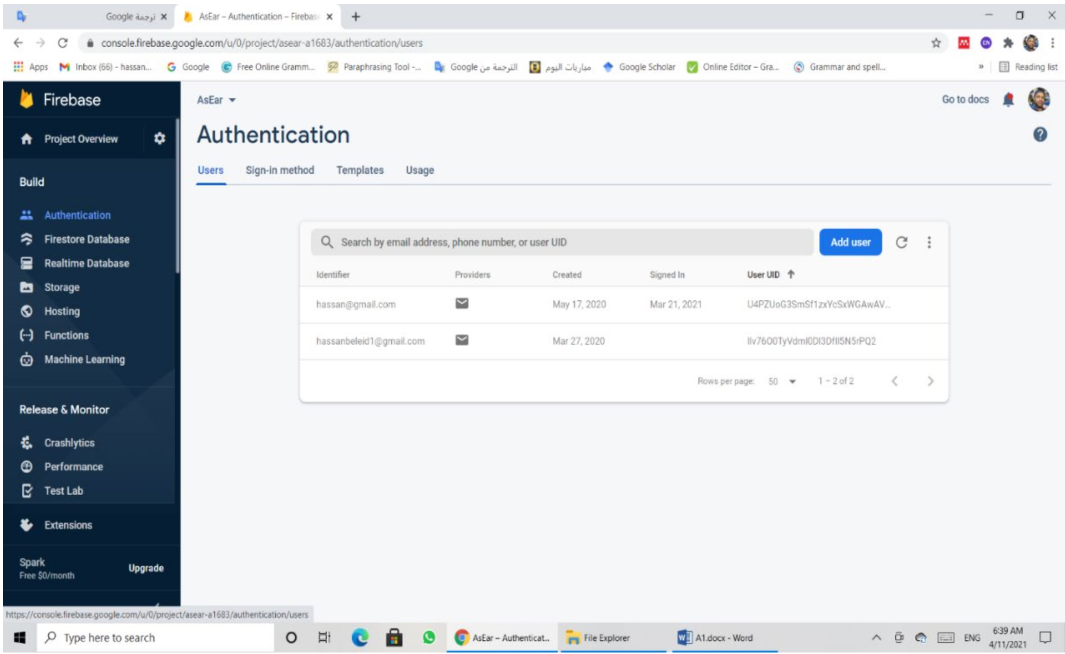


- **Cloud Functions for Firebase:** Cloud Functions for Firebase is a FaaS that is based on events. Cloud Functions for Firebase was first released in 2017 and is still in testing. Functions are created in the JavaScript or TypeScript programming languages in the Node.js environment and using the Express server framework. A single function is triggered by an event. A Realtime Database trigger, Cloud Firestore trigger, HTTP trigger, Cloud Storage trigger, or Cloud Pub/Sub trigger are examples of different types of events. Firebase intelligently maintains and scales function instances based on the load. As a result, a cloud consumer may focus on the function logic (Chuckun, Coonjan, and Nagowah, 2019).

- **Firebase Authentication:** Firebase Authentication is an authentication service that is ready to use. It offers a variety of methods for identifying a user, including email with password, federated identities (Google, Facebook, Twitter), and phone authentication. Clients may simply implement Firebase Authentication using the Firebase SDK. Sign-in, sign-up, and password change methods are all available in the Firebase SDK. To safeguard personal data, Firebase Authentication may be used with Firebase databases (Chuckun, Coonjan & Nagowah, 2019).

Figure 2.15:

Architecture of a Firebase Authentication

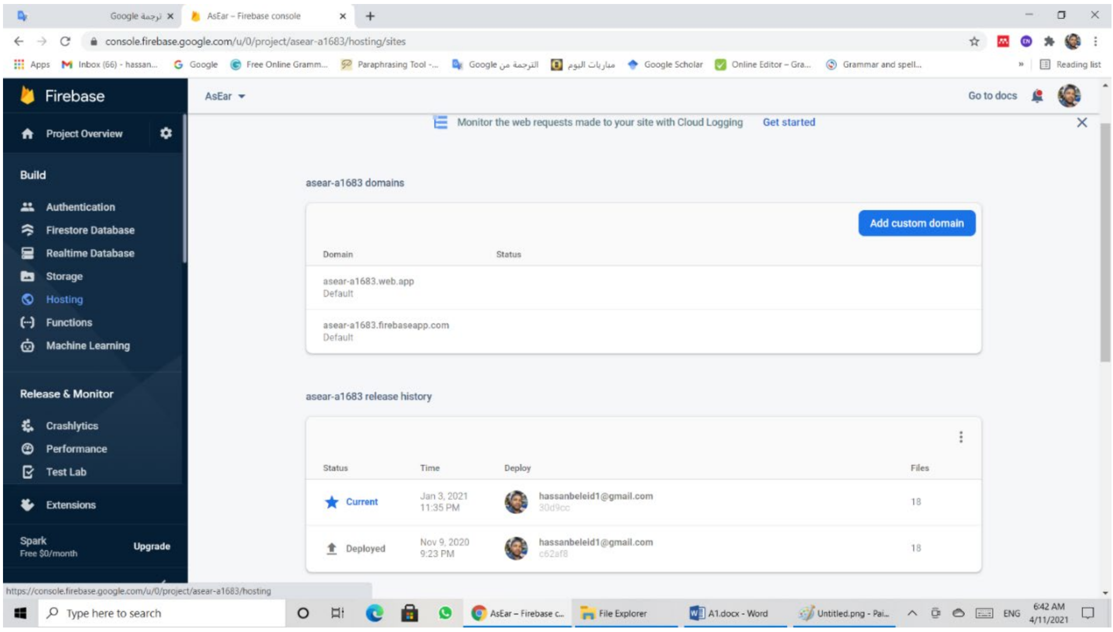


- **Firebase Cloud Messaging.** FCM (Firebase Cloud Messaging) is a cross-platform messaging system with no quotas that allows you to consistently send messages at no cost. GCM/FCM is carried out through a cellular network or over Wi-Fi, and PNS is practically free. FCM is the Android platform's default push messaging system. Application developers may simply deliver notifications to FCM-supported applications using FCM. GCM/FCM performs better (quicker) than SMS in terms of response (Chuckun, Coonjan, and Nagowah, 2019). Firebase Cloud Messaging is a messaging and notification service that connects your devices. It's designed to be dependable, with 98 percent of communications reaching linked devices in 500 milliseconds or fewer, and immensely scalable, with an infrastructure capable of delivering over a trillion messages each week. Every device that uses FCM will be assigned a Registration Id, which will identify it as a distinct device. Registration ID is also known as a token. With their token, an application developer can utilize the HTTP API protocol to deliver notice (in JSON format) to the target device. FCM allows up to 1000 tokens per request. Figure 1 shows an example of the FCM Request Notification Format (Berger and Maly, 2019).

- **Hosting.** Firebase's hosting service allows you to create static webpages and single-page apps using HTML, CSS, and JavaScript. For file and data transmission security, it employs HTTPS and SSL protocols. It does not need the use of Firebase's built-in Content Delivery Network (CDN) (Chuckun, Coonjan, and Nagowah, 2019).

Figure 2.16:

An overview of Hosting



2.1.13 Design Principles and Guidelines of Mobile Applications for Deaf People and Smartphones

- **Plan the Human-Centered Design Process:** In this method, each work of the application interface will be placed on the user needs. In this issue, it is for the people with intellectual disabilities. In this case, different people with hearing disabilities from different regions were asked regarding their suggestions and opinions regarding the application interface (Risald et al., 2018).

- **Understand Specifying the Context of Use:** Understanding the intended product's consumers and their usage environment is the foundation of any UCD approach. As a result, the standard UCD approach starts with identifying users and extends to all stakeholders, or indirect users, who are all involved in the system [20]. We also identify user characteristics and user groups, as well as potential qualities (as defined by ISO), such as skills, education, age, and so on (Brunner et al., 2017).

- **Specifying the User Requirements:** Essentially, at this step, the user's requirements are gathered by extracting information or data, then the information or data is arranged from the data needs of the user, and the user's needs are expressed in different forms or techniques, such as narrative, diagrams, and so on (Pölsterl et al., 2016).

- **Produce Design Solution:** The original design was generated in this stage. Prototypes include sketches, simulations, and other sorts of models that are intended to make ideas visible and allow efficient communication with consumers. This avoids potentially significant expenses and needs for redesigning the product at a later stage in the life cycle. Users must be able to accomplish tasks when design solutions are given to them. The customer input gathered should be factored into the design solution's improvement. It should be iterated indefinitely until the design objectives are achieved (Brunner et al., 2017).

- **Evaluating the Design:** The design solution from the previous stage is assessed in the following activity. The objective is to gather input so that the product may be improved further, as well as to see if the design fulfills the given user requirements, usability goals, and general usability principles. As long as usability goals aren't satisfied, the UCD process cycle will continue (Pölsterl et al., 2016).

Many factors were taken into account when developing an Arabic sign language program (Silva et al., 2019), including portability, extensibility, ease of use, and efficiency. Efficiency, extensibility, performance, portability, reliability, and usability were the five characteristics used to evaluate the program. However, there are certain limitations to the application's language usage. This program is designed for Arabic language users, and the mobile device should have a high-resolution camera to allow for accurate sign language translation. Because the program can only be used with a high-resolution camera, this is a crucial factor to consider in terms of usability (Pölsterl et al., 2016).

As a result, certain mobile phone users with low-resolution cameras may be overlooked, and the system's efficacy is questioned. MOGAT, a game-based mobile application for deaf children created by Zhou et al., was assessed on three dimensions: naturalness, motivation, and pleasure. The application did not adequately satisfy the requirements of all deaf individuals, and additional factors such as accessibility, efficacy, and efficiency might have increased the app's acceptance. Furthermore, because the application is intended at mobile users, mobile application limitations should be considered (Pölsterl et al., 2016).

Mattheiss et al. (2017) on the other hand, created the jFakih mobile games, which are aimed for deaf youngsters who want to learn Jawi using hand signs. In this study, the Nielsen model was utilized as a foundation for usability evaluation, and nine extra characteristics were included in total. Error, ease of use, help, user enjoyment, system performance, game level, navigation, user pleasant, efficiency, memorability, and learnability are the factors to consider. The study also offers various usability approaches or models that may be utilized on application evaluation in the future to better assist deaf youngsters (Mattheiss et al., 2017).

The majority of consumers prefer to utilize goods that are simple to use, perform as expected, and finally provide value. In the context of software engineering, system usability is critical in molding users' perceptions of quality in usage (Alagappan et al., 2010).

The study of the confluence of systems and users, tasks and expectations in the context of usage is known as usability. Since many software products have been judged to be insufficient to satisfy user demands, numerous thorough studies have been done under the name usability, trying to better explain and measure all valid phenomena in one framework or model. The study's findings, as summarized by Weichbroth, indicate that the notion of usability has changed over time. In 1991, the Organization for Standardization (ISO) published the 9126 standard, which defines usability as "a collection of properties of software that impact on the effort required to use it," in response to the need for the software community to standardize some aspects of software products (Bhatti et al., 2015).

The sign language for a certain term may vary throughout time. Non-deaf persons may find it difficult to keep up with the many vocabularies of sign language. Many individuals, including deaf people, use smartphones these days. According to a poll, more than half of all deaf individuals use smartphones. Because of these restrictions, they rely on smartphone applications for talking and video calls. A solution is presented to overcome the difficulty of deaf individuals communicating with regular people. The purpose of this study is to assess the usability of the smartphone as a communication tool that deaf individuals may use to communicate with the general public. Some research on Communication Boards (CB) include the usage of a CB in a hospital for a patient on a ventilator, as well as the investigation of alphabetical organization on CB to make it easier for users (Prasetyaningrum and Gregorius, 2011).

- **Usability Evaluation**: In order to assess usability issues in any system or application, usability evaluation is a critical component. Evaluations with users are used to identify usability problems. Many usability models have been alluded to in the literature for performing usability evaluations. Nelsen, QUIM, mGQM, Harrison, and ISO are examples of common usability evaluation models. These are some of the models for usability testing that have been used in the past. When an application is built for a specific target user, however, the user's needs must be included into the program (Prasetyaningrum and Gregorius, 2011). If the need is missing, the application will fail to satisfy the user and will make the task more difficult (Bhatti et al., 2015).

- **Usability Evaluation Metrics:** Examiners typically utilize usability metrics measurement to determine what they are going to measure. ISO 9241 part 11, advice on usability is one of the current usability metrics. However, this metric has been widely utilized, although it is overused, difficult to link to specific domains, and does not help with any quality criterion (Prasetyaningrum and Gregorius, 2011).

In a developing measuring metric, the GQM approach might be experimental. Furthermore, among various measuring methodologies, this strategy has been regarded as one of the most goal-focused and popular ways employed. Although GQM was previously used to describe and assess objectives for specific projects and settings, it is now being used to express and evaluate goals for all projects and environments, Its goal has been broadened to include quality improvement, progress measurement, and project planning. As a result, it's believed that the GQM technique may be expanded to assess usability guidelines by giving usability guidelines metrics. In addition, this research describes the GQM paradigm's defining phase, demonstrating the outputs of the first three phases of Basili's GQM process, the hierarchy of goals, questions, and relevant metrics (Bhatti et al., 2015).

- **Accessibility of Mobile Applications:** Several prior research studies on the issue of accessibility in mobile applications are now contributing to this study. According to a research conducted by Krainz et al. in 2018, the Android Play Store contains over 3.5 million distinct applications, however the majority of them have accessibility issues (Wardana, 2017). Accessibility of mobile devices, according to Damaceno et al., refers to the capacity to interact appropriately with the operating system of mobile devices. This study takes a broad look at the accessibility issues that persons with visual impairments have while using mobile devices and presents a set of accessibility guidelines to guide future research. According to Eler et al., it's critical to make mobile apps accessible without excluding individuals with disabilities, but there aren't enough tools for developers to check if the user interface components are accessible to screen readers. As a result, developing and evaluating mobile applications is difficult. Ross et al. used tags and accessibility obstacles to assess the accessibility of 5,753 free Android mobile applications. The findings demonstrate that accessibility obstacles remain a pervasive issue, and they recommend that large-scale data be collected and analyzed to address accessibility violations in mobile apps. Mobile apps, according to El-Glaly et al., must be available to everyone. Many of the most popular programs, however, are not (Abdallah & Fayyoumi, 2016). The authors of present a collection of modules for defining the accessibility challenge and simulating the consequences of an accessibility barrier. Design considerations are involved in the construction of accessible mobile apps, according to Carvalho et al., The prototypes created using the WCAG 2.1 accessibility principles and the Talkback screen reader were more compliant with the accessibility requirements, according to Pichiliani et al. underlined the need for alternate access to visual components in mobile apps based on user interface aspects. The findings of this study's evaluation may encourage mobile developers to examine their products' accessibility and offer required support for additional situations. Designers and developers of this sort of technology, on the other hand, frequently overlook the significant difficulties, wants, demands, and expectations of end-users, failing to analyze how they operate and interact with such systems (Weichbroth, 2020). This is sometimes attributed to a lack of universal usability engineering approaches, as well as a lack of expertise with end-user-centered methodologies [24]. Design and development that are solely focused on technological possibilities while ignoring human talents are inadequate. As a result, thorough research is required to determine which combination of media, device, and application is most beneficial in order to improve the quality of end-user experiences. This must be done at the crossroads of psychology and computer science, which is where HCI and usability engineering have always operated. The overarching objective is to improve multidisciplinary research and development in order to provide demonstrable advantages and improved value to end users. In terms of end-users who are deaf or hard of hearing (D/HH), universal access to Social Networking Sites (SNSs) should be prioritized SNSs. On the one hand, the growing popularity of using these sites is the cause (Weichbroth, 2020). For example, Facebook, the most popular social media platform, surpassed 1.1 billion members in 2013. This problem has affected a wide range of social groups, including D/HH users, and has expanded to a variety of areas, including education (Weichbroth, 2018). Accessibility for all individuals must be studied and addressed, as mobile and Internet-based technology become an ever-present and important component of daily life. Technology has the potential to reduce isolation, increase independence, and provide educational, financial, and social opportunities for users; however, barriers and inconsistencies in both hardware and software, as well as on the Internet, can limit access to information and opportunities, especially for people with special needs (Weichbroth, 2018). It is challenging to create computer-based learning for D/HH learners, according to Giannakos and Jaccheri (2014), and it is important to develop in accordance to their demands. D/HH students require a particular learning style or approach while using computers, yet their demands are sometimes ignored in the design process (Weichbroth, 2018). Computer-based instructional games, for example, seldom focus on learners with specific needs, such as D/HH students. A number of studies have been conducted on the usage of technology with D/HH students. These, on the other hand, prefer to focus on things other than EI, such as mastering mathematics, learning sign language, or vocabulary acquisition (Weichbroth, 2018).

D/HH students require a particular learning style or approach while using computers, yet their demands are sometimes ignored in the design process. A small number of studies have looked at deaf communication difficulties and offered advice for smartphone app makers. Smartphone apps provide a way for deaf people to communicate with those around them. As a result, there are few studies that outline the key features and functionalities that should be included in smartphone apps for deaf individuals (Alnfiai & Sampali, 2021). As a result, we looked into current academic studies to see what kinds of difficulties deaf individuals face. We then offered developer suggestions based on the needs of people with special needs. Deaf people's communication obstacles have been addressed in research on assistive technology, and recommendations have been made to help them become more active in their communities. The current publication discusses the design, development, and testing of a mobile ESR system that seeks to improve situational awareness in deaf people. We provide answers to issues encountered during the creation of an ESR system particularly built for deaf users in this exploratory research in the field of assistive computing. Despite its relevance, there are currently few research on this subject. We define the requirements that led the creation of our system and give specifics about the execution of our solution to stimulate future effort. In broad terms, we present a method that uses mobile technology to address the desired ubiquity of a sound recognition service for deaf users. To ensure service availability, we believe that all processing should take place on the mobile device itself (Alnfiai and Sampali, 2021).

2.1.14 Acoustic Fingerprinting

To achieve simi-larity, sound is aligned, and the distance between the two time-frequency diagrams (spectrograms) is calculated (Bird and Bird, 2019), for example, peaks. This method is used to establish a rate of similarity between two sound samples (Bird & Bird, 2019). The main goal of eliciting an audio fingerprint is to be able to compare two sound records for similarities without having to compare the actual big sound files by using a succinct textual representation of the vast sound material instead. Because they are just textual representations of the original sound document, the fingerprint only contains the significant portion of the sound, making it simple to seek for and keep (Han et al., 2021). Sound Fingerprinting methods have recently risen to prominence since they allow for the analysis of sound independent of its format and without the need of watermarks or meta-data. Since music is easily reproduced and disseminated on the internet by music privateers, it has become increasingly widespread (Soman & Murthy illegally, 2015). Algorithms and sound fingerprinting technologies have been successfully used to a variety of applications, with paid application developers taking the lead (Soman & Murthy, 2015). Fingerprint similarity measures allow data to be distinguished from a large library; for example, Shazam's algorithm can recognize a song from a database of millions of songs. However, this technique is frequently used to detect plagiarism (Bird & Bird, 2019). In this thesis, Musicg library has been used to find out the Fingerprint. Musicg is a lightweight audio analysis library, written in Java and developed by Google, with the purpose of reading, cutting, and trimming easily from an input stream. It also provides tools for digital signal processing, and renders the waveform or spectrogram for research and development purpose. Musicg library can be used to compare WAV format files only.

2.1.15 Prerequisites Framework for Deaf and Hard of Hearing People

In an investigation on deaf and hard-of-hearing, participants communicated a need to utilize the framework anywhere (Fanzeres, Vivacqua and Biscainho, 2018). The need to perceive sounds in different settings was affirmed in interviews with experts from the National Institute for the Education of the Deaf (INES, acronym for Instituto Nacional de Educação de Surdos), where they stated the significance of embracing a framework that offers persistent service anywhere. Furthermore, a framework is intended to offer usability. Because of resource limitations, mobile apps might become reliant upon far-off processing, for example, cloud computing (Sahu et al., 2012). This can be an issue especially for applications intended to exchange information in real-time, which are more vulnerable to failure when utilizing services provided remotely. AsEar mobile app has multi-functions some of them depending on cloud computing and processing in real-time and the rest not especially detection sound which is the main function of AaEar mobile app. AsEar mobile app development approach exclusively depends on smartphones because of their mobility and processing capabilities, the system is not dependent on other devices and runs all processes on the smartphone itself, from sound detection to recording comparison, and presents the sound recognition results to the deaf and hard-of-hearing people. Depending on the above-mentioned issues, we have formalized the prerequisites that directed the improvement of As Ear framework, presented in Table 2.1.

Table 2.1:

Prerequisites directing the improvement of AsEar mobile app framework

Requirement	Description
Informativity	The main informative function of the system is sound recognition, but it must also provide real-time visualization/perception of sounds that are being captured or played employing lower-level descriptions of the audio signal. In other words, the system must provide a feedback of the detected sound without the interpretation of classifiers, indicating, for example, the intensity and/or frequency of the audio signal in a form that can be easily interpreted by the user. This information is critical for the deaf user to know precisely the moment when sounds occur and are recorded, recognized or played.
Service availability	The system should perform important processes such as recording and sound detection, and alerting only utilizing resources of the device itself, without depending on remote processing, either by network or some other associated gadget.
Ubiquity	The system should be usable everywhere.
Compatibility	The system works only on Android platforms with the capability to interact with different operating systems using social media or instant messengers.
Usability	The system provides a visual and haptic alarm function to the D/HH person about the event of sounds around him/her. The system likewise gives the historical backdrop of recognized sounds, so the client has the choice to display sounds that were recognized in the past either locally or in the cloud
Knowledge dynamicity	The system must use a knowledge base that supports the addition and exclusion of sound classes dynamically, thus allowing its update.
Responsiveness	Sound detection time, from audio signal processing to alerting results, was in real-time.
Reliability	For high accuracy, the human factor was involved to obtain the required confidence.
	Sharing hearing people experiences
Flexibility	changing the pattern of detection sound

2.2 Related Research

Jain et al. (2022) presented a mobile application for capturing multiple audio samples. They assessed the performance by a large-scale survey on two real-world audio datasets and found a significant, namely a +9.7% gain over the original dataset. The SoundWatch app, created by Huang et al. (2023) , uses a smartwatch to detect ambient noise, which was evaluated by 10 participants with deafness. Research suggests the app is effective in raising their awareness of the environment and assisting in daily activities. In An et al. (2022), deep learning techniques were used to convert daily sounds into spectrograms for analytical purposes. The proposed system captures the sound in real-time and classifies it according to the learning outcome. The execution showed an average rate of 80% in mixed noise. Do et al. (2023) suggested the use of AdaptiveSound as an auditory recognition system with the D/HH feedback loop. The assessment conducted in the real world on actual audio files with 12 D/HH people reveals that the system achieves a substantially higher accuracy of 14.6%. In Chin et al. (2023), an EfficientNet-based system was used inside a wearable device to discover emergency car sirens by classifying the sounds and turning them into a spectrogram. In the online style, 95.2% accuracy was achieved, while the offline style achieved 97.1% accuracy. Asakura (2023) used augmented reality (AR) with machine learning (ML) to detect everyday sounds and represent them visually. The results indicated that daily life in home spaces can be better. In Shiraishi et al. (2020), a smartphone-based deep neural network-based alert sound classification system was used. The results indicated that the classification averages were higher than 98% for both deep neural networks and neural networks. Ştirbu et al. (2023) developed a mobile application based on AppInventor that can be fixed on wearable devices to fade the communication issue faced by D/HH people during emergencies. Ramirez et al.(2022) developed a siren identification system that was enhanced by deep learning technologies and converted siren sound to spectrograms to solve safety issues that face D/HH people. The results demonstrated system reached 91 percent accuracy in real-world siren sound detection. Mirzaei et al. (2020) introduced EarVR system that used a smartphone and AR technologies to analyze 3D sounds in a VR environment, detect sound around a D/HH person, and tell sound direction. The study showed that D/HH participants were unable to complete a complex task in virtual reality without a EarVR system. Alkhalifa and Al-Razgan (2018) developed system using smartphones and

Google Glass, which has been used to frame sound alerts and translate in real-time. The results demonstrated that it is easy to use and acceptable among students. Anwaar et al. (2022) proposed assistive technology can be used by D/HH in dangerous outdoor environments. The proposed system was able to detect sound and some words. Yağanoğlu and Köse (2018) developed a wearable device that is employed to inform hearing-impaired people in real-time about significant sounds. The accuracy of all tests is greater than 90%. Aktaş et al. (2017) developed a system using an Arduino panel with a set of sensors to monitor infants by their deaf parents. When nontypical conditions occur, an alert will appear on guardians' smartphones. The results show alarms have succeeded in warning of abnormal conditions. Kim et al. (2018) designed a haptic conversion method that used a wireless acoustic sensor with a neural network to detect sound and change it into text form. Experiments show hard-of-hearing people pleased the system.

2.2.1 The Gap in the Related Literature

It is therefore significant to adopt the newest technology to assist persons with such disabilities in minimizing the communication gap by detecting all sound, teaching hearing people sign language, and store the sounds in the cloud.

CHAPTER III

METHODOLOGY

The current study portrays the plan, development, and test of a mobile AsEar mobile app framework that intends to extend deaf and hard-of-hearing people sound awareness and face-to-face communication.

3.1 Design AsEar Mobile App

The Agile iterative methodology has been chosen to design AsEar mobile application.

3.1.1 Agile Software Development Methodology

The Agile methodology is an effortless, adaptable, error-free, powerful approach to deliver an incredible product to the market. It also based on an incremental, iterative approach, rather than depth-planning at the commencement of the project. Moreover, Agile is one of the best ways to oversee software development teams. Agile similar to other software development methodologies Waterfall, Spiral Model, V-Model, Prototype Model, etc.). Nevertheless, there are numerous diverse Agile strategies that utilize to organizing projects such as Crystal, Kanban, Extreme Programming (XP), Scrum, and iterative approach.

3.1.2 What is the Agile Iterative Approach?

This methodology concentrate on distributing worth as quickly as conceivable in growths, instead of delivery simultaneously. The methodology is particularly helpful in both product and software development. Therefore, the iterative technique involves the splitting of the development of the products or software during the development of the software into sequences of repeated cycles (iterations). Where by each one delivers various valuable increment or improvement features. The procedure permits the development team to change, review, and debug software development processes permanently to improve the quality of their execution gradually. The agile iterative methodology sets out open doors for steady assessment and improvement being developed cycles. The design of an iterative methodology is straightforward and simple to execute, paying little mind to the unique circumstance.

Step 1: Planning and Analysis. This primary phase involves the iterative life cycle, which has to do with different planning activities, in which the service providers as well as the customers meet up in order to check the stakeholders' and software requirements. It is not useful at this point to check hazards related to associated with the quality of the project assurance prerequisites since this stage will be repeated again for the next iteration which will ensure that the risks are conquered and quality is guaranteed. At the point all the necessary requirements were attained, the analysis is then conducted in order to update the developmental stage that involves the identification of the database model.

Step 2: Design. The design stage will create practical prerequisites like services, programming language, cloud computing, platform, and database, for the architecture of the AsEar mobile app.

Step 3: Implementation. After the previous steps have done, we started writing the code for first version of AsEar mobile app. We then followed the guidelines for coding and employ different front end and back end techniques like the debuggers, interpreters and compilers. We have chosen Java for Android section of App, Java script to code the website. In addition, we selected suitable emulator and virtual server. Moreover, build the technical architecture such as database, screens and programs of the first iteration module.

Step 4: Testing. Immediately the initial iteration code of the model is written, it is therefore considered as the moment for testing its potential issues and bugs, which are mostly overlooked at the previous step. Before testing the whole system, units test were conducted, the first test was on an emulator for the Android section, as for website was tested on a virtual server after we performed units test, which is done in order to check for each of the units codes used in the programming; then the integration test is followed, which is done to verify whether each unit code works properly when integrated; subsequently, the user acceptance test was performed to determine whether the program fulfils the needs of the user for that iterations.

Step 5: Evaluation. After all the steps have been followed in each of the iterations, therefore, there is need for evaluating the entire system and identify the shortage. Before handing over the final project to the deaf, we tested many times with stakeholders and deaf, who reviewed the final product for its validity and efficiency. Therefore, according to deaf and stakeholders' feedback, after initial testing, we gathered their feedback and we started the subsequent iteration, starting from the initial stage, which is planning for more improvement.

Therefore, this is considered as the primary iteration cycle, in which we had successfully developed the basic version of AsEar mobile application. For further improvements in the final version of AsEar mobile app, and according to deaf and stakeholders' feedback we added new vibration levels to identify important sounds deaf, Based on the feedback of the deaf and stakeholders, we went back to the first stage, which is planning, and then each stage is followed in the next iteration cycle that be used in improving the AsEar mobile app version. This process will be done repeatedly until there is no need for further improvements. In addition, we provided user guidelines to explain to users how to use AsEar mobile app.

3.1.3 When to Use Iterative Model

Iterative Model can be used in following:

1. The project is large
2. Requirements are not clear-defined
3. Requirements are changeable
4. The resources for some iterations are not available at the time of use but can be used in later iterations.

3.1.4 Advantages of Agile Iterative Development

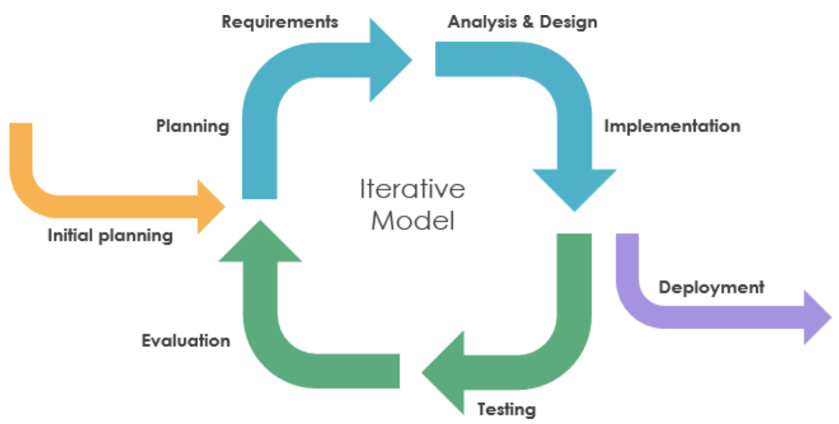
This iterative technique (Adel & Abdullah, 2015) gives the following application to developers of software team:

- Adaptability to make various changes and progress. Its method takes into consideration change during the development process.
- Client partnership. The development team concentrates on client notes, feedback throughout the development process.

- Early danger recognition. Dealing with every cycle is less difficult than dealing with the entire project at once. The iterative methodology permits teams to handle issues from the get-go without needs for backtracking it by the developers.
- Speedy delivery. The iterative step needs minimum time to be spent on documentation and consequently permits advancement groups to invest more time in planning and carrying out projects.
- The modifiable and recurrent nature of the iterative methodology permits the development team to test groundbreaking thoughts for their products.
- Simpler to test and troubleshoot through a smaller iteration (Larman & Basili, 2003).

Figure 3.1:

Iterative Development Model (Miraz & Ali, 2020)



3.2 Design Database

3.2.1 SQLite Database

SQLite is an Open Source database that is written in C-language that carries out a little, quick, high-reliability, and full-merits standard relational database such as SQL syntax. SQLite is the most utilized database among users in the world. Because comes packaged inside innumerable different smartphone applications that individuals utilize each day (Lv et al., 2009). In addition, SQLite Database requires bounded memory at runtime (almost. 250 Kbyte).

(Sound_aware) database contains two tables, sounds and pattern. Sounds table as shown in Table 1 and Table 2 below.

Table 3.1:

The description, length and type of sounds

Field name	Description	Type	Length
SOUND_ID	Auto increment number to store sound id	Integer	-
SOUND_NAME	Using to store sound name	Varchar	50
DESCRIPTION	Use to save sound's description	Varchar	250
TYPE	use to save sound's type	String	-
SOUND_FILE	Use to save sound file path in SQLite	Blob	-

Table 3.2:

The description, datatype and length of sound pattern

Pattern Table

Field name	Description	Datatype	Length
PATTERN_NUM	To store pattern id	Integer	-
PATTERN_TYPE	To save pattern type	Varchar	150

Pattern table contains two fields pattern_num and pattern_type to control pattern of detection sound pattern table has one-row pattern_num which has constant value 1 and pattern_type which changeable from Sensitive to Important and vice versa (Yang et al., 2010).

3.3 Firebase Cloud Computing Project

Actually, we created two projects in Firebase cloud AsEarWeb and AsEar. AsEarWeb project design as a web app that deals with the website to store in the real-time database the sound explanations by hearing people. Also, can control access and logout. AsEar project which is designed as an Android app that links with the main AsEar project, which is programmed by Android Studio to control flow data and synchronize both projects. To manage information flowing to the cloud Firebase cloud computing has many functions listed as follows:

3.3.1 Real-time Database

"asear-a1683" is a real-time database that is part of firebase cloud services asear-a1683 has an Audio node, which is usually named table in a normal database. An "Audio" node contains sound, type, and URL. Sound and type fields save data from website by hearing people after they receiving the link from deaf people through social media or instant messenger URL field represent the sound link which already been uploaded by deaf people.

3.3.2 Cloud Storage

Cloud storage a place to accommodate all sound, and its forms (e.g. the sound of a car, doorbell, and phone ring has a variety of similar forms that need users' synergy to store a large collection of acoustic data, where D/HH upload sound files to the cloud. The download task offering an overview to D/HH about sounds and its forms, which uploaded by other D/HH and download what they are interested in or what is important for them. In addition, the capacity to host all sounds in cloud data storage also cloud offers quick detection of the sound event and share sound experience with others. Furthermore, overcome small smartphone capacity.

3.3.3 Hosting

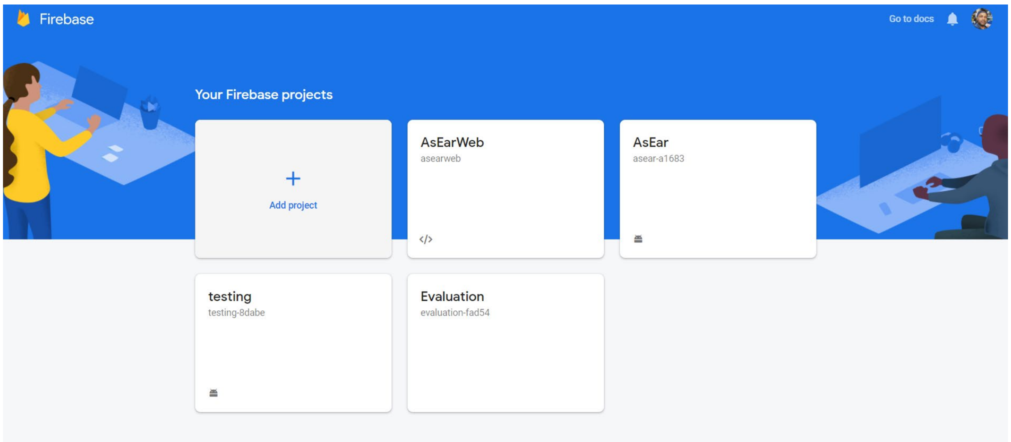
The hosting function established to hosting the website.

3.3.4 Firebase Cloud Messaging

Firebase Cloud Messaging (FCM) is a cross-platform messaging solution that lets users reliably send messages at no cost.

Figure 3.2:

An overview of the AsEar mobile app



3.4 AsEar Mobile App Development Tools

We structured the system for Android smartphones because of their prevalence worldwide and nearly modest cost. We developed the AsEar mobile application using the following standard software and devices.

- Android Studio version 4.1.3 is used to develop applications for Android mobile phones.
- The Firebase cloud is used to store files, store databases, and hosting the website.
- Visual Studio Code is used to program website.
- Dell Inspiron 5559 Windows 10 (64-bit) based laptop.

3.5 Detecting Process and Alert

The design was improved in response to customer comments. The AsEar mobile app offers online services such as downloading, uploading, and communicating via social media. In addition, the app includes an alert feature, which is an offline service that notifies you when sound is detected at any time and from any location. The design aims to increase self-confidence. This has the ability to blur the line between hearing and deaf people. Furthermore, it has the potential to improve written language and allow for greater communication among the deaf (Diefenbach, 2018). Figure 3.3 depicts the general diagram of AsEar mobile app. Figure 3.4 depicts the structure of the flowchart.

AsEar mobile app analyses acoustic data received by smartphone mic which monitors if there is any significant change in the acoustic data pattern. Change in the sound pattern can be a possibility of a new vocal occasion which can be significant considering in case of emergency, privacy, or security, which mean when the D/HH smartphone detected sound, then a comparison between the detected sound and the sounds already stored in local database SQLite called (Sound_aware), if they are matched, then an explanation of the sound will appear on the smartphone' screen if they do not match, then D/HH will upload the sound file to Firebase data storage (cloud storage) and send the link of the file sound to hearing people (volunteers or relatives) through SNSs or Mobile Instant Messengers (MIM), after that hearing people will open file sound in the website which prepared for that and listen to sound then they write their experience about the sound by a saving description of the sound in the firebase database (real-time database) and hearing people can instantly respond on SNSs or MIMs to give feedback about the sound. The functional diagram of the general application shown in Figure 3.4.

Figure 3.3:

The architectural design of enhancing face-to-face communication with D/HH

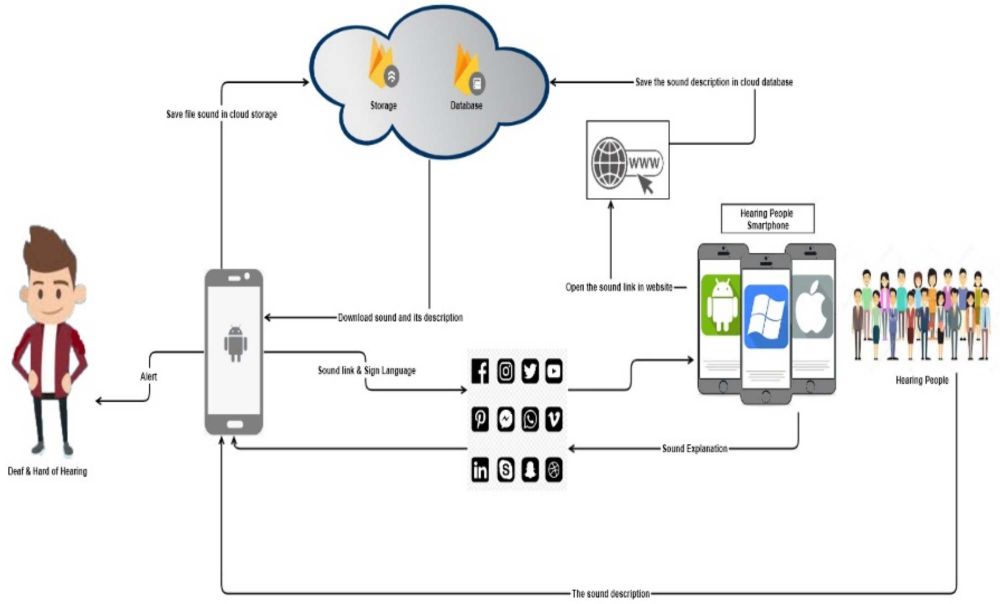
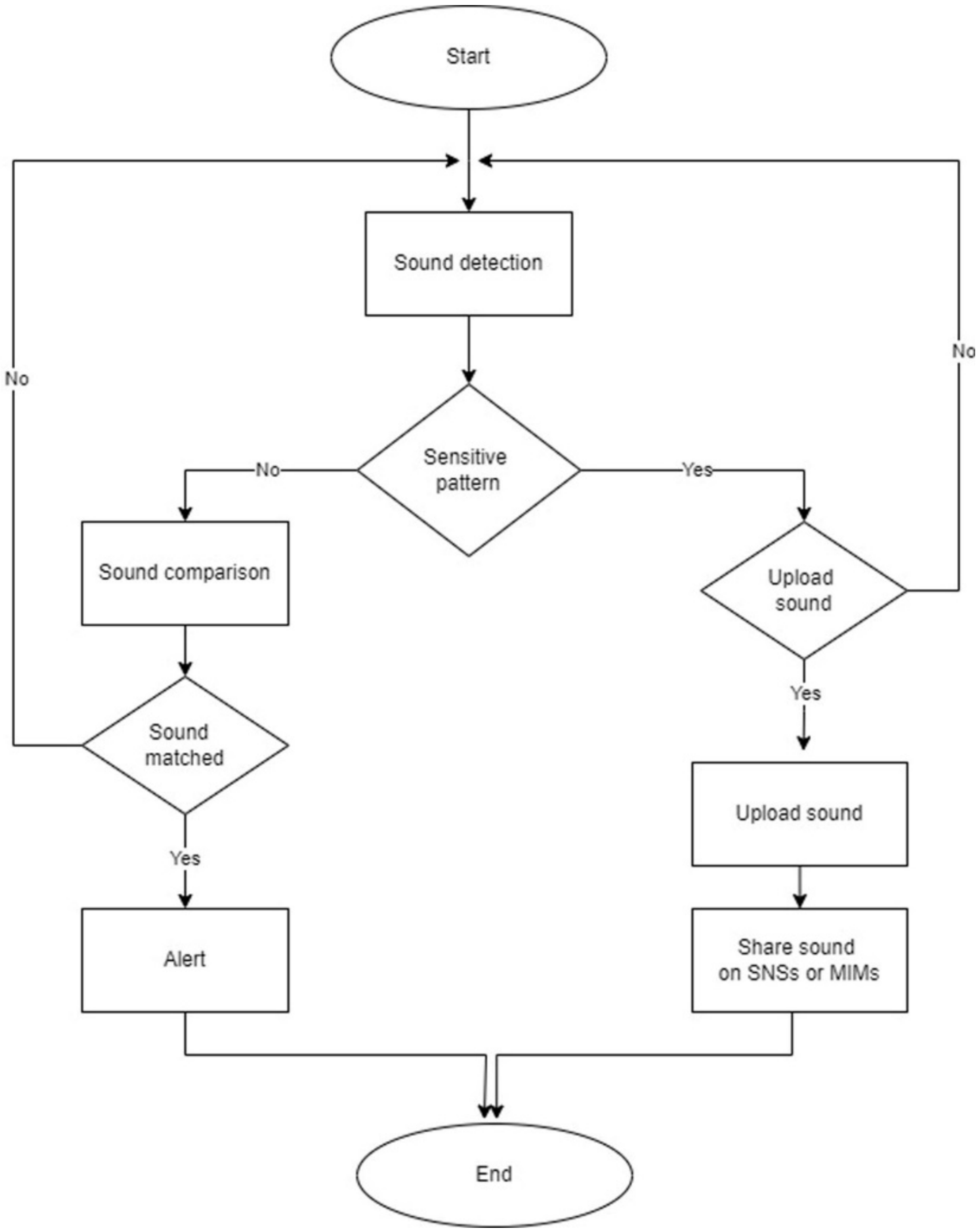


Figure 3.4:

A flow chart that describes steps to alert the deaf by smartphones.



3.6 AsEar Mobile App Features

The primary features of the AsEar mobile app are given below:

- Automatically record sound snippets.
- Automatically detected the sound.
- Relatives and friends can receive notifications on several operating systems, including Windows, iOS, and Android, without downloading the AsEar mobile app.
- Various vibration patterns are available based on the relevance of the sound.
- Detecting significant noises doesn't require internet access.
- The D/HH can download audio posted to the cloud.
- Teach hearing individuals sign language by emailing photographs from D/HH smartphones.
- Send cloud notifications to D/HH smartphones.

3.7 User Involvement

This study used Agile, an iterative development model technique that offers a flexible and adaptive approach to software development, allowing the team to create high-quality software progressively and iteratively while involving the user in each iteration (Ludi, 2023). During the design and development stages, the user experience method was used to assess users' perceptions and sentiments about the application's value, allowing for the extraction of a thorough set of criteria. During the initial meeting, two specialists and four D/HH were shown a low-fidelity prototype of AsEar mobile app at the deaf centre in Sabha, Libya, in order to obtain comments and suggestions during the development stages. The authors, using a low-fidelity prototype, were able to manually record the sound and upload it to cloud storage. During the second meeting, the D/HH and experts provided feedback and requirements. The software now includes suggestions from D/HH and specialists, such as sign language, varied vibration levels based on the sound detected, and two sorts of patterns. The testing phase demonstrated that the AsEar mobile app architecture created by the authors worked. Many enhancements have been done to obtain the final result, such as building a website to create sound descriptions and retrieving sound.

3.8 Recruitment and Study Design

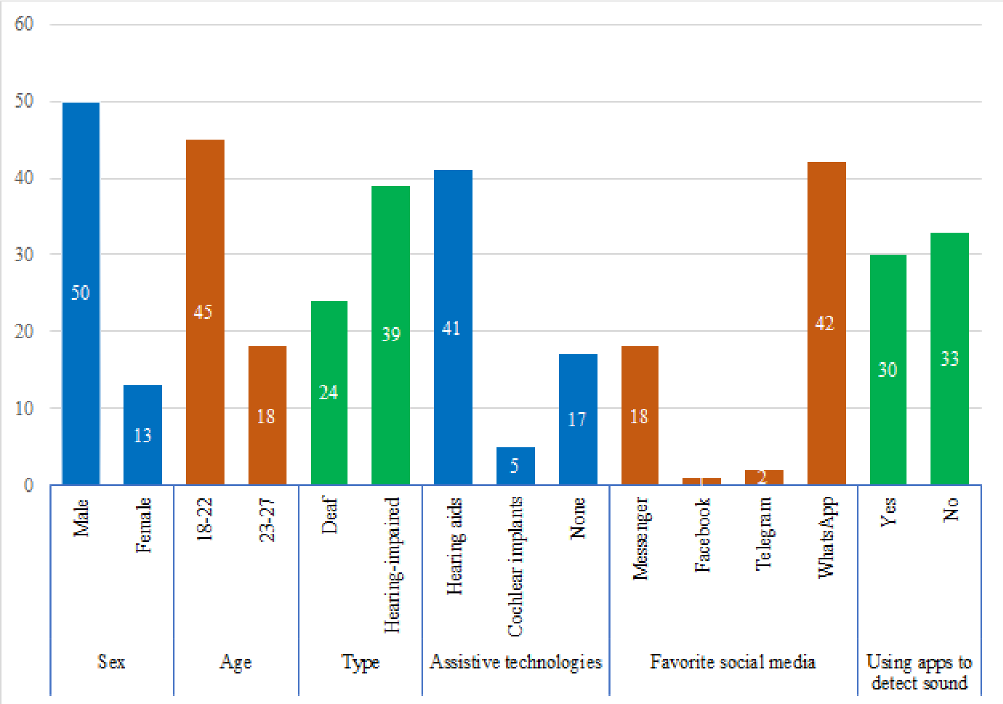
Sixty-three voluntary D/HH individuals were randomly selected from The Sabah Deaf Centre for this investigation. The D/HH participants attended an eighty-minute informational meeting in the conference room. Participants were given a ".apk" file to install on their smartphones during the session. Two sign language experts explained the use of the AsEar mobile app. After three weeks of use, it was important to determine whether the authors' AsEar mobile application effectively detects sound and bridges the communication gap between D/HH and hearing persons. The experimental study employed a mixed-methods approach to use and evaluate the app's efficiency by distributing two questionnaires and conducting interviews. This study uses a mixed method to collect both quantitative and qualitative data. Incorporating the following approaches, a design-based research model was used for the mobile application of the study for people with DDH. In addition, the usability of AsEar mobile app was evaluated using SUS tests. In addition, the semi-interview method was used to collect users' opinions about the performance of the developed mobile app.

3.8.1 Participants

Six volunteers with experience creating mobile applications evaluated and tested the final version of the AsEar mobile app side by side with 63 D/HH participants. Figure 3.5 depicts the demographic features and preferences of 63 D/HH who participated in the study. 50 participants were male, while 13 were female. 45 individuals were between the ages of 18 and 22, with 18 falling between the ages of 23 and 27. 24 of those present were deaf, whereas 39 were hard of hearing. In terms of assistive technologies, 41 participants' utilized hearing aids, 5 used cochlear implants, and 17 did not use any. Participants' preferences for social media or instant messengers were as follows: 18 selected Messenger, one selected Facebook, two preferred Telegram, and 42 chose WhatsApp. Regarding the use of noise detection apps, the results showed.

Figure 3.5:

Displays the demographic details of the participants, their preferred social media platforms, assistive technologies, and sound detection app usage



3.9 Data Collection Tools

Three different methods have been used to collect data from D/HH participants in this study, which are SUS, satisfaction questionnaires, and interviews.

3.9.1 System Usability Scale

The system usability scale (SUS) is regarded as an effective and standard method for distinguishing usable from unusable systems. It was first used by Brooke (1996); it is easy to use and produces accurate results even with small sample sizes (Cheah et al., 2023). The SUS contains 10 items on a 5-point Likert scale, in which five mean, "strongly agree," whereas one means "strongly disagree." SUS can be computed as follows:

First, we get the summation of odd-numbered items, which are

$X = (p1+p3+p5+p7+p9)$

Second, we gather the summation of even-numbered items, which are

Y= (p2+p4+p6+p8+p10)

Then subtract one from X   X0 = (X-1)

Then subtract five from Y   Y0 = (5-Y)

Then we gather the scores X0 and Y0, then multiply them by 2.5.

SUS=(X0+Y0)* 2.5

After that, we get the scale from zero to 100. Table 3.3 shows interpreting and mapping to their adjectival rate.

Table 3.3:

SUS Score Interpretation (Gutiérrez and Rojano-Cáceres, 2020)

SUS score	Adjectival rate
100-85	The best imaginable
73-84	Excellent
53-72	Good
38-52	Fair
24-37	Poor
0-25	The worst imaginable

3.9.2 Satisfaction Scale

The satisfaction scale, adapted from Sadiq et al. (2021), is used to assess D/HH's satisfaction with AsEar mobile app. The questionnaire consists of 10 items and is designed using a five-point Likert scale.

3.9.3 Interview

The semi-restructured interview method was used with sixty-three participants individually to gain deeper insights into their experiences, comments on the app's usefulness, and suggestions for the AsEar mobile app. We were asking them the next questions.

1. Do you like the interface and design of the AsEar mobile app?
2. What is your opinion about teaching hearing people sign language with the AsEar mobile app?
3. What do you suggest for the AsEar mobile app development?

Written notes were used to capture participants' feedback after being translated from sign language.

3.10 Data Analysis Methods

To analyze collected data, we used SPSS for SUS. We divided the items into odd-numbered items (1, 3, 5, 7, and 9) and subtracted one from the score. For even-numbered items, which are (2, 4, 6, 8, and 10) subtract five from the score. Then we gather the scores for all scores, and then multiply them by 2.5. After that, we convert the scale from 0 to 100. Finally, we got our results. Moreover, we use descriptive statistics to measure the mean and standard deviation for each item. To analyze the satisfaction scale, we also use descriptive statistics to measure the mean and standard deviation for each item. For both questionnaires, we test the reliability with Cronbach's alpha. For interview after we got an answer from each person from D/HH, we changed it to good, very good, and excellent, and then we took a general idea of each question and changed it to a percentage.

3.11 Procedure

This section shows the procedure we did to achieve the final AsEar mobile app (see Table 3.4).

Table 3.4:

The stages of AsEar mobile app development

No	Phase
1	Literature review
2	Find gap
3	Select technologies
4	Select group to test
5	Revise and return
6	Final app
7	App used by D/HH three weeks
8	Data collection (evaluation)
9	Analysis data
10	Report

CHAPTER IV

RESULTS

This chapter presents the findings obtained after developing AsEar mobile app and the results of the evaluation performance of the proposed system in sound detection.

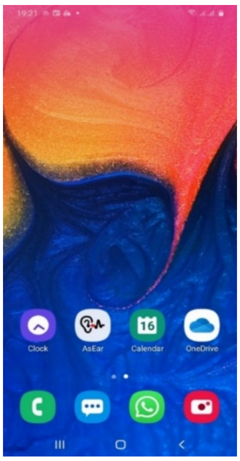
4.1 The Developed Mobile Application (AsEar)

4.1.1 AsEar Interface

After downloading AsEar mobile app on a smartphone, two directories will be created; the first is "AsEar_Recorder" where the recorded file sound will be stored under-name RecordedFile.wav. We use one file to consume less memory. The second directory is "AsEar_Sounds" where all sound files will be saved. For comparison, the "RecordedFile.wav" file will be compared with all sound files in the directory "AsEar_Sounds", we use musicg 1.4.2.2 library for the comparison process, and we use "fingerprintSimilarity" to find the similarity of sound. We defined the similarity to compare the sound to >= 70% if the similarity is equal to or greater than 70%, which means the same sound occurred (Bishop, 2006), then it will retrieve the file name and sound type from the SQLite database, which name is "Sound aware".

Figure 4.1:

Photo of AsEar mobile app icon

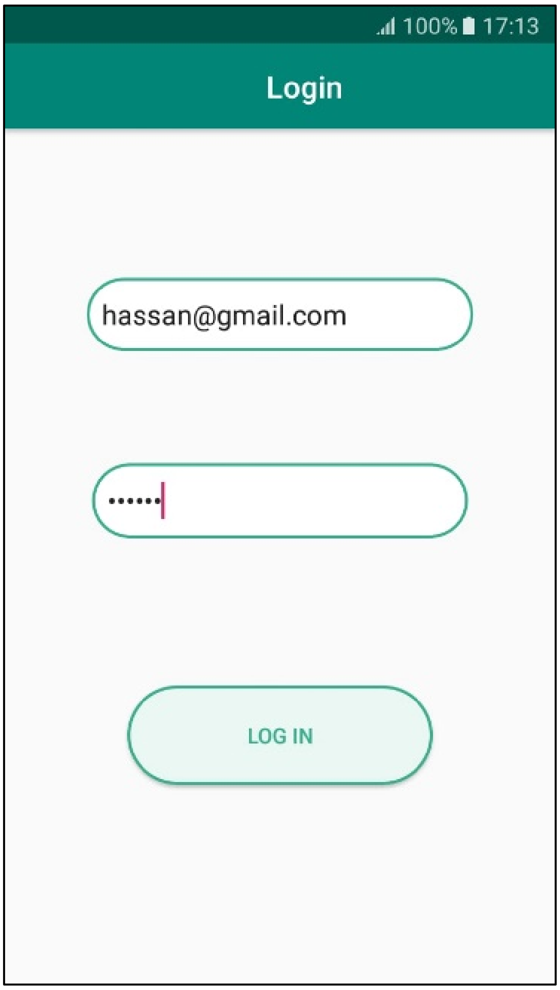


4.1.2 Login Screen

After install, the AsEar mobile app on the smartphone the first screen will appear login screen where the user required to enter the correct Password, which is “123456”, and correct email address, which is “hassan@gmail.com”, when the user enter wrong email address or password the alert message will appear which says please enter correct email address and password. Login screen illustrates in Figure 4.2 after user entered correct email address and password then he/she get to main-menu screen which shown in Figure 4.3.

Figure 4.2:

A snapshot of the login screen

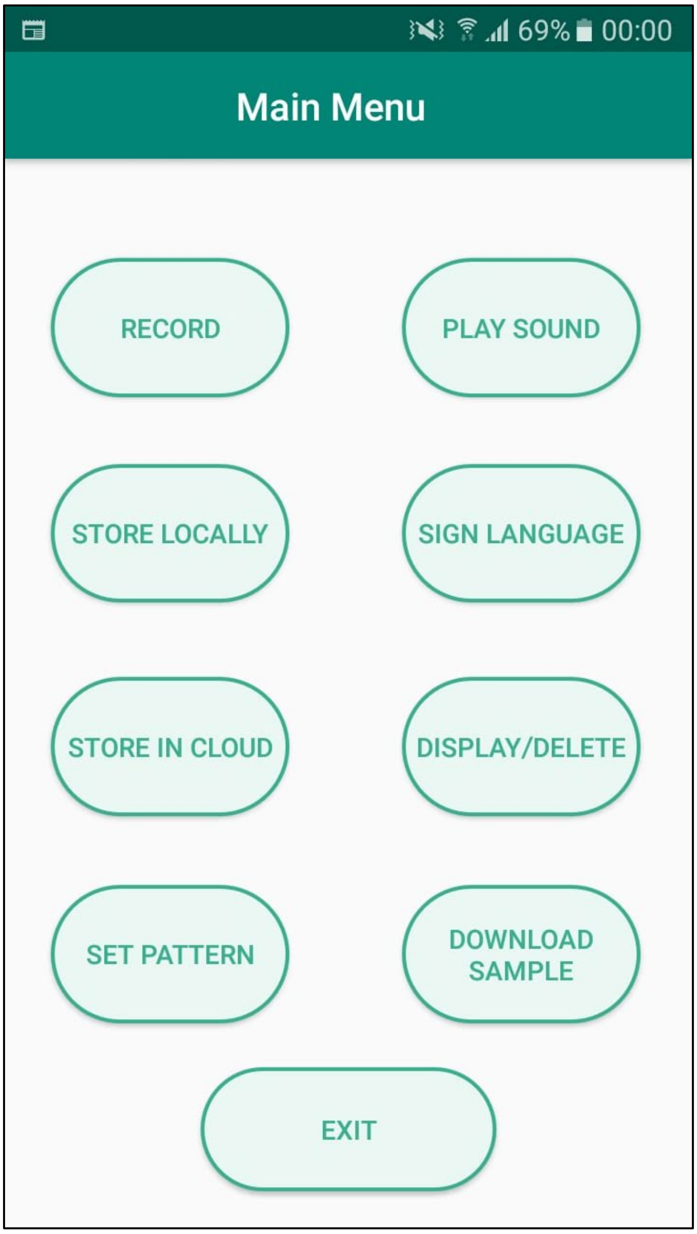


4.1.3 Home Screen

After making sure that, the email is correct and the password is correct, the "Home Screen" will pop up where the user enters to other tasks such as recording, play sound, store locally, store in cloud, display/delete sound, set pattern, download sound from cloud, or exit form app.

Figure 4.3:

A snapshot of the main menu of AsEar mobile app

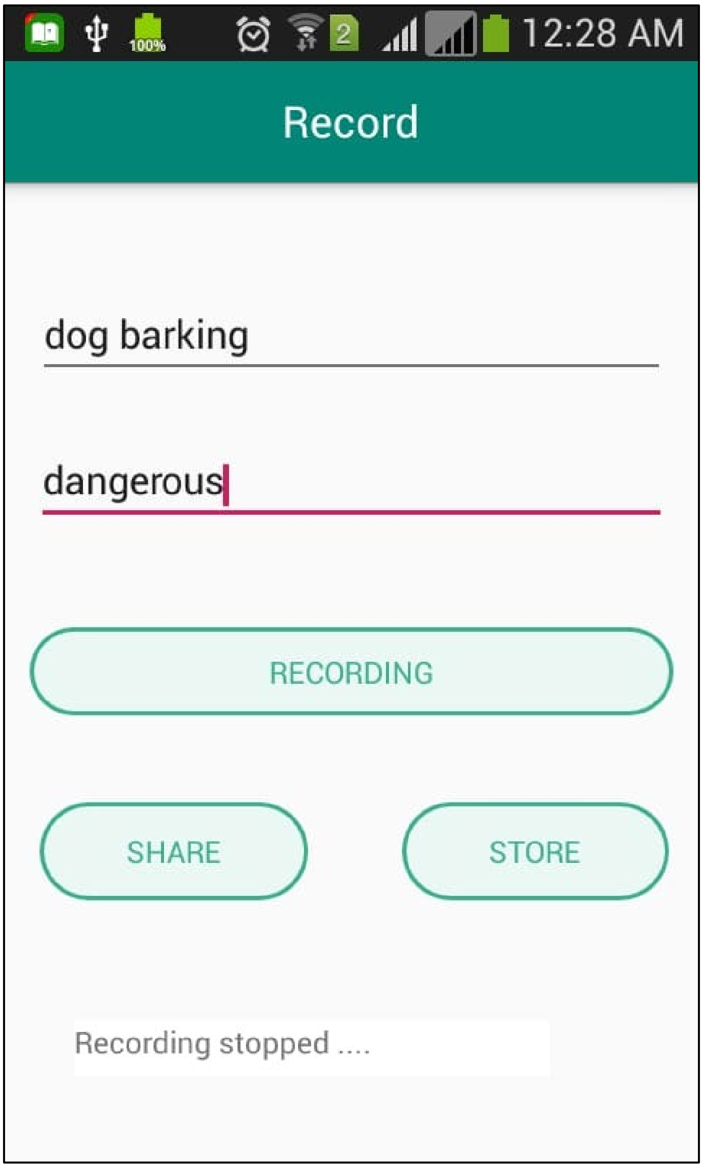


4.1.4 Recording Sound

When the user click on "Record" button from main-menu the screen record will come up where, the user able to record sound by clicking on "RECORDING" button, after record the sound he/she either share the sound by click on "SHARE" button the friend on social media or click on "STORE" button to store the sound on smartphone.

Figure 4.4:

Show record screen



4.1.5 Play Sound

Hearing people, which are the volunteers or relatives of deaf person, can listen to the sound by clicking on "PLAY SOUND" button.

4.1.6 Sign Language

In this choice D/HH will able to send sign language and its explanations to hearing people to increase their knowledge about sign language and easy to communicate with them next time. When D/HH click on sign language button in main menu, he/she will able to send sign language through application.

4.1.7 Display/ Delete

In this section, the D/HH displays all sound files stored in the smartphone as shown in Figure 4.5. Also, D/HH is able to delete an unwanted sound file by clicking on the sound then the sound name will be pasted in the sound name section by a tap on "DELETE" a button confirmation message will appear as illustrates in Figure 4.6 which ask D/HH if he/she sure to delete this sound.

Figure 4.5:

A snapshot of the display/delete screen

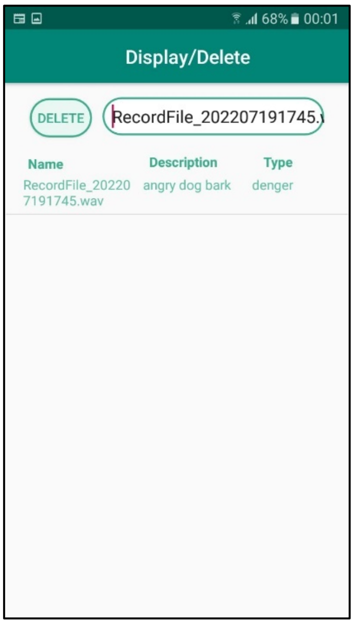
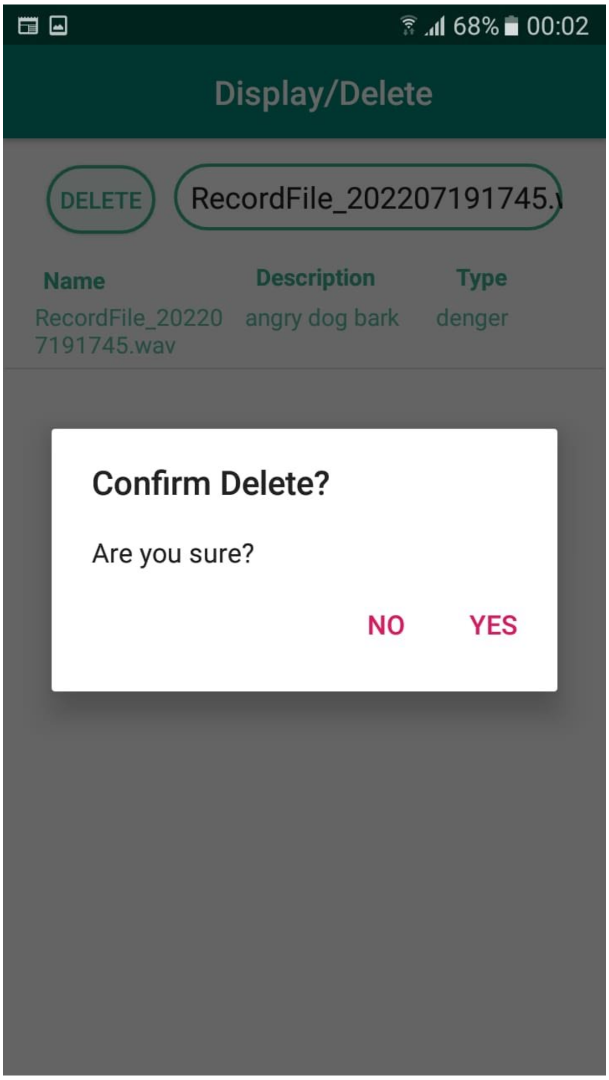


Figure 4.6:

Delete confirmation pop-up menu snapshot

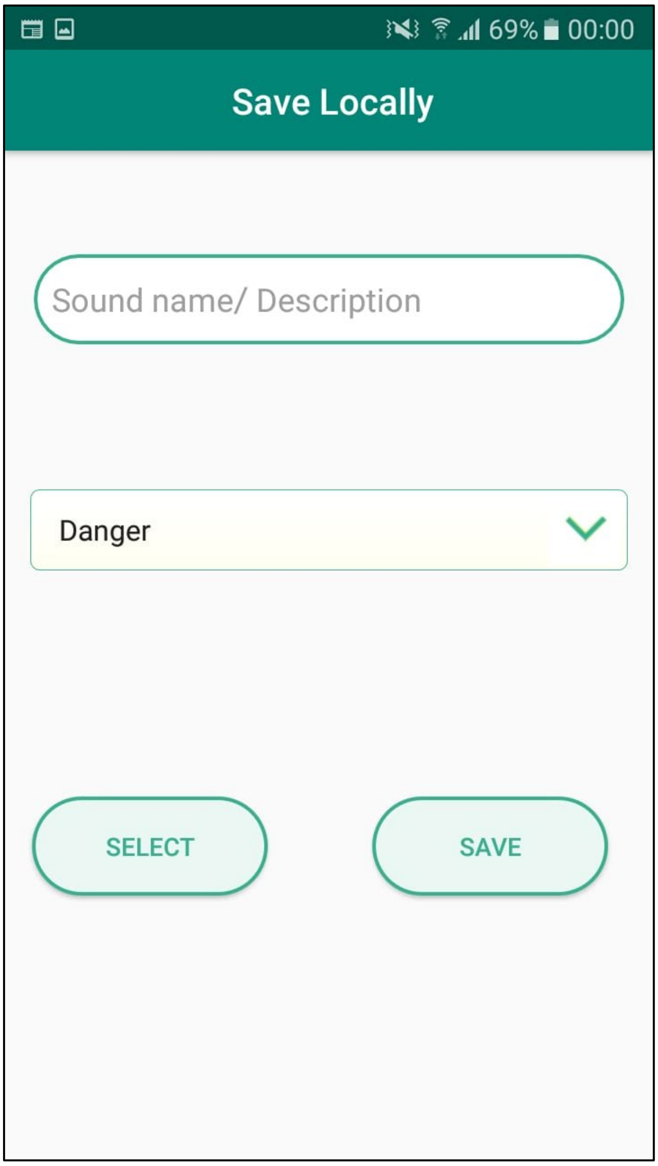


4.1.8 Store Sound Locally

In this task, D/HH need hearing people to listen and write the fact of the sound, first hearing person press "PLAY" button to listen to the sound then he/she able to write the fact of that sound, when the hearing people clicking on locally button the sound and its description will store in the local database.

Figure 4.7:

Save sound file locally

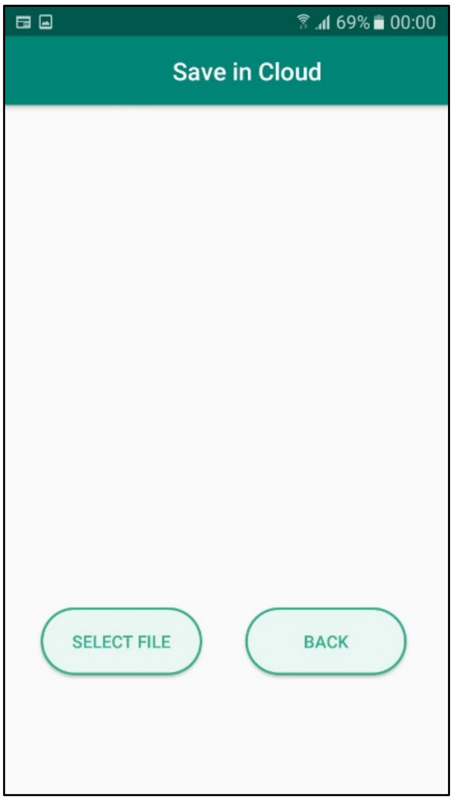


4.1.9 Save Sound in Cloud

D/HH can send the sound file to cloud by two methods, first method from "Saving in Cloud" screen or "Sensitive Alert" screen, "Saving in Cloud" screen as shown in Figure 4 where the D/HH people click on the select button to choose file sound which recorded previously, then clicking on the ok button to send the file. The second method from "Sensitive Alert" screen as shown in Figure 8 during the alerting where the D/HH can click on share button. In both methods the D/HH user sends two URLs through SNSs or MIMs, the first URL is a website that deals with the sound, the second URL is the sound itself, when the relatives/friends navigate to the website as appeared in Figure 4.9, they can paste the sound URL in the specified section, then they listen to sound by clicking on the play button thereafter they write the sound description and type of that sound, afterward press the save button to store data in the cloud database. In addition, relatives/friends can instantly reply through SNSs or MIMs about the detected sound after they listen to it on the website.

Figure 4.8:

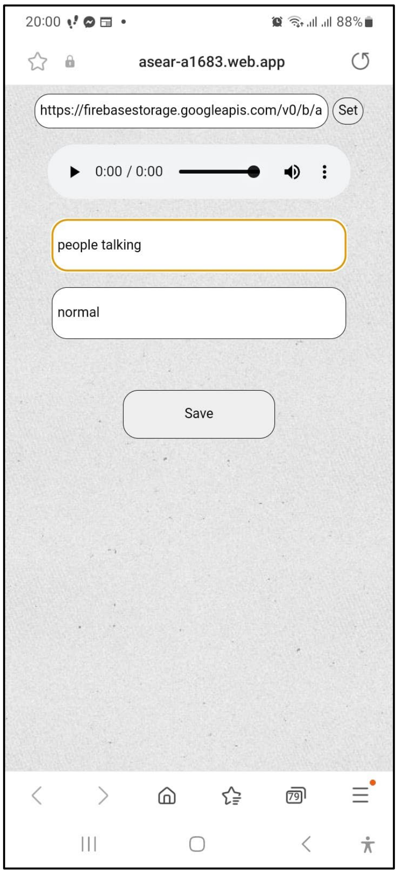
Save sound file in cloud



By click on “SELECT FILE” button on this screen the user can select a file from the smartphone and upload it to the Firebase data storage cloud.

Figure 4.9:

Website to manage sound detected



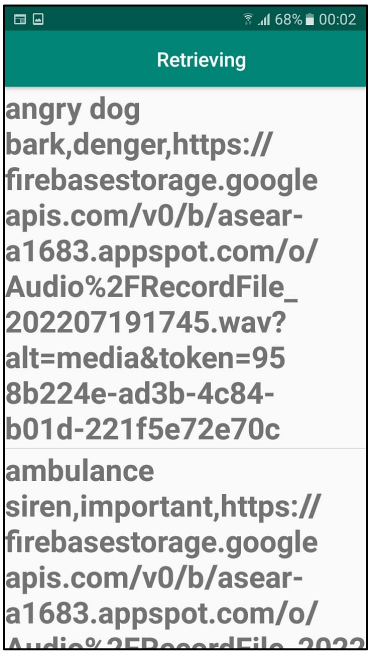
The hearing people will be received two URLs through social media or instant messenger, one of sound and the other for the website that they navigate, first, they copy sound URL. when they clicking on the website link they will navigate to the website first they paste the sound URL then click on “set” button thereafter they can listen to the sound by clicking on “play” button subsequently they can write an explanation about the sound detected by typing the sound name and sound type after that click “save” button to store explanation in real-time database.

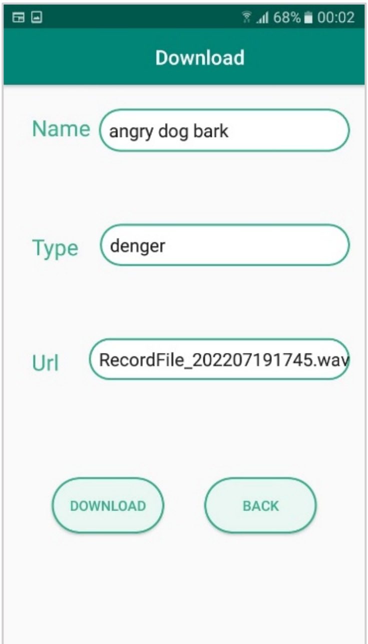
4.1.10 Download Files Sound

With this merit, D/HH can browse all sounds in cloud storage using their smartphones and choose what they want to download as illustrated in Figure 4.10a. After choosing sound Figure 4.10b will appear if D/HH click on "DOWNLOAD" button, the downloaded file will store in local storage and database "SQLite" the D/HH will alert about this sound in future even if there is no internet connection. First, the user should download important sounds from the cloud data storage to be alert about the important sound events.

Figure 4.10:

Download sound file from cloud to local SQLite database





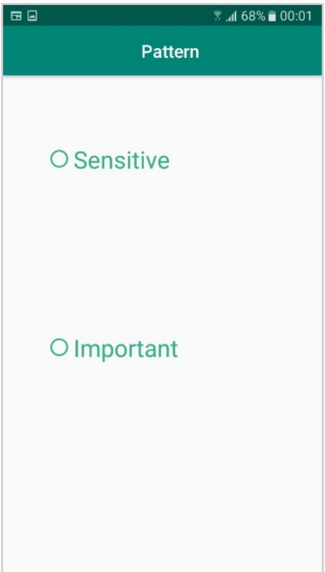
(a) Retrieve all sounds **b)** Download the chosen file from the cloud

4.1.11 Pattern level

To extend battery life, we use two different patterns, the sensitive pattern which is the default pattern that allows users to detect most sound occurring around the D/HH, the normal pattern for detecting important sounds to the D/HH people. In other words, pattern limited to detecting files sound which already stored in smartphone memory, this means the smartphone's screen will be switched off most times which contributed to long battery life.

Figure 4.11:

Pattern type



4.1.12 Alerting

Alerting depends on the pattern when the D/HH set the normal pattern, subsequently, the detecting process will be restricted, when the detected sound matches with the stored sound, the alerting screen will appear with an explanation and vibration to warn D/HH about the detected sound, as shown in Figure 4.12 detected sound was dog barking. On another hand, when the D/HH set the sensitive pattern where the device able to detecting all sound events when a new sound detected by a smartphone microphone the alert screen as shown in Figure 4.13 will pop up which allows the D/HH to upload the sound file to the cloud and share in on SNSs or MIMs by clicking on the "SHARE" button or clicking on cancel button to finish the screen.

Figure 4.12:

Alert when the device detects stored sound

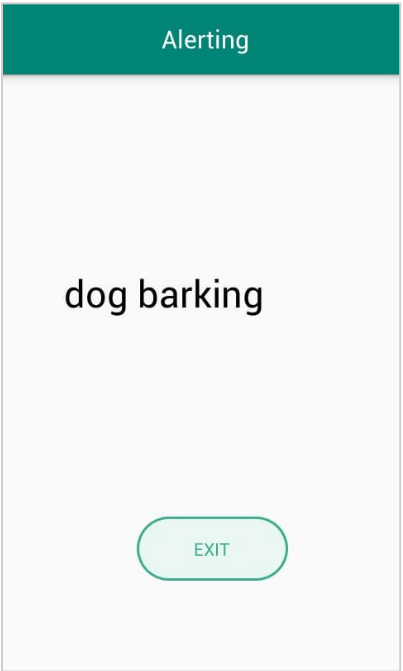
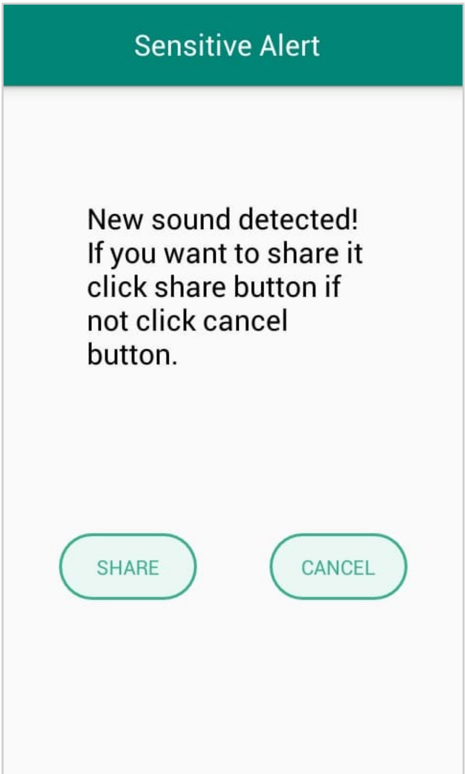


Figure 4.13:

Alert when the device detects non-stored sound

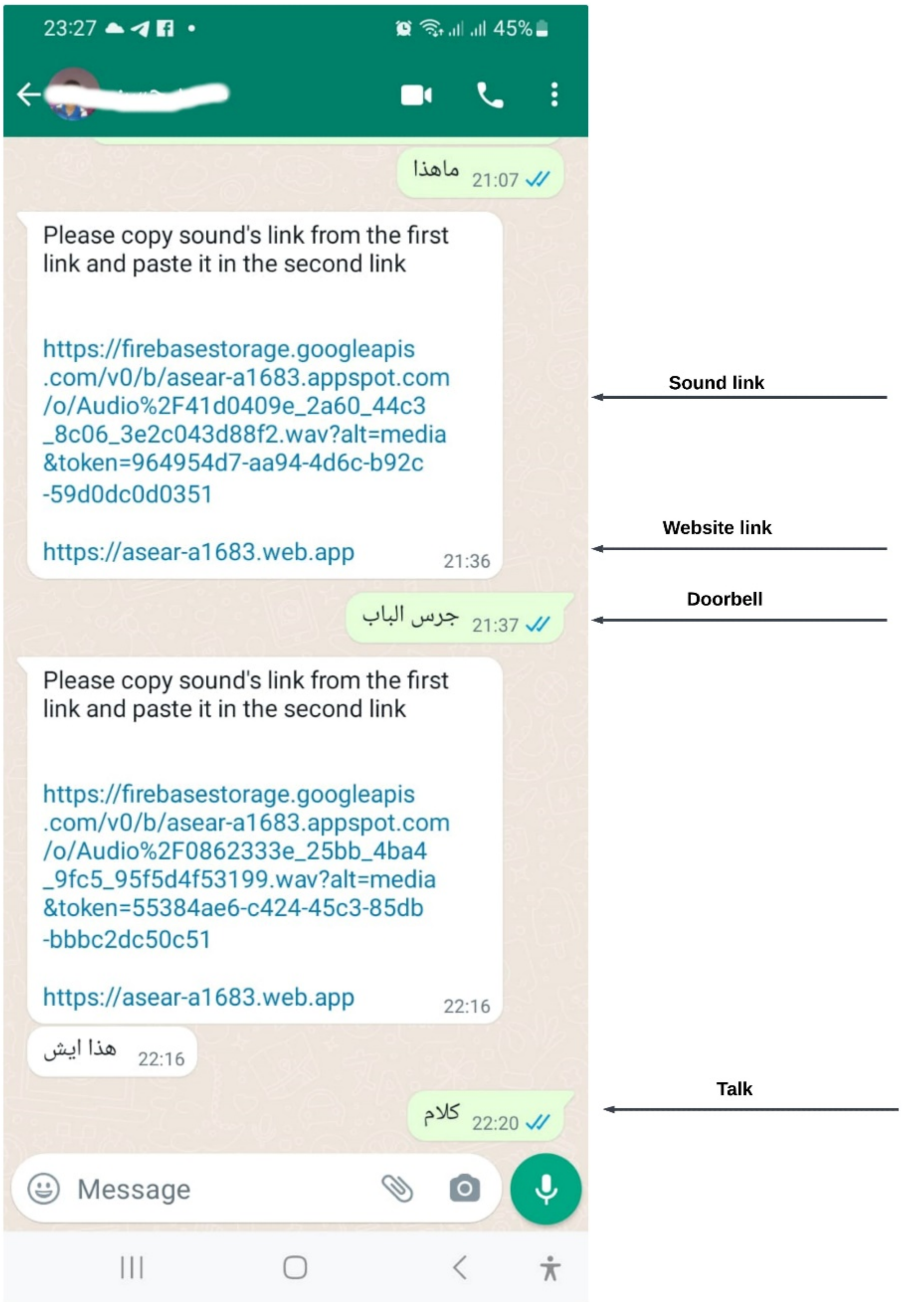


4.1.13 Share on Social Media

When the user presses the SHARE button, he/she can share it on SNSs or MIMs; in this case, use share it on WhatsApp.

Figure 4.14:

Share detected sound on WhatsApp.

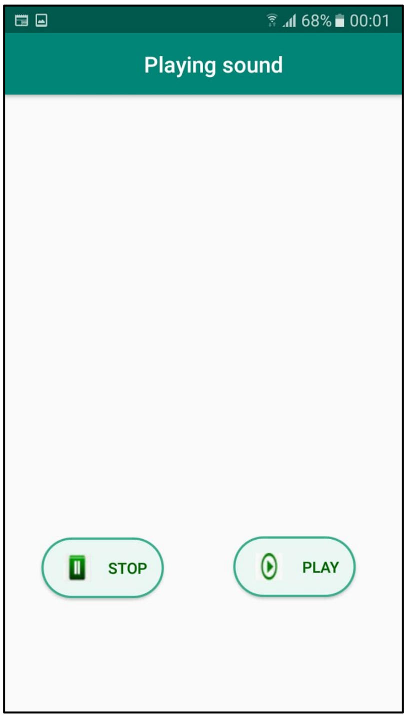


4.1.14 Play Sound

When the user clicks on the play sound button screen playing sound will appear which is shown in Figure 4.15. The hearing person can listen to sound by clicking on the play sound button to know the sound type.

Figure 4.15:

Playing recorded sounds



4.1.15 Exit Button

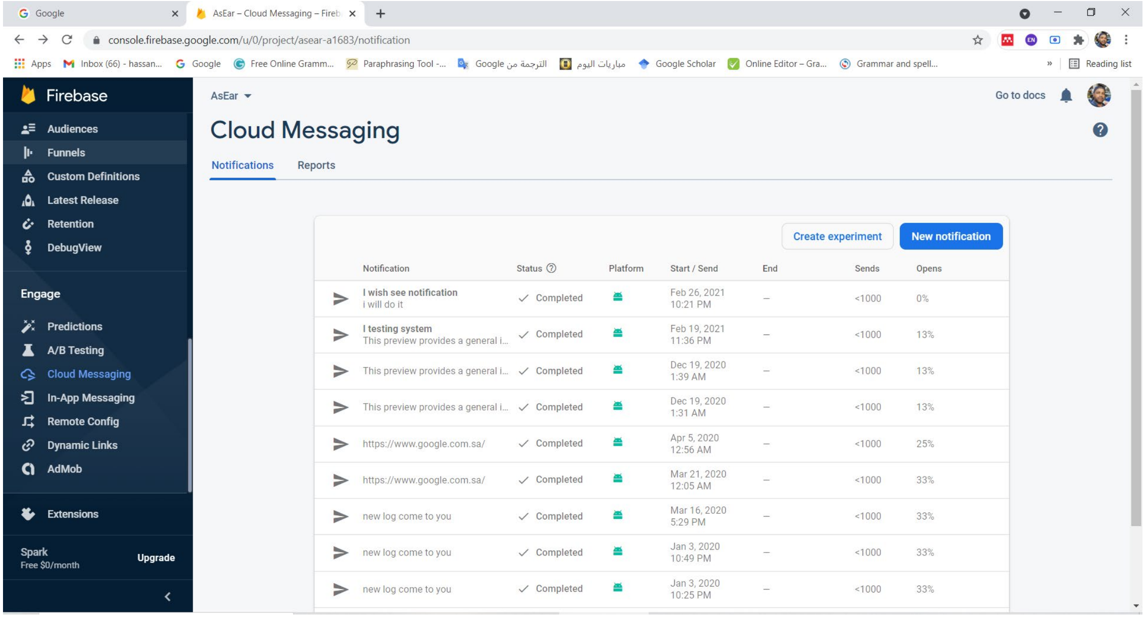
After everything is done the patient can then click on “Exit button” on the home screen to close AsEar mobile application on his/her smartphone.

4.1.16 Sending Notifications

The AsEar mobile app users can receive notifications from Firebase Cloud Messaging, which is useful in general, disasters, or in public events.

Figure 4.16:

Notification sending to D/HH by stakeholders



4.2 Evaluation of the Developed Mobile Application (AsEar)

It was necessary to determine whether the AsEar mobile application developed by the authors is an adequate tool to more actively involve the deaf in dialogues with hearing people on social media. Furthermore, in order to ascertain which topics needed attention and improvement. Two questionnaires were distributed, and a semi-constructed interview was conducted to evaluate the app's performance and design.

4.2.1 Usability Test Results

The System Usability Scale (SUS) has been used to assess the usability of the AsEar mobile app among users. SUS is a rapid and reliable tool that offers an individualized view of the user's usability of a system. Participants in the SUS rate how much they agree with each statement on a five-point Likert, comprising ten items in total. We have used the standard SUS questionnaire with a change of the "system" word to the "AsEar" word in each statement in the original questionnaire. D/HH users might use the app's design to record sound examples for training purposes. We assessed usability through participant training, use of the AsEar mobile app, and their qualitative input. By accurately recording, detecting, uploading, downloading, and categorizing samples, each participant was able to use the software. Cronbach's alpha (α) was utilized to assess the reliability test, which was 0.807. Data from 63 D/HH participants were collected and analysed using the SPSS program for the SUS, which scored 78.25 out of 100 as indicated by Aini and Khasanah (2023), which suggests "perfect usability". The usability test results show that the developed mobile app's performance is acceptable and usable by D/HH people. Figure 4.17 depicts the interpretation of the SUS score measurement.

Figure 4.17:

Illustrates SUS score classification (Aini & Khasanah, 2023)

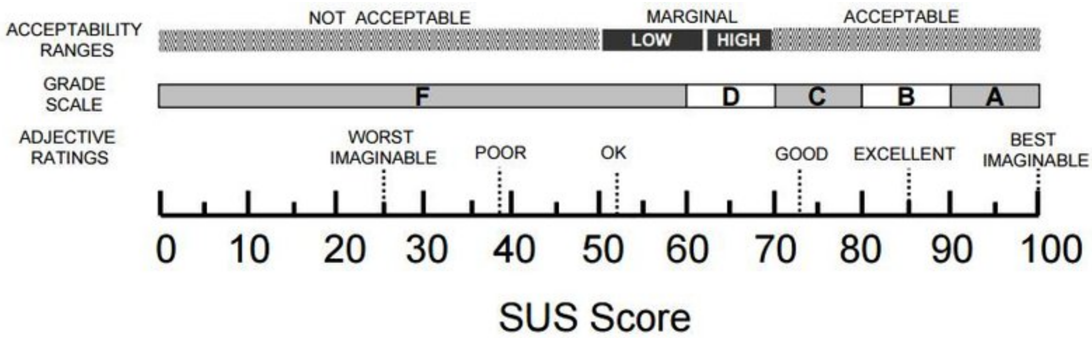


Table 4.1:

SUS Score

ID	SUS1	SUS2	SUS3	SUS4	SUS5	SUS6	SUS7	SUS8	SUS9	SUS10	SUS Score
P1	5	2	5	1	4	2	5	3	5	3	82.50
P2	5	1	4	3	5	1	5	3	5	3	82.50
P3	2	1	4	1	4	2	4	1	4	1	80.00
P4	4	1	4	1	4	2	4	1	4	1	85.00
P5	3	3	5	2	5	1	5	3	4	3	75.00
P6	5	2	4	2	4	2	4	3	5	3	75.00
P7	4	2	4	1	4	2	5	1	4	1	85.00
P8	4	1	4	3	5	2	3	1	5	1	82.50
P9	5	2	5	3	5	2	5	3	4	3	77.50
P10	4	3	5	2	4	3	4	2	4	2	72.50
P11	5	3	4	1	4	1	4	2	4	2	80.00
P12	3	3	4	2	4	2	4	1	4	1	75.00
P13	1	2	1	1	3	1	1	1	1	1	52.50

P14	2	2	4	2	5	1	5	1	2	1	77.50
P15	4	2	5	1	4	1	4	1	2	1	82.50
P16	4	1	4	2	5	1	4	3	5	3	80.00
P17	5	1	4	3	5	1	5	3	5	3	82.50
P18	3	1	4	1	4	2	4	1	4	1	82.50
P19	4	1	4	1	4	2	4	1	4	1	85.00
P20	4	3	5	2	5	1	5	3	4	3	77.50
P21	5	2	4	2	4	2	4	3	5	3	75.00
P22	4	2	4	1	4	2	5	1	4	1	85.00
P23	4	1	4	3	5	2	3	1	5	1	82.50
P24	5	2	5	3	5	2	5	3	4	3	77.50
P25	4	3	5	2	4	3	4	2	4	2	72.50
P26	5	3	4	1	4	1	4	2	4	2	80.00
P27	3	3	5	2	4	2	4	1	4	2	75.00
P28	1	2	4	1	4	1	5	1	1	1	72.50
P29	2	2	4	2	5	1	5	1	2	1	77.50
P30	4	2	5	1	4	1	4	1	2	2	80.00
P31	5	2	5	1	4	2	5	3	5	3	82.50
P32	5	1	4	3	5	1	5	3	5	3	82.50
P33	2	1	4	1	4	2	4	1	4	1	80.00
P34	4	1	4	1	4	2	4	1	4	1	85.00
P35	3	3	5	2	5	1	5	3	4	3	75.00
P36	5	2	4	2	4	2	4	3	5	3	75.00
P37	4	2	4	1	4	2	5	1	4	1	85.00
P38	4	1	4	3	5	2	3	1	5	1	82.50
P39	5	2	5	3	5	2	5	3	4	3	77.50
P40	4	3	5	2	4	3	4	2	4	2	72.50
P41	5	3	4	1	4	1	4	2	4	2	80.00
P42	3	3	4	2	4	2	4	1	4	1	75.00
P43	1	2	1	1	3	1	1	1	1	1	52.50
P44	2	2	4	2	5	1	5	1	2	1	77.50
P45	4	2	5	1	4	1	4	1	2	1	82.50
P46	4	1	4	2	5	1	4	3	5	3	80.00
P47	5	1	4	3	5	1	5	3	5	3	82.50
P48	3	1	4	1	4	2	4	1	4	1	82.50
P49	4	1	4	1	4	2	4	1	4	1	85.00
P50	4	3	5	2	5	1	5	3	4	3	77.50
P51	5	2	4	2	4	2	4	3	5	3	75.00
P52	4	2	4	1	4	2	5	1	4	1	85.00
P53	4	1	4	3	5	2	3	1	5	1	82.50

P54	5	2	5	3	5	2	5	3	4	3	77.50
P55	4	3	5	2	4	3	4	2	4	2	72.50
P56	5	3	4	1	4	1	4	2	4	2	80.00
P57	3	3	5	2	4	2	4	1	4	2	75.00
P58	1	2	4	1	4	1	5	1	1	1	72.50
P59	2	2	4	2	5	1	5	1	2	1	77.50
P60	4	2	5	1	4	1	4	1	2	2	80.00
P61	1	2	4	1	4	1	5	1	1	1	72.50
P62	2	2	4	2	5	1	5	1	2	1	77.50
P63	4	2	5	1	4	1	4	1	2	2	80.00
Average											**78.25**

Moreover, all the developed mobile app responses were accepted as assistive technology for sound awareness and the platform's ability to communicate sound on social media and instant messengers with greater precision, as well as engage the deaf in written language implications. Furthermore, the responses of the participants show that the training procedure was typically simple and that the alerts were adequate. All participants agreed that they would find this kind of app beneficial and said they were likely to use it. Share on social media and all sounds on the cloud were among the top two features that users enjoyed most about the app. Moreover, the result shows that most of the participants provide positive feedback on the usability of the AsEar mobile app on social media and mobile messengers. One of the major highlights from the participants is that the application can be used as a supplementary teaching and learning tool for people who are deaf and wish to learn written language anytime and anywhere.

It can be seen from Table 4.1 that D/HH users giving low scores (1 to 2) to negative statements about the developed mobile app can be seen as a positive indicator of the system's quality. Similarly, the fact that users rated positive statements about the app between 3 and 4 reflects their satisfaction with the system. These results highlight that user satisfaction with the system's usability confirms the application’s usability.

Table 4.2:

D/HH Users' Opinions on the App's Usability

N	Item Question	Mean	Std. Deviation
1	I think that I would like to use this AsEar frequently	3.70	1.227
2	I found the AsEar unnecessarily complex	1.97	.740
3	I thought the AsEar was easy to use	4.24	.756
4	I think that I would need the support of a technical person to be able to use this AsEar	1.75	.761
5	I found the various functions in this AsEar were well integrated	4.33	.539
6	I thought there was too much inconsistency in AsEar	1.60	.610
7	I would imagine that most people would learn to use AsEar very quickly	4.25	.842
8	I found the AsEar very cumbersome to use	1.76	.911
9	I felt very confident using AsEar	3.70	1.240
10	I needed to learn a lot of things before I could get going with AsEar	1.84	.884

4.2.2 Satisfaction Test Results

The satisfaction questionnaire was adapted from Sadiq et al. (2021) with changes in the items to match the study objective. Table 2 shows the results of the satisfaction questionnaire items by presenting the mean and standard deviation for each item. The results of the satisfaction questionnaire show high reliability and internal consistency, as Cronbach's alpha value reached 0.805.

It can be observed from Table 4.2 that the average user ratings for most items are above 4.00, except for one item. This result can be interpreted as an indication that users are satisfied with the developed mobile application. Only the 4th item "*I am satisfied with the quality of sound detected by the AsEar mobile app* (Mean=3.97, SD=.761) received a score below 4. This indicates that further work on sound detection in the developed application is needed, and we will continue to put effort into improving user satisfaction in this area.

The highest score was obtained from the 7th item "*I can easily recognize alerts through the AsEar mobile app"* (Mean = 4.48, SD=.618). The fact that alerts caused by surrounding sounds are perceived thanks to the developed mobile application can be interpreted as the application achieving its intended goal.

The second-highest score was obtained from the 8th item "*The AsEar mobile app is convenient to use anytime and anywher*e" (Mean=4.40, SD=.555). D/HH individuals may not always have someone by their side to assist or support them. However, they need to gather information about their surroundings to carry out essential activities. The analysis of the collected data revealed that, thanks to the developed mobile application, D/HH individuals can receive assistance whenever they need information, regardless of their location. This demonstrates that the desired goal has been achieved—developing an application that can assist D/HH individuals.

Consequently, the seventh and eighth items show the highest values, providing evidence of the importance of recognizing alerts and the ability to use the application anywhere.

Table 4.3:

The scale of D/HH's satisfaction

No	Items	Mean	Std. Deviation (SD)
1	I consider the sound-sharing feature on the AsEar mobile app to be highly important.	4.11	.650
2	My hearing friends frequently engage with the sound I share through the AsEar mobile app.	4.30	.586
3	I found the download feature on the AsEar mobile app crucial.	4.29	.682
4	I am satisfied with the quality of sound detected by the AsEar mobile app.	3.97	.761
5	My written language skills have improved after using the AsEar mobile app.	4.02	.635
6	The AsEar mobile app encourages me to communicate with hearing people.	4.25	.718
7	I can easily recognize alerts through the AsEar mobile app.	4.48	.618
8	The AsEar mobile app is convenient to use anytime and anywhere.	4.40	.555
9	I am highly satisfied with the development of the AsEar mobile app.	4.13	.707
10	I am likely to recommend AsEar mobile app to my friends.	4.19	.644

5.2 Participants' Opinions on the Developed Mobile App

When considering the interview responses, it was overwhelmingly evident that a consensus emerged in favor of an application architecture that fosters both effective detection and seamless communication. The participants, spanning a diverse range of perspectives, unanimously endorsed the idea. Remarkably, the application left a positive impression on the majority of respondents.

- ***Do you like the interface and design of the AsEar mobile app?***

Overall, the design received favorable reviews for the developed mobile app's overall appearance and feel. Participants responded favorably to the presentation's aesthetics, which included the colors, typography, and organization. One of the attendees mentioned how simple it is to utilize the log in to access the AsEar mobile app. The font was quite useful. All participants praised the developed mobile app's overall look and feel, praising the colors and how clean and polished it appeared. The colors were practical and consistent. Size and placement of the buttons were correct. The main menu's buttons clearly point users to screens. One of D/HH reported she could hear the unidentified sound on the recording screen, which required hearing individuals to hear distinct noises otherwise. In addition, Paly sound screen I got help from my hearing friend to listen to the sound and save sound information. Also, Store locally screen I got help from my hearing friend to listen to the sound and store sound in my smartphone. First download screen, one of D/HH stated it is nice to check all sounds stored in the cloud about the design he said mixed sound names, explanations, and URLs.

Another participant mentioned that they used their hearing friend's help to store the sound in the cloud on the Store in Cloud screen. Easy to switch between patterns on the set pattern screen. Most D/HH participants (89%) were satisfied with the AsEar's mobile app design.

Student 1: "Stated the list of sound names was clear."

Student 2: "I can identify the exit button."

Student 3: "Said the download screen needs more space between the sound name and URLs."

Student 4: “Stated that the colors were very coordinated.”

Student 5: “Reported that the font sizes were very coordinated and readable.”

- ***What is your opinion about teaching hearing people sign language with the AsEar mobile app?***

Although the use of sign language consisted of transmitting photographs, the deaf expressed delight after sharing sign language with hearing people using the app. This sharing has resulted in a sense of satisfaction for D/HH members and the good influence of the application on improving comprehensive communication. The majority of D/HH participants (92%) expressed their happiness in using sign language to communicate with hearing friends, even superficially.

Student -1: “Reported that if there is the possibility to add video screen call.”

Student -2: “Stated that if there is the possibility to convert sign language instantly to text.”

Student -3: “reported that if there is the possibility to add converting sign language instantly to emoji.”

- ***What do you suggest for the AsEar mobile app development?***

D/HH opinions and recommendations demonstrate their active participation with the AsEar mobile application and willingness for continual improvement. The D/HH participants have made specific recommendations to improve the sign language screen, such as adding images of their sign language and a live broadcast of sign language. Most D/HH participants (91%) suggested adding more options for using sign language.

CHAPTER V

DISCUSSION

This chapter interprets the results presented in the results chapter, provides a critical analysis of the results, and compares them with the results of the existing literature.

5.1 Discussion

Many D/HH people may just prefer not to utilize sound detection applications, which could be because they are more comfortable with other forms of communication or because they do not encounter situations in which these apps would be beneficial. All participants thought the idea of using a cell phone for alertness was beneficial. The majority of participants were pleased with the operation and the concept of using hearing persons as mediators to determine the nature of the detected sound. According to (Alkhalifa & Al-Razgan, 2018) D/HH, people who use assistive listening devices frequently miss sounds and rely on hearing others to learn about them. The human aspect in recognizing sound nature was extremely precise. Although we have informed D/HH's friends and relatives about the necessity of answering on time, the response may be delayed due to their attitude, mood, connectivity (Cheah et al., 2023; Ensink et al., 2024), or activity. In general, the participants were pleased with the time they spent responding by hearing others. The download capability of the AsEar mobile app was critical for D/HH. They might listen to sounds provided by other users and download those that intrigued them based on their surroundings. The AsEar mobile app allows you to recognize sounds. As D/HH noted, sound recognition was impressive for identifying sounds like doorbells, dog barking, knocking on the door, and so on. However, in some circumstances, the AsEar mobile app appears to be imprecise in recognizing sound, which could be due to noise or audio variances (Kilpatrick & Wolbers, 2020). Writing is becoming an increasingly crucial aspect of social interaction, particularly in the age of texting, emailing, blogging, Facebook posting, and tweeting. Writing allows for easier, more effective communication with a greater number of deaf persons than ever before. Participants reported a considerable improvement in written language after using the AsEar mobile app. Participants maintained their performance levels. No one did worse after using the AsEar mobile app. One of the participants stated that his vocabulary had grown, and he had to look up the definitions of new words on occasion. D/HH likes brief responses from hearing people (Kilpatrick & Wolbers, 2020). The majority of participants said that the AsEar mobile app encourages them to communicate with hearing individuals via SNS and MIMs. D/HH participants commended the AsEar mobile app's ease of recognition of various vibrating patterns as well as the visual notifications it provides. This method is compatible with D/HH patients' sensory preferences (Mathew et al., 2023). D/HH employees underlined the system's convenience in being accessible at any time and from any location. Most participants stated that uploading sounds on social media and messaging apps helped them identify the sounds, therefore they would suggest the AsEar mobile app to their friends. Regarding interview questions, practically everyone praised the application architecture that supports sound detection and communication. D/HH persons were pleased when hearing people utilized their sign language, which can improve communication in general and solve the challenges that D/HH students face when attempting to interact and communicate with hearing people in educational settings (Mohammdi & Elbourhamy, 2023). Furthermore, D/HH users have suggested improvements to the sign language panel. To guarantee technology is actually beneficial and promotes accessibility and quality of life for all users, it should reflect D/HH persons' actual needs, including cultural differences that may lead to various preferences for sound perception, such as varying noises of interest. Some alarm systems fail to consider user-centered design, which involves potential users through an iterative development process (Sætren et al., 2024). Because of this lack of adaptability, potential consumers find them less successful. Certain alarm systems can be costly, inconvenient, or require multiple modifications or a long acclimation time. Additionally, some assistive devices are not socially acceptable among D/HH people (Huang et al., 2023) because they betray their disability status.

Table 5.1:

Comparison between current study and literature

References	Technologies	Evaluation	Research Method	Interface Design Principles	Detection Method	Store Clips of Sounds	User involvement	Sound to be Detected	Results
Jain et al. (2022)	Smart phone	large-scale survey	large-scale survey	Not-Declared	Sound Recognition	Cloud	Not-declared	Important Sounds	Two real-world audio datasets and found a significant, namely a +9.7% gain over the original dataset
Huang et al. (2023)	Smart phone & smartwatch	Evaluated by10 D/HH participants Easy to use	User-Centered Design	Yes	Sound Recognition	locally	Not-declared	Important Sounds	Research suggests the app is effective in raising their awareness of the environment and assisting in daily activities
An et al. (2022)	Bracelets & Deep learning	-	Applied research	Not-Declared	Deep learning	locally	Not-declared	Important Sounds	The execution showed an average rate of 80% in mixed noise

Do et al. (2023)	Feedback-loop auditory recognition system & smart phone	Evaluated by12 D/HH participants	Adaptive Sound Recognition with User Feedback	Not-Declared	Sound Recognitio n	locally	Not-declared	Important Sounds	The system achieves a substantially higher accuracy of 14.6%
Chin et al. (2023)	Wearable device	-	Wearable Edge Sound Recognition System	Not-Declared	Sound Recognitio n	locally	Not-declared	Alarm Sounds	In the online style, 95.2% accuracy was achieved, while the offline style achieved 97.1% accuracy
Asakura (2023)	Augmented Reality (AR)	-	Augmented Reality Sound Visualization System	Not-Declared	Sound Recognitio n	locally	Not-declared	Important Sounds	The results indicated that daily life in home spaces can be better
Shiraishi et al. (2020)	Deep neural networks based on Smart phone	-	Quantitative Methodology	Not-Declared	Machine learning,	locally	Not-declared	Alarm Sounds	The results indicated that the classification averages were higher than 98% for both deep neural networks and neural networks
Ştirbu et al. (2023)	Smart phone & wearable devices	-	User-Centered Design	Not-Declare	Sound Recognitio n	Not-declared	Not-declared	Alarm Sounds	Important of wearable devices to fade the

									communication issue faced by D/HH people during emergencies
Ramirez et al. (2022)	Computer and deep Learning	-	Deep Learning-Based Siren Sound Identification	Not-Declared	Deep learning,	Locally	Not-declared	Alarm Sounds	The results demonstrated system reached 91 percent accuracy in real-world siren sound detection
Mirzaei et al. (2020)	AR and Smart phone	Evaluated by 20 D/HH participants	Mixed-Methods	Not-Declared	Sound Recognitio n	Locally	Not-declared	Important Sounds	The study showed that D/HH participants were unable to complete a complex task in virtual reality without a EarVR system
This Study	Smart phone with advantages of Cloud computer, SNSs and MIMs.	SUS, satisfaction questionnaire, semi-interview with involved 63 D/HH	Mix-Methods	Yes	Sound Recognitio n	Cloud & locally	Agile method	All Sound	The results demonstrated that D/HH people are satisfied with the app, and it is easy to use.

Table 5.1 presents information comparing similar studies conducted in this research with those in the literature that use mobile technologies. This highlights the originality of this study. It can be seen from Table 5.1 that the detection of sound applications in literature is uncommon, especially in smartphones, making it very difficult to find many studies in the literature that are similar to ours. In this study, the advantage of using a cloud computer was obvious, where D/HH can browse all sounds in cloud storage using their smartphones and choose what they want to download, which also reduces the load on their smartphones. Many assistive technologies have been designed for D/HH individuals that have unique benefits, but smartphones are the most widely favoured among D/HH people depending on several factors, such as their affordability and versatility. To ensure the functions of mobile apps run as required and offer remarkable user experiences, many methods can be used, such as SUS and interviews, which have been used in this study.

HAPTER VI

CONCLUSION AND RECOMMENDATION

In this chapter, the study will conclude this thesis by presenting the research conclusions and the contribution of this thesis to healthcare and information technology. Also, present recommendations for researchers, D/HH people, and governments. Moreover, it provides suggestions for future studies.

6.1 Conclusion

The current thesis describes suitable procedures used in developing applications for minimizing issues related with people suffering from deaf and those with hard hearing, whom are mostly characterized with inability of speaking and hearing, whom are mostly not involve in numerous social considerations, educational attainment and job opportunities as compared with their counterparts owing to their disorders. It equally gives an overview used as a communication app, which can serve as a medium that bridge the communication between deaf and normal people. Generally, there is lack of applications used in communication by deaf people with suitable and desired features. More also, there is also lack of Smartphone applications having features that meets all the necessary requirements recommended by various studies in the published technical literature. Therefore, the current study developed a robust smartphone application knowns as AsEar that can be used in detecting sound around people with hearing disabilities, more also, it can be used in sending this sounds via different social networks and instant messengers to their close ones in case they do not recognize the sound so that they interpret it for them. Hence, this can help in harmonizing things and ensure that this disable people are not involve in both educational and social life just like their normal counter parts. Therefore, this will enrich their reading and writing skills so that their relatives and friends will understand the basic principles of the sign language and more importantly brings about a sense of belonging into the society.

6.2 Limitations

- The app only works on Android platform.
- The target group does not suffer from any kind of blindness, also target group know the principles of reading and writing
- Availability of Internet connection to download sounds from cloud computing.
- Smartphone limitations, such as microphone-specific limitations.

6.2 Recommendations

The results of the current study indicate the need for running evaluation research in the future on people with hearing disabilities to determine the perspective of the patients, who are the major consumers and targets of mobile applications. According to this report, the general perspective regarding the consumers' point of view will be more understood, and hence this will provide various recommendations that can be used in improving the quality of the application.

6.2.1 Recommendations for Researchers

More research are required in this field of sound detection by involving new technologies such as artificial intelligence (AI) tools such as machine learning, natural language processing, machine learning algorithms, and deep learning to improve classification accuracy and adapt to real-world scenarios.

6.2.2 Recommendations for Deaf and Hard of Hearing People

Deaf and hard-of-hearing people should be made aware of the importance of technology because it ensures their safety, improves their quality of life, and makes them less dependent on others. The use of technology is very important for the deaf and hard of hearing, especially that which converts sound into vibrations and visual signals at the same time, which can be beneficial for them. It can enhance their awareness of sound events everywhere.

6.2.3 Recommendations for Governments

Governments can promote sound detection for deaf and hard-of-hearing people by encouraging and funding the use of sound detection technologies that provide visual and vibration alerts. They can also support early hearing detection programs to identify early treatment options for hearing loss at an early age. In addition, increasing access to assistive technologies by D/HH would greatly benefit society.

6.3 Future Works

The AsEar mobile app can be developed from these aspects:

- Expand on the current research by analysing sound stored in the cloud (Firebase) using artificial intelligence (AI) tools such as machine learning, natural language processing, machine learning algorithms, and deep learning to improve classification accuracy and adapt to real-world scenarios. Moreover, developing the AsEar mobile app to work on other operating systems, such as iOS.

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APPENDICES

APPENDIX A

Scientific Research Ethics Committee Approval

NEAR EAST UNIVERSITY

SCIENTIFIC RESEARCH ETHICS COMMITTEE

06.04.2023

Dear Hassan Beleid Muamer Mohammed

Your application titled **"Design and Development of a Mobile Application for Deaf and Hearing Impaired People to Create Sound Awarenes"** with the application number NEU/AS/2023/190 has been evaluated by the Scientific Research Ethics Committee and granted approval. You can start your research on the condition that you will abide by the information provided in your application form.

Prof. Dr. Aşkın KİRAZ

The Coordinator of the Scientific Research Ethics Committee

APPENDIX B

Turnitin Similarity Report

FULL THESIS-AFTER JURY

by HASSAN BELEID MUAMER MOHAMMED

Submission date: 05-Feb-2025 03:25PM (UTC+0200)
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NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

DEPARTMENT OF COMPUTER INFORMATION SYSTEM

HELP DEAF AND HARD-OF-HEARING PEOPLE GAIN SOUND AWARENESS THROUGH A MOBILE APPLICATION

PhD THESIS

Hassan Beleid Muamer MOHAMMED

Supervisor

Prof. Dr. Nadire ÇAVUŞ

Nicosia

December, 2024

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APPENDIX C

Java Source Codes
(The Backend Section)

```
public class Retrieve extends AppCompatActivity {
    ListView listView;
    FirebaseDatabase database;
    private    DatabaseReference ref;
    ArrayList<String> list;
    ArrayAdapter<String>adapter;
  public Manip_sound manip;
    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_retrieve);
        this.setTitle("                          Retrieving");
        manip = new Manip_sound();
        listView =(ListView)findViewById(R.id.listView);
        database=FirebaseDatabase.getInstance();
        ref =database.getReference().child("Audio");
        list=new ArrayList<>();
        adapter= new ArrayAdapter<String>(this, R.layout.sound_info, R.id.sound_inf,
list);
        ref.addValueEventListener(new ValueEventListener() {
            @Override
            public void onDataChange(@NonNull DataSnapshot dataSnapshot) {
                for(DataSnapshot ds:dataSnapshot.getChildren()){
                    manip=ds.getValue(Manip_sound.class);

list.add(String.valueOf(manip.getSound()+","+manip.getType()+","+manip.getUrl())
);

            }
```

```
            listView.setAdapter(adapter);
          }
          @Override
          public void onCancelled(@NonNull DatabaseError databaseError) {
          }
        });
        listView.setOnItemClickListener(new AdapterView.OnItemClickListener() {
          @Override
          public void onItemClick(AdapterView<?> parent, View view, final int
position, long id) {
              String selectedFromList =
String.valueOf((listView.getItemAtPosition(position)));
              String names = selectedFromList;
              String[] namesList = names.split(",");
              String name1 = namesList [0];
              String type2 = namesList [1];
              String url3 = namesList [2];
              Intent myIntent = new Intent(view.getContext(), Download.class);
              myIntent.putExtra("name1",name1);
              myIntent.putExtra("type2", type2);
              myIntent.putExtra("url3", url3);
              startActivity(myIntent);
          }
        });
    }
}
```

APPENDIX D

Curriculum Vitae

PERSONAL INFORMATION

Surname, Name	: Hassan Mohammed
Nationality	: Libyan
Date and Place of Birth	: 25 December 1976, Benbya
Marital Status	: Married
Mobile Phone	: +90 05338703588
e-mail	: hassanbeleid1@gmail.com

EDUCATION

Degree	Institution	Year of Graduation
M.Sc.	Department of Computer Systems, the Institute of Applied Sciences, at Near East University	2016
B.Sc.	Department of Systems Programming and Analysis, Faculty of Technical Sciences-Sabha.	1999

WORK EXPERIENCE

Year	Place	Enrollment
2000 –2001	Higher Institute of Science and Technology Wadi Ajal	Head of Computer department
2002	Higher Institute of Science and Technology Wadi Ajal	Tourism representative in the Youth Association
2001- 2006	Higher Institute of Science and Technology Wadi Ajal	Teacher
2005	Higher Institute of Science and Technology Wadi Ajal	IC3 trainer
2006	Higher Institute of Science and Technology Wadi Ajal	ICDL trainer
2006-2011	Higher Institute of Science and Technology Wadi Ajal	Teacher
2006	Germany	Training in Germany

2011-2013	Higher Institute of Science and Technology Wadi Ajal	Head of field training department
2014-2015	Near East University	Presentative of Libyan students at Near East University
2015-2024	Near East University	Teaching at Near East School
2019	Near East University	Lecturer in foundation program at Near East University

FOREIGN LANGUAGES

- Fluent spoken and written English

PUBLICATIONS

- Mohammed, H. B., & Cavus, N. (2024). Utilization of Detection of Non-Speech Sound for Sustainable Quality of Life for Deaf and Hearing-Impaired People: A Systematic Literature Review. *Sustainability*, *16*(20), 8976. https://doi.org/10.3390/su16208976

- Mohammed, H.B.M., Ibrahim, D. & Cavus, N. Mobile device based smart medication reminder for older people with disabilities. *Qual Quant* **52** (Suppl 2), 1329–1342 (2018). https://doi.org/10.1007/s11135-018-0707-8

HOBBIES

- Reading, football, Table tennis, and traveling.

OTHER INTERESTS

Programming Languages, Databases, Data Structures, Information Systems, Mobile Technologies, Management Information Systems, Information Technologies, Information Security, and Artificial intelligence.