End-User Requirements of an Assistive Technology for Profoundly Deaf Parents with Infants

By

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DECLARATION OF ORIGINALITY

I, Zukile Bright Mxhego (213300893), hereby declare that the dissertation for the degree Master of Information Technology is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another University or for any other qualification.

SIGNATURE:

DATE: December 2022

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“It always seems impossible until it's done.” – Nelson Mandela

DEDICATION

I dedicate this work to three people:

My late mother, Zodidi Mxhego

My sister and her daughter, Akhona and Khwezi Mxhego, respectively.

ABSTRACT

As the number of deaf people in the world increases, the amount of parents who are deaf, is also growing. The world is increasingly relying on technology from which deaf parents can, and do, benefit significantly. Deaf parents are able to rely on available technology such as assistive technologies to overcome functional limitations. However, assistive technologies are often abandoned within a short period of time of being acquired. The abandonment of assistive technologies is believed to be due to a lack of proper elicitation of requirements. Therefore, the problem identified in this research is a lack of understanding of end-user requirements of an assistive technology for profoundly deaf parents with infants.

A literature review together with logical argumentation was conducted and applied to identify and recommend a method suitable for eliciting end-user requirements for assistive technologies. Thereafter, an integrative literature review and thematic analysis was done to extract needs and challenges of profoundly deaf parents with infants, and group them according to themes that emerged. Finally, making use of the recommended method and the extracted *needs* and *challenges* of profoundly deaf parents with infants, twenty-eight end-user requirements of an assistive technology for profoundly deaf parents with infants were elicited.

The twenty-eight elicited end-user requirements consist of eighteen end-user requirements that express functions of an assistive technology for profoundly deaf parents with infants, and ten end-user requirements that express an overall goal/objective to be attained by profoundly deaf parents with infants when the assistive technology is designed and developed. To evaluate the elicited end-user requirements, only the eighteen end-user requirements that express functions of an assistive technology for profoundly deaf parents with infants were considered. The evaluation was done by assessing both existing and emerging assistive technologies to understand the comprehensiveness of the eighteen elicited end-user requirements that express functions of an assistive technology for profoundly deaf parents with infants.

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CHAPTER 1

1. INTRODUCTION

Chapter 1 is an introduction to the research project and will describe how the research will be conducted. Chapter 1 provides a background to the research, clearly stating the problem it aims to address, and the objectives to successfully conduct the research. Furthermore, the chapter discusses the methodology, delimitation of the research, and the dissertation structure.

Chapter 1 is structured as follows:

Section	Header
1.1.	Background
1.2.	Research Problem
1.3.	Research Objectives
1.4.	Research Methodology
1.5.	Delimitation
1.6.	Dissertation Structure
1.7.	Conclusion

1.1 Background

An estimated 15% of the world's population consists of disabled people (Shahrestani, 2017). More than five percent of the 15% consists of deaf people (World Health Organization, 2021a). According to Marti and Recupero (2019), about 900 million more people will be affected between 2019 and 2050. Hersh and Johnson (2003, p. 29) categorised deafness as “conductive, sensorineural, mixed, and central” deafness. The categories of deafness are also associated with four main degrees of hearing loss, namely: mild, moderate, severe, and profound hearing loss (Felman, 2018). Each category may result in any of the degrees of hearing loss. Table 1.1 provides an overview of the occurrence and causes of the categorised deafness.

Table 1.1: Categories of Deafness (Felman, 2018; HearCanada, n.d; and Hersh & Johnson, 2003, pp. 29-30)

Category	Occurrence	Cause
Conductive	Occurs when there is a problem with the outer and/or middle ear.	Earwax, glue ear, ear infection, perforated eardrum, malfunction of the ossicles or a defective eardrum.
Sensorineural	Occurs when hair cells in the cochlea/inner ear are damaged.	Long-term exposure to loud noises and age.
Mixed	Occurs when there is a problem in both the inner and outer ear.	Combination of both conductive and sensorineural hearing impairment.
Central	Occurs when there is dysfunction within the pathway of the ear.	Head injury, disease, or tumour.

Being deaf can be challenging in several ways, such as being a deaf parent with an infant (Mohite & Jadhav, 2021). The first two years (0 to 24 month) are an important period between parents and infants to build trust and attachment regardless of the hearing status (Ting, Hao, & Ching-chiuan, 2013). According to Colclasure (2004), it is unnerving to become a deaf parent due to the inability to hear the infant crying or saying

“Mom” or “Dad”. In some cases, deaf parents may not be confident of their mothering abilities or gain social support as there is no special services or programmes targeting at deaf parenting (Ting et al., 2013). Deaf parents sometimes give up their parental rights, because they “felt that their disability would place their infant at a disadvantage in society if they raised the kids themselves” (Ting et al., 2013, p. 3579).

One way of supporting deaf parents with infants is by assistive technologies. Assistive technologies are defined as “items, equipment, or products that can be used to increase, maintain, or improve functional capabilities of individuals with some disability” (Shahrestani, 2017, p. 3). There are various types of assistive technologies which range from software to hardware to improve quality of life. Examples include “everything from eating, mobility, sensory aids, to robotics and computer systems” (Blackburn & Cudd, 2012, p. 193).

One of the models for developing, researching, assessing, and evaluating assistive technologies is the Human Activity Assistive Technology (HAAT) model (Cook & Polgar, 2015). The HAAT model emphasises a human centred approach, where the focus is on a person doing something in a specific context using an assistive technology. Figure 1.1 shows the HAAT model with four components: Human, Activity, Context, and Assistive Technology.

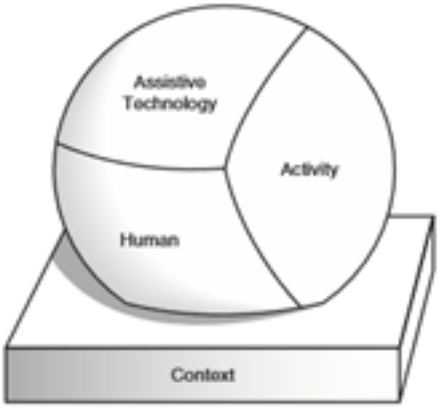

Figure 1.1: HAAT Model (Cook & Polgar, 2015).

Table 1.2 further defines the components of the HAAT model as stated by Cook and Polgar (2015, pp. 9-10), and provides an understanding of their meaning in the context of this research.

Table 1.2: HAAT Model Meaning in Deaf Context

Components	Description	Deaf Context
Human	A body that performs an activity, engage in the community, and uses an assistive technology	A profoundly deaf parent with hearing/deaf infants. Infants are aged 0-23 months (0-2 years) (World Health Organization, 2021b).
Activity	It is "the execution of a task or action by an individual".	A profoundly deaf parent looking after an infant
Context	A more inclusive environment, including social and cultural contexts.	A profoundly deaf parent *independently* looking after an infant in a *home setting.*
Assistive technology	"Any product, instrument, equipment, or technology adapted or specially designed for improving functioning of a disabled person."	Device(s) providing an alert to a profoundly deaf parent about the state of the infant, taking the place of "hearing".

A study done by Newell, Gregor, Morgan, Pullin, and Macaulay (2011) shows that there is a high level of assistive technology abandonment, which Blackburn and Cudd (2012) suggest there is something wrong. Assistive technology abandonment is described as "a situation in which the consumer stops using a device even though the need for which the device has been obtained still exists" (Cook & Polgar, 2015, p. 469). One of the reasons for assistive technology abandonment is a lack of suitable products (Blackburn & Cudd, 2012). Assistive technologies have to meet the users' needs by considering their context or environment (Cook & Polgar, 2015). Therefore, the commercial success of a product is based on robust specification of requirements to fit the purpose and meet users' needs (Blackburn & Cudd, 2012).

1.2 Research Problem

There are several existing assistive technologies available for deaf parents to buy and use for monitoring infants. However, existing assistive technologies were not initially developed for deaf parents with infants (Ting et al., 2013) and are therefore missing important requirements to fit into their context (Lakshmi, Lalitha, Malashree, Mohana Priya, & Singh, 2021). This increases the risk of abandoning the assistive technology by deaf parents. Therefore, the problem this research intends to address is a lack of understanding of end-user requirements of an assistive technology for profoundly deaf parents with infants. Addressing this problem could improve quality of life for both deaf parents and infants.

1.3 Research Objectives

To address the problem stated in section 1.2, the main and sub-objectives of this research are as follows:

Main Objective
To compile end-user requirements of an assistive technology for profoundly deaf parents with infants.

Sub-Objectives
To identify a method for eliciting end-user requirements for assistive technologies.
To extract the needs and challenges of profoundly deaf parents with infants.
To elicit end-user requirements of an assistive technology for profoundly deaf parents with infants.

1.4 Research Methodology

A rigorous process is required to make sure that research is conducted systematically from start to finish, to address the problem identified. Figure 1.2 shows the research process that will be followed to address the problem identified in section 1.2. The legend illustrating the objectives, data collection and data analysis methods, and outputs of the research in Figure 1.2, is shown at the bottom of the diagram.

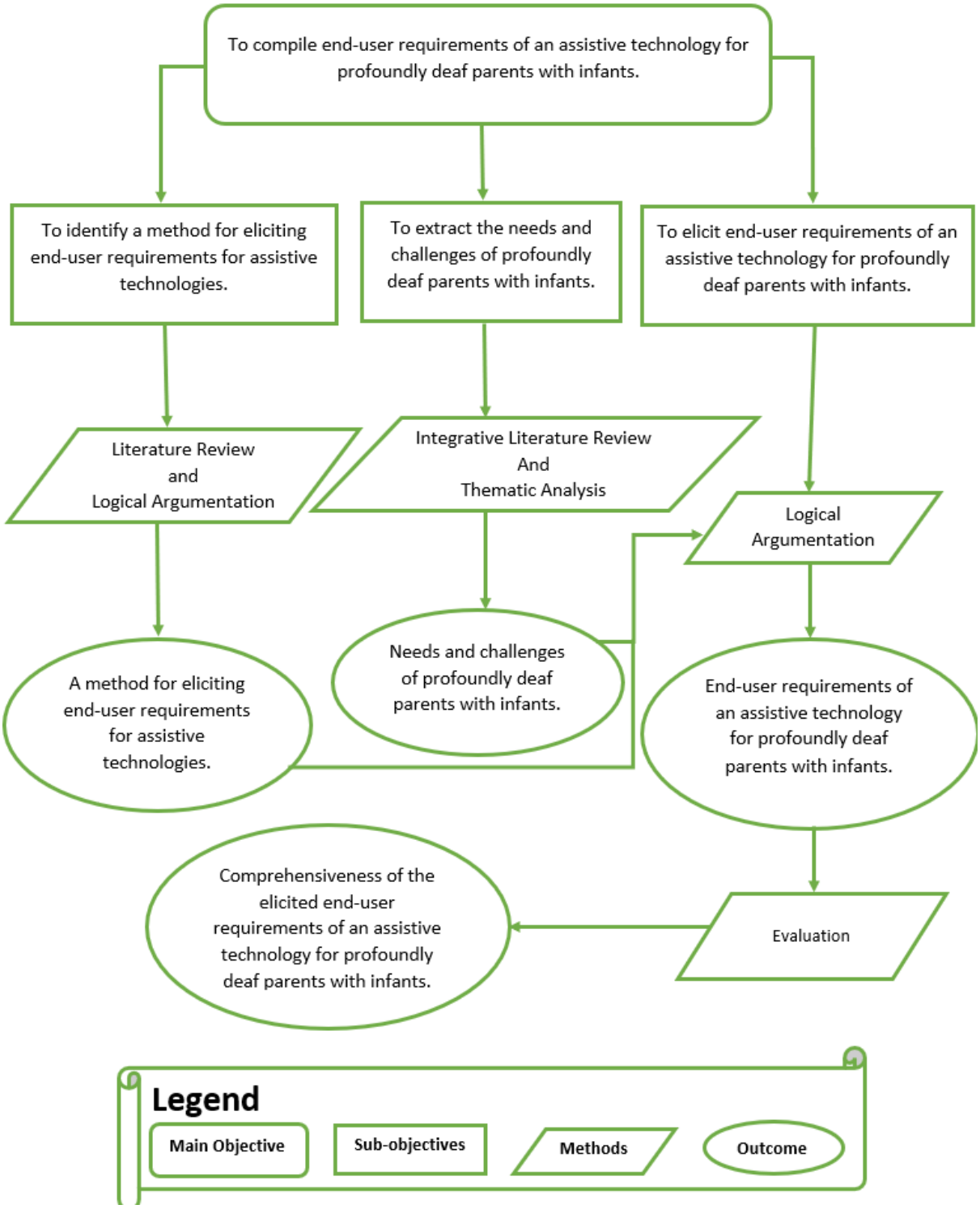

Figure 1.2: Research Process

The main objective of this research is to compile end-user requirements of an assistive technology for profoundly deaf parents with infants. The main objective will be achieved by addressing three sub-objectives. Figure 1.2 illustrates how the research will address the identified problem by showing the objectives, methods of data collection and data analysis, and the output.

The first sub-objective of this research is to identify a method for eliciting end-user requirements for assistive technologies. This objective will be achieved by conducting a literature review and making use of logical argumentation to review available methods and provide recommendations on a suitable method to elicit end-user requirements for assistive technologies. A literature review is a process of collecting, investigating, or reading literature that has been published to keep up to date with the research field (Olivier, 2009). Logical argumentation can be understood by first understanding what argumentation means. Argumentation as quoted from Dung's work from 1995, is described as the ability "to synthesise ideas in arguments, to understand complex statements, to perform scientific reasoning, or to express thoughts" in order to obtain conclusions (Carrera & Iglesias, 2015, p. 510). Therefore, logic argumentation can be defined as the ability to understand, reason, argue, and express thoughts in a logical manner that leads to a particular decision or conclusion.

The second sub-objective of this research is to extract *needs* and *challenges* of profoundly deaf parents with infants. This will be achieved by making use of an integrative literature review and thematic analysis to collect and analyse all the required and relevant data. An integrative literature review is defined as a "distinctive form of research that generates new knowledge about the topic reviewed" (Torraco, 2005, p. 356). Furthermore, Torraco (2005, p. 356) states that an integrative literature review "reviews, critiques, and synthesises literature" to develop new theoretical frameworks and perspectives on new and old topics. When the literature is collected in order to extract *needs* and *challenges* of profoundly deaf parents with infants, this research will make use of thematic analysis to extract and develop themes from the data. Thematic analysis is "a method for identifying, analysing, and reporting patterns (themes) within data" (Braun & Clarke, 2006, p. 79). Furthermore, thematic analysis "can be a method that works both to reflect reality and to unpick or unravel the surface of 'reality'" (Braun & Clarke, 2006, p. 81).

The third sub-objective of this research is to elicit end-user requirements of an assistive technology for profoundly deaf parents with infants. By logistically arguing towards the elicitation of end-user requirements of an assistive technology for profoundly deaf parents with infants, the third sub-objective will make use of the recommended method identified through sub-objective one, and the *needs* and *challenges* of profoundly deaf parents with infants extracted through sub-objective two. The elicited end-user requirements of an assistive technology for profoundly deaf parents with infants will thereafter be evaluated to provide an understanding of their comprehensiveness and to achieve the main objective of this research.

1.5 Delimitation

The data collection for this research took place in a period of hard lockdown during the COVID-19 pandemic; no interaction with the end-users – profoundly deaf parents – conducted.

1.6 Dissertation Structure

The sub-sections below provide a summary of the contents of each chapter:

1.6.1 Chapter 1: Introduction

Chapter 1 focuses on a brief background and understanding of the research. The chapter provides an overview of assistive technology development and abandonment, the problem statement, objectives, methodology, delimitations, and the dissertation structure.

1.6.2 Chapter 2: Requirements Elicitation for Assistive Technologies

Chapter 2 focuses on identifying a method for eliciting end-user requirements for assistive technologies. about the chapter also discusses assistive technologies, the reasons for abandonment of assistive technologies, and the requirements elicitation activity. Furthermore, Chapter 2 will provide recommendations on a suitable method for eliciting end-user requirements for assistive technologies.

1.6.3 Chapter 3: Needs and Challenges of Profoundly Deaf Parents with Infants

Chapter 3 focuses on following a structured approach to extract the *needs* and *challenges* of profoundly deaf parents with infants. The chapter will make use of an integrative literature review and thematic analysis to extract, analyse, synthesise, and document *needs* and *challenges* of profoundly deaf parents with infants.

1.6.4 Chapter 4: End-User Requirements of an Assistive Technology for Profoundly Deaf Parents with Infants

Chapter 4 focuses on eliciting end-user requirements of an assistive technology for profoundly deaf parents with infants. The elicitation activity makes use of the assistive technology requirements elicitation method recommended in Chapter 2 and the *needs* and *challenges* of profoundly deaf parents with infants extracted in Chapter 3, to elicit end-user requirements of an assistive technology for profoundly deaf parents with infants. Furthermore, the chapter will evaluate the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants to determine the comprehensiveness of the elicited set of end-user requirements.

1.6.5 Chapter 5: Conclusion

Chapter 5 will provide a summary of the dissertation by presenting a summary of the research, achievement of objectives, evaluating trustworthiness of the research, research limitations, and recommendations for further research.

1.7 Conclusion

This chapter discussed the background of this research, the problem statement, the objectives needed to successfully complete the research, the process that will be followed to achieve the identified objectives, and the discussion about what each chapter entails. Chapter 2 will discuss assistive technologies and methods to elicit end-user requirements.

CHAPTER 2

2. REQUIREMENTS ELICITATION FOR ASSISTIVE TECHNOLOGIES

Chapter 1 provided the background, context, and the research process. Chapter 1 also stated the research problem, objectives, delimitations, and dissertation structure. In Chapter 2, assistive technology abandonment, the requirements elicitation activity, and the requirements elicitation methods for assistive technologies will be discussed.

Chapter 2 is structured as follows:

Section	Header
2.1	Background
2.2	Assistive Technologies
2.3	Assistive Technologies for Deaf People
2.4	Assistive Technology Abandonment
2.5	Requirements Elicitation
2.6	Requirements Elicitation for Assistive Technologies
2.7	Requirements Elicitation from Deaf People
2.8	Conclusion

2.1 Background

If someone cannot function effectively in a world they live in, there are three ways to solve such an issue: 1) change the individual, 2) provide individuals with tools they can use, or 3) change the environment (Vanderheiden, 1998). This is to allow the individual to feel part of the society and allow them to be independent. To understand these approaches, further discussion is provided in Table 2.1.

Table 2.1: Approaches to Effective Functioning of Disabled Individuals (Vanderheiden, 1998, pp.30-31)

Approaches	Examples
Change the Individual	This includes "surgical intervention, therapy, training, and education" to teach individuals how to improve the way they are living.
Provide Individuals with Tools They Can Use	This includes "prosthetics, orthotics, and assistive technologies (may be customised to fit users' needs)".
Change the Environment	This includes applying design techniques that results in solutions that are more flexible, adaptable, accessible, and usable to disabled people.

In Table 2.1, one of the approaches highlighted is to provide individuals with assistive technologies. Assistive technologies play an important role in enabling disabled people to live independently in the environment they are in (Blackburn & Cudd, 2012). Assistive technologies are one of several ways to assist disabled people to reduce the disabling influence of many environments (Cook & Polgar, 2008). A large number of deaf people depend on assistive technologies and consider them to be important and necessary (Nierling, Maia, Hennen, Wolbring, Bratan, Kukk, Čas, Capari, Krieger-Lamina, & Mordini, 2018).

2.2 Assistive Technologies

Assistive technologies are defined as "items, equipment, or products that can be used to increase, maintain, or improve functional capabilities of individuals with some disability" (Shahrestani, 2017, p. 3). Similarly, assistive technologies are defined as "any product, instrument, equipment, or technology adapted or specially designed for

improving functioning of a disabled person" (Cook & Polgar, 2015, p. 2). Both definitions highlight the importance of assistive technologies in improving the lives of disabled people.

There are various assistive technologies ranging from software to hardware, which includes "everything from eating, mobility, sensory aids, to robotics and computer systems" (Blackburn & Cudd, 2012, p.193). Assistive technologies can be mainstream (off-the-shelf) or specialised (custom) products (Cook & Polgar, 2015). Table 2.2 provides an overview of three categories of assistive technologies for people with disabilities, namely: commercially available technologies, modified or adapted commercial technologies, and custom or specialty designed technologies.

Table 2.2: Categories of Assistive Technologies for Disabled People(Cook & Polgar, 2015)

Category	Description
Commercially available technologies	These are technologies that can be purchased by users off-the-shelf. They are for the vast majority of people with disabilities.
Modified or adapted commercial technologies	These are technologies modified to fit the needs of users with a disability when commercially available technologies cannot meet user requirements.
Custom or specialty designed technologies	These are technologies specially designed for people with a disability when commercially available technologies and modified technologies cannot meet user requirements.

2.3 Assistive Technologies for Deaf People

The National institute on Deafness and other Communication Disorders (NIDCD) (2019) in the United States of America (USA) has provided three categories of available assistive technologies for deaf people, namely: 1) assistive listening devices, 2) augmentative and alternative communication devices, and 3) alerting devices. Table 2.3 provides an overview of the three available assistive technology categories for deaf people as described by the NIDCD.

Table 2.3: Categories of Assistive Technology for Deaf People (National Institude on Deafness and Other Communication Disorders, 2019)

Category	Description
Assistive listening devices	These devices amplify sound to allow people with hearing problem to be able to hear. Examples are hearing aid and cochlear implant.
Augmentative and alternative communication devices	These devices help users with communication disorders to express themselves. Examples include a picture board, and speech recognition programmes.
Alerting devices	These devices alert deaf people to know that an event is taking place. Examples include a doorbell, telephone, alarm, blinking light, or baby monitoring device, amongst others.

2.4 Assistive Technology Abandonment

According to Blackburn and Cudd (2012), only 18% of all new assistive technologies brought to the market are sustainably successful. Therefore, the high level abandonment of assistive technology suggests that there is a problem (Blackburn & Cudd, 2012). The main reason for assistive technology abandonment is described as a lack of suitable products (Blackburn & Cudd, 2012). Other reasons that contribute to assistive technology abandonment include: lack of user opinion in selection process, lack of proper performing devices, maintenance cost/affordability, stigmatisation and discrimination, usability issues, and lack of designs that accommodate changing user needs and priorities (Blackburn & Cudd, 2012; Cook & Polgar, 2015; Phillips & Zhao, 1993; Shahrestani, 2017).

Infeasible complex problems, poor communication, too much information to be handled, incomplete user requirements, poorly presented results that are inconsistent, short route to bring the products to the market for profitability, and putting less focus on rigorous requirements elicitation, are further reasons why assistive technologies fail or are abandoned (Blackburn & Cudd, 2012).

2.5 Requirements Elicitation

Requirements elicitation requires effective communication between stakeholders and developers (Zhang, 2007). The means of communication with stakeholders to elicit requirements is categorised into conversational, observational, analytic, and synthetic methods (Zhang, 2007). Table 2.4 provides an overview of the categorised communication methods for eliciting requirements.

Table 2.4: Requirements Elicitation Methods (Zhang, 2007)

Category	Description and Examples
Conversational	Utilised to interact with users to elicit requirements; also referred to as verbal methods. Conversational methods include interviews, workshops, focus groups, brainstorming etc.
Observational	Observational methods provide a rich way to elicit requirements that are difficult to verbalise, this includes social analysis, observation, ethnographic study, protocol analysis etc.
Analytic	Analytic methods elicit requirements through existing documents or knowledge, these includes requirements reuse, documentation studies, content analysis, laddering, card sorting, repertory grid etc.
Synthetic	Also referred to as collaborative methods, a combination of conversation, observation, and analytic methods to elicit requirements. Synthetic methods include scenarios, passive storyboards, prototyping, interactive storyboards, JAD/RAD sessions, and contextual inquiry.

The four categories of methods are created to assist engineers in selecting the correct method to elicit requirements (Zhang, 2007). Regardless of which elicitation method(s) have been selected, the elicitation activity consist of 5 important steps, namely: 1) understanding the application domain; 2) identifying the source of requirements; 3)

analysing stakeholders; 4) selecting the techniques, approaches, and tools to use; and 5) eliciting the requirements from stakeholders and other sources (Zowghi & Coulin, 2005). Table 2.5 provides an overview description of the steps for eliciting requirements.

Table 2.5: Requirements Elicitation Steps (Zowghi & Coulin, 2005)

Steps	Description
1. **Understanding the application domain**	Refers to an understanding of the context in which the system will be implemented. This includes a description of existing processes and related problems; exploration of system related to political, organisational, and social aspects; and to any system constraints that may be enforced.
2. **Identifying the sources of requirements**	Refers to identifying all possible sources for eliciting requirements. This includes users, system stakeholders, experts, existing systems and processes, and existing documentation.
3. **Analysing the stakeholders**	Refers to the analysis and involvement of all relevant people who may be affected or have an interest in the development and implementation of the system. Stakeholders includes users, customers (project sponsors) and partners, and any group or individuals internal and external to the organisation.
4. **Selecting the techniques, approaches, and tools to use**	Refers to the selection of suitable techniques, approaches, and tools based on a specific project context. There are various reasons that may influence the selection of techniques, approaches, and tools to use. This includes influences such as: 1) the technique, approach, or tool is selected based on current knowledge of the analyst, 2) the technique, approach, or tool is selected based on favouritism, 3) the technique, approach, or tool is selected based on the specific

Steps	Description
	methodology to be followed, and 4) the technique, approach, or tool is selected based on analysts intuition.
5. Eliciting the requirements from stakeholders and other sources	Refers to the actual process of eliciting requirements using the selected techniques, approaches, and tools. This includes the elicitation of stakeholders needs and wants, determining future processes, and how the system will support, satisfy, and address problems, processes, operations, and objectives of the business.

2.6 Requirements Elicitation for Assistive Technologies

Assistive technologies fill a unique and important role in the lives of the people they are intended for. Assistive technologies are designed in consideration of the intended users to ensure the product fits their needs, wants, and environment (Blackburn & Cudd, 2012). Table 2.6 provides categories of methods to elicit end-user requirements for assistive technologies, and their examples as discussed by Blackburn and Cudd (2012).

Table 2. 6: Requirements Elicitation Methods for assistive technologies (Blackburn & Cudd, 2012).

Category	Description
User requirements by proxy	The methods in this category are often applied at the beginning of the user requirements process. This includes stakeholder meetings, brainstorming sessions, competitor analysis and RAD/JAD workshops, among others.
User consultation methods	The methods in this category are advantageous for direct involvement of users to elicit their perceptions, opinions, and attitudes towards a particular topic. This includes interviews, focus groups, analysis of existing documentation, prototyping, and storyboarding.

Category	Description
Observational methods	The methods in this category are for 1) observing the user's current activities to identify their tasks and difficulties; or 2) observe the users' interactions with a prototype. This includes video cameras, audio recorders and/or other measurement sensors – movement sensors, physiological sensors.

Even though methods such as those discussed in Table 2.7 exist, Blackburn and Cudd (2012) note that there is no 'gold standard' method for eliciting end-user requirements for assistive technologies. According to Zacharias, Campese, dos Santos, da Cunha, & Costa, (2019), traditional methods for eliciting requirements focus on the project needs instead of the users' needs. Furthermore, assistive technology developers follow a 'common-sense' approach to understand users' needs and desires to produce a prototype (Blackburn & Cudd, 2012).

Therefore, Zacharias et al. (2019) identified the *User Stories* method as a suitable approach for understanding end-users' needs when developing new assistive technologies. The *User Stories* method is a software development method for eliciting quality requirements and to improve communication between end-users and developers of assistive technologies (Zacharias et al., 2019). The *User Stories* method consists of three important elements: the WHO (role, end-user, or actor), the WHAT(goal, feature, functionality, capability, task, or activity), and the WHY (objective) (Wautelet, Heng, Kolp, & Mirbel, 2014).

The three elements represent "WHO *wants the functionality*, WHAT *functionality end-users or stakeholders want the system to provide*, and *the reason* WHY *the end-users or stakeholders need the system for"* (Wautelet et al., 2014, pp. 211-212).

The following is a format or template adopted from Cohn work of 2004: as [end-user/WHO], I want/want to/need/can/I would like [need/WHAT] because [value proposition/WHY] (Wautelet et al., 2014; Zacharias et al., 2019). The method is used to communicate requirements in a natural language that can be easily understood by all stakeholders (Wautelet et al., 2014). The format and language of the *User Stories* method makes it easy for assistive technology developers to translate needs into

product requirements (Zacharias et al., 2019). Therefore, user stories should describe system functionality for the desired product in user perspective (Zacharias et al., 2019). Cohn (2004) states that a good user story consists of 6 attributes, namely: 1) independent, 2) negotiable, 3) valuable to end-users or customers, 4) estimatable, 5) small, and 6) testable. Table 2.7 provides an overview description of the attributes of a good user story.

Table 2.7: Attributes of a Good User Story (Cohn, 2004)

Attribute	Description
Independent	Stories should be independent from one another to avoid prioritisation, planning, and estimation problems.
Negotiable	Stories are not requirements that must be implemented, they are negotiable between users and developers.
Valuable to users or customers	Stories must be valuable to users. However, some projects include stories that are not valuable to users.
Estimatable	Developers must be able to estimate or guess the time it will take to “turn a story into working code”.
Small	Stories cannot be too big or too small as that will result in problems when planning.
Testable	Stories must be testable for developers to know if coding is done.

The Zacharias et al. (2019) study adopted the *User Stories* method and modified it for eliciting quality requirements for medical devices, specifically assistive technologies. The modified *User Stories* method consists of 4 steps, namely: 1) user identification and selection; 2) tools preparation; 3) user interaction; and 4) the stories registration and validation. Zacharias et al. (2019) added a new “tools preparation step” from the original steps of the *User Stories* method found in software development in order to fit the context of assistive technologies.

The tools preparation step is added for 1) developing interview scripts that will guide conversations with companions and occupational therapists, and 2) for the development of a concept prototype based on existing devices for inclusion of end-users. Users will interact with the concept prototype while being observed by the usability team in order to elicit requirements, and the elaborated scripts from interviews will be utilised to develop user stories by the usability team (Zacharias et al., 2019). Furthermore, user stories are then discussed and agreed on by the usability team and developers. Table 2.8 provides an overview description of the modified *User Stories* method for a better understanding of what each step entails.

Table 2.8: *User Stories* Method for Assistive Technologies (Zacharias et al., 2019)

Step	Description
1. User identification and selection	In this step, brainstorming is required to identify users.
	In this step, users are selected based on different criteria such as value for Project and ease of access.
2. Tools preparation	In this step, interview scripts are prepared.
	In this step, a prototype is also prepared.
3. User Interaction	In this step, occupational therapist and companions of users are encouraged to tell stories of users based on the user's perspective.
	In this step, users are observed while interacting with the prototype.
4. Stories registration and validation	In this step, stories are written and validated after step 3 is concluded.
	In this step, stories are written in cards by the usability team and validated by both usability and engineering teams.

2.7 Requirements Elicitation from Deaf People

Stakeholders in the requirements development process include users, developers, legislators, and decision-makers (Sharp, Finkelstein & Galal, 1999). In the context of this research, the focus is on deaf users as stakeholders. Table 2.9 provides an overview of some of the methods/techniques for communicating with deaf people.

Table 2.9: Communication Methods for Deaf People (Al-Megren & Almutairi, 2019; Lenneberg, Rebelsky, & Nichols, 1965; Nathan, Hussain, & Hashim, 2016; Ting, Hao, & Ching-chiuan, 2013)

Method/technique	Description
Sign language interpreter	An individual able to communicate using signed, spoken, and written language. The individual acts as a mediator to assists deaf and hearing people to communicate with each other.
Written notes	A form of communication by writing down thoughts/ideas for others to read.
Ethnographical field observations	A method of observing people in an environment doing a particular task/activity.
Lipreading	Observing a person's lips while they are talking to try and make out what they are saying. This technique requires that the deaf person observing understands the language.
Oral communication	Making use of speech to communicate. This requires that the deaf person understands the language.
Miming	An oral communication without spoken words. This also requires that the deaf person understands the language.
Pantomime (theatre)	A stage/theatre production for entertaining people.

Method/technique	Description
Pictogram language	Making use of signs/icons/images/drawing to convey a message.
Sign language	Use of hands and body to communicate with other people. This typically involves: Fingerspelling – spelling out of words by your fingers/hands; cued-speech: use of specific hand gestures to convey a message.
Multimedia	A combination of text, audio, images, animations, or video into a single presentation to communicate.

Users usually write their own stories, however, in assistive technology development, some users struggle to do this (Zacharias et al., 2019). Therefore, further modification of the already modified *User Stories* method to fit into the deaf context is required. The further modification of the *User Stories* method to fit into the deaf context also consists of the four steps which were discussed in section 2.6.

In the user identification and selection (Step 1) of the *User Stories* method, deaf users are identified and selected based on the context, value for project, and ease of access. This is aligned with the modified *User Stories* method by Zacharias et al. (2019). In the tools preparation step (Step 2) of the *User Stories* method, interview scripts are developed to structure the conversation with deaf users, audiologists, and companions of deaf users to collect their stories.

The first modification of the *User Stories* method to fit into the deaf context is at Step 2, the tool's preparation step. Zacharias et al. (2019) suggest that a prototype should be developed. However, for the deaf context, no prototype is to be developed at the tools preparation step before requirements have been elicited. This is to give users an opportunity to have a key role in the design and development of the assistive technology, and to ensure that the technology meets deaf users' needs, wants, and environment (Blackburn & Cudd, 2012). Furthermore, in the deaf context, during the tool's preparation step, it is important to also identify a sign language interpreter to

ensure effective communication between designers/developers of assistive technologies and deaf users.

The second modification of the *User Stories* method to fit into the deaf context is at step 3, the user interaction step. Since there is no prototype developed at the tools preparation step (step 2), deaf users will not interact with a prototype as suggested by Zacharias et al. (2019) in their modification of the *User Stories* method. Furthermore, due to the difficulties experienced by deaf users in communicating with the hearing community, deaf users can narrate their own stories assisted by a sign language interpreter. In a case where deaf users are unable to narrate their own stories, audiologists and companions of deaf users are encouraged to narrate user stories from the users' perspective.

The third modification of the *User Stories* method to fit into the deaf context is at Step 4, the user stories registration and validation step. According to Zacharias et al. (2019) in the modified *User Stories* method, user stories are written by the usability team and validated by both usability and engineering teams after the user interaction step (Step 3). In the deaf context, stories are written and validated during the interaction with deaf users assisted by a sign language interpreter and/or during interaction with audiologists and companions of deaf users. Thereafter, similar to Zacharias et al. (2019), user stories are written by the usability team. Table 2.10 provides a comparison of Zacharias et al. (2019) modified *User Stories* method, with the modified *User Stories* method for the deaf context.

Table 2.10: *User Stories* Method for Deaf Context

Step	*User Stories* method for Assistive Technologies	*User Stories* method for Assistive Technologies for deaf context
1. User identification and selection	In this step, brainstorming is required to identify users.	In this step, brainstorming for deaf user identification is required.
	In this step, users are selected based on different criteria such as value for	In this step, deaf users are selected based on different criteria such as

Step	*User Stories* method for Assistive Technologies	*User Stories* method for Assistive Technologies for deaf context
	the project and ease of access.	value for the project and ease of access.
2. Tools preparation	In this step, interview scripts are prepared.	In this step, interviews scripts are prepared.
	In this step, a prototype is prepared.	In this step, no prototype is developed or prepared.
		In this step, a sign language interpreter is identified.
3. User Interaction		In this step, a conversation with deaf users that narrate their stories can be facilitated with assistance from a sign language interpreter.
	In this step, occupational therapists and companions of users are encouraged to tell stories of users in users' perspective.	In this step, audiologists and companions of users are encouraged to tell stories of deaf users in the users' perspective.
	In this step, observation of users while interacting with the prototype is done.	In this step, there is no interaction with a prototype.
4. Stories registration and validation		In this step, stories can be written during the interaction with deaf users, assisted by a sign language interpreter.

Step	*User Stories* method for Assistive Technologies	*User Stories* method for Assistive Technologies for deaf context
	In this step, stories are written and validated after Step 3 is concluded.	In this step, stories can be written during the interaction with audiologist and companions of deaf users.
	In this step, stories are written on cards by the usability team and validated by both usability and engineering teams.	In this step, stories are written on cards by the usability team and validated by both usability and engineering teams.

2.8 Conclusion

Chapter 2 provided a discussion on assistive technologies, the reasons for assistive technology abandonment even though the need still exists, and the requirements elicitation activity to understand how to elicit requirements for assistive technologies. Chapter 2 concluded by recommending the *User Stories* method as suitable for eliciting end-user requirements for assistive technologies, which was further modified to fit into the deaf context. Chapter 3 will utilise existing literature to extract the needs and challenges of profoundly deaf parents with infants.

CHAPTER 3

3. NEEDS AND CHALLENGES OF PROFOUNDLY DEAF PARENTS WITH INFANTS

Chapter 2 discussed assistive technologies from a general perspective to the specific context of this research. Furthermore, reasons for assistive technology abandonment, and methods for eliciting end-user requirements were also discussed. Chapter 2 also provided recommendations on a suitable method to elicit end-user requirements for assistive technologies and further modified the method to fit into the deaf context. Chapter 3 will extract the needs and challenges of profoundly deaf parents with infants as a starting point to elicit end-user requirements in this context.

Chapter 3 is structured as follows:

Section	Header
3.1	Background
3.2	Methodological Approach
3.3	Designing the Review
3.4	Conducting the Review
3.5	Analysing the Review
3.6	Writing the Review
3.7	Conclusion

3.1 Background

In Chapter 2, the *User Stories* method has been identified and recommended as a suitable method for understanding assistive technology users. The *User Stories* method consists of 4 steps, namely: 1) user identification and selection; 2) tools preparation; 3) user interaction; and 4) stories' registration and validation (Zacharias et al., 2019). InChapter 2, the *User Stories* method has been modified to fit into the deaf context. Due to the coronavirus pandemic, the direct user interaction required in Steps 1, 2, and 3 of the *User Stories* Method was replaced with an alternative method based on secondary data.

In Chapter 2 (section 2.5), end-user requirements elicitation categories such as conversational, observational, analytic, and synthetic methods were discussed in Table 2.4. In this chapter, the analytic methods category for eliciting end-user requirements, which includes going through existing documents or knowledge such as requirements reuse, documentation studies, content analysis, laddering, card sorting, repertory grid etc, are selected. Therefore, this chapter makes use of existing literature as an alternative to Steps 1, 2, and 3 of the *User Stories* method to extract the required data.

3.2 Methodological Approach

There are multiple methods, techniques, and approaches that can be followed to conduct a literature review and analysis. These methods, techniques, and approaches include the systematic literature review, integrative literature review, qualitative content analysis, and thematic analysis, among others. Due to the lack of published literature in this research topic, an integrative literature review was selected as the most suitable approach for collecting the required literature. An integrative literature review combines perspectives and insights from different fields by reviewing, critique, and synthesising literature to develop new theoretical frameworks and perspectives on a topic (Torraco, 2005). Furthermore, integrative literature reviews are intended to address "mature topics or new, emerging topics" to create "initial or preliminary conceptualizations and theoretical models" (Torraco, 2005, p. 357).

There are various strategies, standards, and guidelines for conducting a literature review (Snyder, 2019). In this research, four basic phases identified by Snyder (2019) to conduct an integrative literature review were followed. The four basic phases are: 1) designing the review, 2) conducting the review, 3) analysis, and 4) writing up the review.

Table 3.1 provides an overview/description of the four phases followed when conducting an integrative literature review.

Table 3.1: Phases of an Integrative Literature Review (Snyder, 2019, pp. 336-337)

Phase	Description
1. Designing the review	This phase is for determining the need for conducting an integrative literature review, the type of data to be collected, and understanding the intended users.
2. Conducting the review	This phase is for the actual conducting of the literature review "after deciding on the purpose, specific research questions, and type of approach".
3. Analysis	After conducting an integrative literature review, depending on the objective of the research, a suitable method/technique should be applied to identify the required data.
4. Writing up the review	The final phase of the integrative literature review includes documenting the entire process that was followed to achieve the chapter objective. A review can be conducted in different ways, and every review should be reported in a transparent way. Furthermore, the review reporting should provide details on how the literature was "identified, analysed, and synthesised".

Further discussion of how each phase of the literature review was applied to collect existing literature for extracting the needs and challenges of profoundly deaf parents with infants is provided in sections 3.3 to 3.6.

3.3 Designing the Review

Phase 1 (designing the review) of an integrative literature review is to determine the need for conducting a literature review, the type of data to be collected, and understanding the intended users. Due to the first three steps of the *User Stories* method not being implemented in this research, the integrative literature review is selected as a suitable approach to collect the required literature. Thereafter, the *needs* and *challenges* of profoundly deaf parents with infants will be extracted. After the review

and analysis are completed, the output could be used by the usability team and/or engineering team. In this research, a '*need*' is a desire, and/or function of a profoundly deaf parent with an infant and a '*challenge*' is an issue or barriers that profoundly deaf parents experience while looking after infants, especially when the infant is out of sight.

3.4 Conducting the Review

Phase 2 (conducting the review) of the integrative literature review is the actual doing part of conducting the literature review "after deciding on the purpose, and specific research questions, and type of approach" (Snyder, 2019, p. 337). As stated in Phase 1, the literature review in this chapter is conducted to understand and extract the needs and challenges of profoundly deaf parents with infants from existing literature. To identify and collect relevant existing literature, the following keywords were selected, 1) *deaf parents* AND *infants*; and 2) *deaf* AND *parents* AND *infants*. The keywords were selected to search online academic databases and academic sites such as: PubMed, IEEE, JSTOR, EbscoHost, ResearchGate, and Google Scholar.

Depending on the searching capability of each online database and academic site to collect existing literature, both keywords (1 and 2) were used. The searching criteria included searching for all keywords in the title and/or abstract, looking for academic publications written in English, and looking for academic publications that are publicly available. Due to dearth of published literature, no specific dates and types of academic publications were used as part of the selection criteria. Furthermore, it is important to note that there are terminologies used in other papers to refer to the selected keywords, such as 1) newborn, children, or baby to refer to infants; 2) mother, father, or caregiver to refer to parents; and 3) hearing impairment to refer to deaf; among others. Depending on the searching capabilities of each data source, different filtering options were applied to obtain the required academic publications.

Using the keywords: *deaf parents* AND *infants*, 197 academic publications in total were found, and using keywords: *deaf* AND *parents* AND *infants*, 348 results were found. By reading the titles and/or abstracts of the search results from each data source, the total number of relevant papers were recorded. Using the keywords: *deaf parents* AND *infants*, 7 relevant academic publications were found in total, and using the keywords: *deaf* AND *parents* AND *infants*, 10 relevant academic publications were found. Duplicate academic publications were identified and removed from the total number of

relevant academic publications. After removing the duplicates, 3 academic publications were identified and selected using the keywords: *deaf parents* AND *infants*, and another 3 academic publications were identified and selected using the keywords: *deaf* AND *parents* AND *infants*.

The selected academic publications were read to identify whether *needs* and *challenges* of profoundly deaf parents with infants could be extracted. Table 3.2 and Table 3.3 provide details on how the search for academic publications was done and the search results from the selected keywords.

Table 3.2: Search Results for Keywords: *deaf parents* and *infants*.

Database	Number of results (filtering options)	Number of relevant papers	Number of used papers
PubMed	11 (title/abstract)	0	0
	3 (title)	0	0
IEEE	0 (document title)	0	0
	0 (publication title)	0	0
	1 (abstract)	0	0
JStor	2 (Title, all content, English)	0	0
	8 (abstract, all content, English)	1	1 (Lenneberg et al., 1965)
Ebscohost	10 (all databases, title)	0	0
	49 (all databases, abstract, removed all duplicates, have access to full-text)	1	1 (Lenneberg et al., 1965)

Database	Number of results (filtering options)	Number of relevant papers	Number of used papers
ResearchGate	100	4	2 (Ting et al., 2013; Singleton & Tittle, 2000)
Google scholar	13 (title only)	1	1 (Lenneberg et al., 1965)
Total	**197**	**7**	**3**

Table 3.3: Search Results for Keywords: *deaf*, *parents*, and *infants*

Database	Number of results (filter)	Number of relevant papers	Number of used papers
PubMed	66 (title/abstract)	1	1 (Lenneberg et al., 1965)
	12 (title)	1	1 (Lenneberg et al., 1965)
Google scholar	18 (title only)	1	1 (Lenneberg et al., 1965)
IEEE	0 (document title)	0	0
	0 (publication title)	0	0
	1 (abstract)	0	0
JStor	3 (Title, all content, Eng.)	1	1 (Lenneberg et al., 1965)

Database	Number of results (filter)	Number of relevant papers	Number of used papers
	19 (abstract, all content, Eng.)	1	1 (Lenneberg et al., 1965)
Ebscohost	41 (all databases, title)	1	1 (Lenneberg et al., 1965)
	88 (all databases, abstract, removed duplicates, full-text, Eng.)	0	0
ResearchGate	100	4	3 (Ting et al., 2013; Lenneberg et al., 1965; Singleton & Tittle, 2000)
Total	**348**	**10**	**3**

During literature search 545 search results (197 + 348) were recorded. After reading the title and/or abstract of the academic publications from the search results, 17 (7 + 10) academic publications were identified as relevant including duplicates. Further selection criteria such as academic publications that consist of online full-text access or PDFs were applied to make sure that only relevant and publicly available academic publications were selected for extracting the *needs* and *challenges* of profoundly deaf parents with infants. By reading each individual academic publication, identifying and removing all duplicates, 3 academic papers were selected to extract the *needs* and *challenges* of profoundly deaf parents with infants.

All academic publications excluded in the selection process were focused on education, culture, communication development, parent-child interaction, speech and language development, older children, and behavior, among others. The academic publications were excluded because they were not relevant to the context of this research and could

not be selected for extracting the *needs* and *challenges* of profoundly deaf parents with infants.

3.5 Analysing the Review

Phase 3 (analysing the review) of the integrative literature review is for identifying and applying a suitable method to identify the required data depending on the research objective. A method for analysing data when conducting an integrative literature review depends on the objectives of the research (Snyder, 2019). Therefore, different methods such as qualitative content analysis and thematic analysis, among others, may be used depending on what needs to be addressed. In this chapter, the aim is to understand the needs and challenges of profoundly deaf parents with infants. Therefore, for the purpose of this research, thematic analysis was identified as the most suitable analysis method. Thematic analysis is a "method for identifying, analysing, and reporting patterns (themes) within data" that reports on experiences and the reality of the group under study (Braun & Clarke, 2006, p. 79).

The objective of this section is to extract data pertaining to the *needs* and *challenges* of profoundly deaf parents with infants to develop an understanding of their experiences and reality. Therefore, in this chapter, thematic analysis is applied to extract and organise the *needs* and *challenges* of profoundly deaf parents with infants from the identified and selected papers in Section 3.4. Thematic analysis is a widely used method recommended for researchers to organise and describe data in rich detail (Braun & Clarke, 2006). There are four phases to theme development, namely: 1) initialisation, 2) construction, 3) rectification, and 4) finalisation (Vaismoradi, Jones, Turunen, & Snelgrove, 2016). Table 3.4 provides an overview/description of the four phases when conducting a thematic analysis.

Table 3.4: Phases of Thematic Analysis (Vaismoradi et al., 2016, p. 103-107)

Phase	Description
1. Initialisation	In this phase, data is read multiple times to formulate meaning and understand participants' perspectives.
2. Construction	In this step, data is coded, and similarities and differences are identified. Furthermore, coding is done by providing

Phase	Description
	labels to the data and the labels are then grouped to form themes to represent repeating ideas that capture important data in relation to the research question.
3. Rectification	In this step, time away from the data is required to "increase their sensitivity and reduce any premature and incomplete data analysis". Thereafter, a process of checking and confirming that the themes constructed correspond with the data is required. Furthermore, a theme may have sub-themes which provide a comprehensive view of the data.
4. Finalisation	In this step, the researcher is required to document the entire process followed to construct themes. This can be done by providing a narrative story line of how the themes were constructed to initiate new ideas and collection of new data.

This section provides details on how each phase of the thematic analysis was followed to extract the *needs* and *challenges* of profoundly deaf parents with infants and develop themes and sub-themes.

3.5.1 Initialisation

In the Initialisation phase (Phase1) of the thematic analysis data is read multiple times to formulate meaning and understand participants' perspectives. In this chapter, three academic papers (numbered a to c) in Table 3.5, were identified and selected through literature review for extracting *needs* and *challenges* of profoundly deaf parents with infants. The selected academic papers were read more than once. The first time was to understand the context of each academic paper, followed by an iterative process of reading and highlighting all sentences/phrases that describe a *need* or a *challenge* of a profoundly deaf parent looking after an infant.

The terms *needs* and *challenges* are selected as categories for the data to be extracted and analysed. According to Vaismoradi et al., (2016), a category is a high level construct/concept identified at the beginning of an analysis process to group similar

data. Under each category, sentences/phrases found in selected academic papers that describe a *need* or a *challenge* were documented. Table 3.5 shows all the sentences/phrases describing a *need* or a *challenge* of a profoundly deaf parent with infants that were extracted from each selected academic paper.

Table 3.5: *Needs* and *Challenges* (Lenneberg et al., 1965; Singleton & Tittle, 2000; Ting et al., 2013)

a) Designing a communication device for deaf parents and a hearing infant (Ting et al., 2013)	
Context: Designing and testing a prototype of a technology for deaf parents with infants.	
Sentences/Phrases describing *Needs*	Sentences/Phrases describing *Challenges*
1. For design, parents expressed the ability of always being connected to their infants. 2. For design, parents expressed the ability to always feel their infants even when they are out of sight. 3. For design, parents expressed the need to hear their infants even when they are out of sight. 4. Several persons suggested an in-situ lighting system as they are more sensitive to the lighting signals, such as blink lightings. 5. Due to daily housework such as washing dishes, the assistive technology should be water resistant.	1. Audio alert is the primary function for existing baby monitors, which deaf parents do not have access to. 2. Due to the lack of appropriate baby monitors, coping strategies are used by deaf parents to look after infants. 3. Deaf people hear sound by using the sense of touch. Most existing products are missing tactile modality. 4. One of the coping strategies used by deaf parents when looking after their infants is to constantly check up on the infant. 5. Some deaf parents give away their parental rights because they feel they do not want to put their children at a disadvantage in society.

6. Deaf parents expressed the worry of missing their infant's cry. 7. Deaf parents expressed the need to always be connected to their infants even if they are out of sight. 8. For design, parents expressed the ability of always being able to visually see their infants.	6. Most incidents of an infant crying happen when a deaf parent is not in the presence of the infant, e.g., waking up. 7. Even though deaf parents came up with coping strategies, none of them effectively help independent parenting. 8. The quality of interaction was rated low when there is a mismatch of hearing status between the infant and the parent than when both are hearing or deaf. 9. Deaf adults might not get social support as most programs focus on deaf children. 10. Some deaf parents expressed being deaf as a challenge because they will not hear their infant cry.
b) The vocalizations of infants born to deaf and to hearing parents (Lenneberg et al., 1965)	
Context: observing vocal behavior of babies born to hearing and deaf parents	
Sentences/Phrases describing *Needs*	Sentences/Phrases describing *Challenges*
9. Eager to prove they can create a normal environment for their infants. 10. Eager to prove themselves to the hearing world.	11. Some deaf parents are using a light alert system, but the system is organised in such a way that the parents need to look at the room to know the state of the baby.

	12. Abnormal noises made by deaf parents such as banging pots and pans, and slamming doors, can cause infants to cry. 13. Reaction to, and interpretation of sounds by deaf people is different from those who can hear. 14. Sounds made by infants such as crying and cooing, are a form of verbal communication.
c) Deaf parents and their hearing children (Singleton & Tittle, 2000)	
Context: review of deaf community, family, parenting, issues, and the role of children with deaf parents.	
Sentences/Phrases describing *Needs*	Sentences/Phrases describing *Challenges*
	15. Parents' deafness may interfere with the development of the child. 16. The parents of deaf parents may intervene in raising the children and even usurp parental authority from deaf parents. 17. Professionals have a tendency to bypass deaf parents and directly deal with their children or family members. 18. Deaf parents may not have equal access to education on effective parenting.

From the three selected academic papers, 10 sentences/phrases describing *needs*, and 18 sentences/phrases describing *challenges* of profoundly deaf parents with infants

were extracted. The extracted *needs* and *challenges* of profoundly deaf parents with infants form part of the first coded data that is applied for further analysis.

3.5.2 Construction

In the Construction phase (Phase 2) of the thematic analysis data is coded, and similarities and differences are identified. In Table 3.5, 10 *needs* and 18 *challenges* of profoundly deaf parents with infants were extracted from selected papers. In Table 3.6 and Table 3.7, sentences/phrases describing *needs* of profoundly deaf parents with infants are labelled N01 to N10, while sentences/phrases describing *challenges* of profoundly deaf parents with infants are labelled C01 to C18. In both Table 3.6 and Table 3.7 an "**X**" is used to link a *need* or a *challenge* with the paper it was extracted from.

When reading the extracted sentences/phrases from Table 3.5, similarities were identified. To further organise the extracted *needs* and *challenges* of profoundly deaf parents with infants, similar sentences/phrases linked with papers were grouped together to form themes. The grouping of sentences/phrases describing *needs* and *challenges* is done to develop a broader understanding of the experiences and reality of profoundly deaf parents with infants. Table 3.6 and Table 3.7 shows the linking and grouping of sentences/phrases describing *needs* and *challenges* of profoundly deaf parents with infants to develop themes.

Table 3.6: Theme Development from Sentence/Phrases Describing *Needs*.

Themes	Sentences/phrases describing a need	Papers		
		a	b	c
Alert the parent about the state of the infant	**N01:** Parents expressed the ability of always being connected to their infants.	**X**		
	N02: Parents expressed the ability to always feel their infants even when they are out of sight.	**X**		
	N03: Parents expressed the need to hear their infants even when they are out of sight.	**X**		

Themes	Sentences/phrases describing a need	Papers		
		a	b	c
Lighting to capture attention	**N04:** Several persons suggested an in-situ lighting system as they are more sensitive to the lighting signals, such as blink lightings.	**X**		
Water resistant	**N05:** Due to daily housework such as washing dishes, the assistive technology should be water resistant.	**X**		
Able to hear	**N06:** Deaf parents expressed the worry of missing their infant's cry.	**X**		
Feel movement	**N07:** Deaf parent expressed the need to always be connected to their infants even if they are out of sight.	**X**		
Have visual on the infant	**N08:** Parents expressed the ability to visually see their infants.	**X**		
Creating a normal environment	**N09:** Deaf parents are eager to prove they can create a normal environment for their infants.		**X**	
Prove themselves	**N10:** Deaf parents are eager to prove themselves to the hearing world		**X**	

Table 3.7: Theme Development from Sentence/Phrases Describing *Challenges*.

Themes	sentences/phrases describing challenges	Papers		
		a	b	c
Audio alert is the primary function	**C01:** Audio alert is the primary function for existing baby monitors, which deaf parents do not have access to.	**X**		
Lack of appropriate baby monitors	**C02:** Due to the lack of appropriate baby monitors, coping strategies are used by deaf parents to look after infants.	**X**		
Missing tactile alert on assistive technologies	**C03:** Deaf people hear sound by using the sense of touch. Most existing products are missing tactile modality	**X**		
Visible lighting not effective if in a different room	**C04:** Some deaf parents have a light alert system, but the system is organised in such a way that the parents need to look at the room to know the state of the baby.		**X**	
False alerts	**C05:** Abnormal noises made by deaf parents such as banging pots and pans, and slamming doors, can cause infants to cry.		**X**	
Sound interpretation is different from hearing parents	**C06:** Reaction to, and interpretation of sounds by deaf people is different from those who can hear.		**X**	
Coping strategy	**C07:** One of the coping strategies used by deaf parents when looking after their infants is to constantly check up on the infant.	**X**		

Themes	sentences/phrases describing challenges	Papers		
		a	b	c
Lack confidence in parenting	**C08:** Some deaf parents give away their parental rights because they feel they do not want to put their children at a disadvantage in society.	**X**		
Most incidents happen when infant is waking up	**C09:** Most incidents of an infant crying happen when a deaf parent is not in the presence of the infant, e.g., waking up	**X**		
Parenting strategies are ineffective	**C10:** Even though deaf parents came up with coping strategies, none of them effectively help independent parenting	**X**		
Low interaction with infant	**C11:** The quality of interaction was rated low when there is a mismatch of hearing status between the infant and the parent than when both are hearing or deaf	**X**		
Sounds made by infants as communication	**C12:** Sounds made by infants such as crying and cooing are a form of verbal communication.		**X**	
Lack of support	**C13:** Deaf adults might not get social support as most programs focus on deaf children.	**X**		
Inability to hear	**C14:** Some deaf parents expressed being deaf as a challenge because they cannot hear their infant cry.	**X**		
	C15: parent's deafness may interfere with the development of the child.			**X**

Themes	sentences/phrases describing challenges	Papers		
		a	b	c
Hearing people lack trust for deaf parents to be independent	**C16:** The parents of deaf parents may intervene in raising the children and even usurp parental authority from deaf parents.			**X**
	C17: Professionals have a tendency to bypass deaf parents and directly deal with their children or family members.			**X**
Lack of educational support	**C18:** Deaf parents may not have equal access to education on effective parenting.			**X**

A practical example of linked and grouping sentences/phrases can be seen in the above Table 3.6 where N01, N02 and N03 are linked with the selected academic papers and grouped together to form a theme called ‘Alert the parent about the state of the infant’. Furthermore, sentences/phrases that were linked but not grouped were left as standalone and a theme was developed because they bring a new, or different idea, to the dataset. An example of a standalone sentence/phrase which resulted to the development of a theme can be seen in the above Table 3.7 where C01 is not grouped, and formed a theme called ‘Audio alert is the primary function’. With the understanding of the deaf context and the chapter objective, the linking and grouping of the extracted *needs* and *challenges* of profoundly deaf parents with infants resulted into 24 themes being constructed.

3.5.3 Rectification

In the rectification phase (Phase 3) of the thematic analysis, time away from the data is required to “increase their sensitivity and reduce any premature and incomplete data analysis” (Vaismoradi et al., 2016, p. 106). Thereafter, a process of checking and confirming that themes constructed correspond with the data is required. Furthermore, a theme may have sub-themes to obtain a comprehensive view of the data. Therefore, after time away from the sentences/phrases describing *needs* and *challenges* of

profoundly deaf parents with infants, further analysis of the constructed themes was conducted.

After further analysis of the 24 (8 + 16) constructed themes in Table 3.6 and Table 3.7, two main themes emerged. The emerging of the two main themes resulted in the 24 themes becoming sub-themes. Therefore, sub-themes with similar ideas were further linked and grouped together under one main theme. The two main themes constructed are 'Technology and Parenting'. The Technology main theme is constructed to provide an understanding of all the *needs* and *challenges* of profoundly deaf parents with infants that are technology related. This includes what the technology should be able to do, how it should function, and what it should consist of, among others. The parenting main theme is constructed to provide an understanding of all the *needs* and *challenges* of profoundly deaf parents with infants that are related to parenting. This includes deaf mothers' experiences, how other people perceive deaf parents, and what deaf parents want.

Under the technology main theme, 9 (3 + 6) sub-themes were constructed, and under the parenting main theme, 15 (5 + 10) sub-themes were constructed. Table 3.8 and Table 3.9 shows an overview of how the 24 (9 + 15) themes were further linked and grouped together to construct main themes and sub-themes to represent the *needs* and *challenges* of profoundly deaf parents with infants.

Table 3.8: Theme Development from *Needs*.

Main themes	Sub-themes	Needs labels
Technology	Alert the parent about the state of the infant	N01, N02, N03
	Lighting to capture attention	N04
	Water resistant	N05
Parenting	Able to hear	N06
	Feel movement	N07
	Have visual on the infant	N08

Main themes	Sub-themes	Needs labels
	Creating a normal environment	N09
	Prove themselves	N10

Table 3.9: Theme Development from *Challenges*.

Main Theme	Sub-themes	Challenges labels
Technology	Audio alert is the primary function	C01
	Lack of appropriateness	C02
	Missing tactile alert on assistive technologies	C03
	Visible lighting not effective if in different room	C04
	False alerts	C05
	Sound interpretation is different from hearing parents	C06
Parenting	Coping strategy	C07
	Lack confidence in parenting	C08
	Most incidents happen when infant is waking up	C09
	Parenting strategies are ineffective	C10
	Low interaction with infant	C11
	Sounds made by infants as communication	C12
	Lack of support	C13
	Inability to hear	C14, C15

Main Theme	Sub-themes	Challenges labels
	Hearing people lack trust for deaf parents to be independent	C16, C17
	Lack of educational support	C18

3.5.4 Finalisation

In the Finalisation phase (Phase 4) of the thematic analysis, the researcher is required to document the entire process followed to construct themes (Vaismoradi et al., 2016). This can be done by providing a narrative story line of how the themes were constructed to initiate new ideas and collection of new data. Therefore, in this chapter, theme construction is documented and narrated in section 3.5.2 to section 3.5.3.

3.6 Writing the Review

Phase 4 (Writing up the review) of the integrative literature review, requires documenting the entire process that was followed to achieve the objective. The writing of the integrative review in this research clearly documents how the literature was identified, analysed, and synthesised. The writing up of the review in this chapter is done in section 3.3 to section 3.5.

3.7 Conclusion

In Chapter 3 the *needs* and *challenges* of profoundly deaf parents with infants were extracted and organised into main themes and sub-themes. In Chapter 4, the actual elicitation of end-user requirements of an assistive technology for profoundly deaf parents with infants will be conducted.

CHAPTER 4

4. END-USER REQUIREMENTS OF AN ASSISTIVE TECHNOLOGY FOR PROFOUNDLY DEAF PARENTS WITH INFANTS

In Chapter 3, *needs* and *challenges* of profoundly deaf parents with infants were extracted and organised into main themes and sub-themes. Chapter 4 will elicit end-user requirements of an assistive technology for profoundly deaf parents with infants.

Chapter 4 is structured as follows:

Section	Header
4.1.	Background
4.2.	User Stories Registration
4.3.	End-User Requirements: User Stories
4.4.	End-User Requirements: User Stories Validation
4.5.	Discussion: Lessons Learnt
4.6.	Conclusion

4.1 Background

The *User Stories* method has been identified and recommended in Chapter 2 as the most suitable method for understanding assistive technology users. The *User Stories* method consisting of four steps, namely: 1) user identification and selection; 2) tools preparation; 3) user interaction; and 4) the stories registration and validation. In Chapter 2, the *User Stories* method has been modified to fit into the deaf context. Steps 1 to Step 3 of the *User Stories* method were replaced by a literature review conducted in Chapter 3 to extract the required data. In this chapter, Step 4 of the *User Stories* method was implemented.

The goal of the 'stories' registration and validation' step (Step 4) is to identify user stories from the data extracted in the previous step (Step 3) of the *User Stories* Method (Zacharias et al., 2019). Thereafter, the usability and engineering team will discuss the stories for validation (Zacharias et al., 2019). Chapter 4 will make use of the *needs* and *challenges* of profoundly deaf parents with infants extracted in Chapter 3 as input into Step 4 of the *User Stories* method. Therefore, in this chapter, the 'stories' registration and validation' step (Step 4) is applied.

Step 4 of the *User Stories* method consists of two parts, registration and validation, which will be covered in this chapter. The registration part of user stories is done in section 4.2, and the validation part is done in sections 4.3 and 4.4 by translating user stories into end-user requirements and evaluating the elicited end-user requirements by assessing existing and emerging technologies.

4.2 *User Stories* Registration

The use of the *User Stories* method connects user with product requirements by obtaining and communicating user stories in a simple language (Zacharias et al., 2019). In Chapter 2 (section 2.6), the *User Stories* method is recommended as suitable for understanding users' needs when developing new assistive technologies. The first part of Step 4 of the *User Stories* method is to register user stories. The registration of user stories in this research is done by reading the *needs* and *challenges* of profoundly deaf parents with infants together with the main and sub-themes constructed in Chapter 3. To register user stories, there is a specific format that is adopted: "as [the WHO], I want/want to/need/can/I would like [the WHAT] because [the WHY]" (Wautelet et al., 2014, p. 211).

The format adopted for formulating the user stories consist of three elements, the WHO, WHAT, and WHY elements. The WHO represents the role, user, or actor; the WHAT represents the goal, feature, functionality, capability, task, or activity; and the WHY represents an objective (Wautelet et al., 2014). The WHY element is an "umbrella term of a goal or objective to be attained" (Wautelet et al., 2014, p. 220). Therefore, the WHY element is not emphasised in templates for formulating user stories because it is considered the same as the WHAT element, unless a low level expression of the WHY element is needed (Wautelet et al., 2014). This research also applies Wautelet et al., (2014) understanding of the WHY element when formulating user stories.

In this research the "I want/want to/need/can/I would like" part of the *User Stories* method to express the WHAT element depends on how the *needs* and *challenges* of profoundly deaf parents with infants were extracted. If a *need* or *challenge* is not extracted directly from a deaf parent e.g., extracted from companions of deaf users, audiologists, or observers, "would like" is selected. Furthermore, if a *need* or *challenge* is extracted directly from a deaf parent, "I want/want to/need/can" is selected.

Table 4.1 provides user stories' registration from the *needs* and *challenges* of profoundly deaf parents with infants, applying the format and attributes of the *User Stories* method. The user stories are labelled US01 to USn where 'US' stands for '*User Stories*', and 'n' stands for the last number of the formulated user stories.

Table 4.1: User Stories Formulated from *Needs* and *Challenges*

Sentences/phrases describing needs and challenges	User Stories
N01: Parents expressed the ability of always being connected to their infants.	**US01:** As a deaf parent, I want to always be connected to the infant.
N02: Parents expressed the ability to always feel their infants even when they are out of sight.	**US02:** As a deaf parent, I want to always feel the infant even when out of sight.
N03: Parents expressed the need to hear their infants even when they are out of sight.	**US03:** As a deaf parent, I need to "hear" the infant even when they are out of sight.

Sentences/phrases describing needs and challenges	User Stories
N04: Several persons suggested an in-situ lighting system as they are more sensitive to the lighting signals, such as blink lightings.	**US04:** As a deaf parent, I would like a clearly visible alert when the baby monitor is not in my sight.
N05: Due to daily housework such as washing dishes, deaf parents' hands may get wet.	**US05:** As a deaf parent, I would like the device to not be affected by water because of my daily housework.
N06: Deaf parents expressed the worry of missing their infant's cry.	**US06:** As a deaf parent, I need to know when the infant is crying.
N07: Deaf parent expressed the need to always be connected to their infants even if they are out of sight.	**US07:** As a deaf parent, I need to always be connected to the infant even if they are out of sight.
N08: Parents expressed the ability to visually see their infants.	**US08:** As a deaf parent, I want to visually see the infant.
N09: Deaf parents are eager to prove they can create a normal environment for their infants.	**US09:** As a deaf parent, I would like to create a normal environment for the infant.
N10: Deaf parents are eager to prove themselves to the hearing world.	**US10:** As a deaf parent, I would like to prove myself to the hearing world.
C01: Audio alert is the primary function for existing baby monitors, which deaf parents do not have access to.	**US11:** As a deaf parent, I would like an alternative alert to audio.
C02: Due to the lack of appropriate baby monitors, coping strategies are used by deaf parents to look after infants.	**US12:** As a deaf parent, I would like an appropriate baby monitor.

Sentences/phrases describing needs and challenges	User Stories
C03: Deaf people hear sound by sense of touch. Most existing products are missing tactile modality.	**US13:** As a deaf parent, I would like products to have tactile alert.
C04: Some deaf parents have a light alert system, but the system is organised in such a way that the parents need to look at the room to know the state of the baby.	**US14:** As a deaf parent, I would like to receive a clear alert without checking the infant's room.
C05: Abnormal noises made by deaf parents such as banging pots and pans, and slamming doors, can cause infants to cry.	**US15:** As a deaf parent, I would like to know when noise made by myself that causes the infant to cry.
C06: Reaction to, and interpretation of sounds by deaf people is different from those who can hear.	**US16:** As a deaf parent, I would like to interpret sounds so that I can react accordingly.
C07: One of the coping strategies used by deaf parents when looking after their infants is to constantly check up on the infant.	**US17:** As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them.
C08: Some deaf parents give away their parental rights because they feel they do not want to put their children at a disadvantage in the society.	**US18:** As a deaf parent, I want to avoid putting my children at a disadvantage in society.
C09: Most incidents of an infant crying happen when a deaf parent is not in the presence of the infant, e.g., waking up.	**US19:** As a deaf parent, I would like to know when the infant is crying even if the infant is not in my presence.

Sentences/phrases describing needs and challenges	User Stories
C10: Even though deaf parents came up with coping strategies, none of them effectively help independent parenting.	**US20:** As a deaf parent, I would like to be able to parent independently.
C11: The quality of interaction was rated low when there is a mismatch of hearing status between the infant and the parent than when both are hearing or deaf.	**US21:** As a deaf parent, I would like to improve my quality of interaction with the infant.
C12: Sounds made by infants such as crying, and cooing are a form of verbal communication.	**US22:** As a deaf parent, I would like to know when the infant makes sounds because sounds made by infants are a form of verbal communication.
C13: Deaf adults may not get as much social support, as most programs focus on deaf children.	**US23:** As deaf parent, I would like to receive social support.
C14: Some deaf parents expressed being deaf as a challenge because they cannot “hear” their infant cry.	**US24:** As a deaf parent, I want to “hear” when the infant is crying.
C15: Parents’ deafness may interfere with the development of the child.	**US25:** As a deaf parent, I would like to ensure that my deafness does not interfere with the development of the child.
C16: The parents of deaf parents may intervene in raising the children and even usurp parental authority from deaf parents.	**US26:** As a deaf parent, I would like my parents to not take over parental authority.

Sentences/phrases describing needs and challenges	User Stories
C17: Professionals have a tendency of bypassing deaf parents and directly deal with their children or family members.	**US27:** As a deaf parent, I would like professionals to interact with me not bypass me because of my hearing status.
C18: Deaf parents may not have equal access to education on effective parenting.	**US28:** As a deaf parent, I would like equal access to education on effective parenting.

4.3 End-User Requirements: User Stories

The second part of Step 4 of the *User Stories* method is to validate user stories. This section provides the translation of user stories into end-user requirements of an assistive technology for profoundly deaf parents with infants. In Table 4.1 (section 4.2) the *needs* and *challenges* of profoundly deaf parents with infants have been translated into user stories by applying the *User Stories* method. According to Zacharias et al., (2019), the formulated user stories also express end-user requirements for consideration when developing assistive technologies. This is in line with Blackburn and Cudd (2012) who are of the opinion that understanding what users need will always generate requirements. The format of the user stories makes it easy for the development team to translate stories into product features (Zacharias et al., 2019). Therefore, in this research, the registered user stories express end-user requirements of an assistive technology according to the perspective of deaf users.

After reading, understanding, and considering the context of the research, two categories of end-user requirements emerged: 1) End-user requirements that express functions of an assistive technology for profoundly deaf parents with infants, and 2) end-user requirements that express an overall goal or objective to be attained by designing, developing, and deploying an assistive technology for profoundly deaf parents with infants. This is in line with the two main themes (technology and parenting) that emerged in the categorisation and grouping of *needs* and *challenges* of profoundly deaf parents with infants in Chapter 3 (section 3.5).

Table 4.2 provides a compiled list of end-user requirements that express functions of an assistive technology for profoundly deaf parents with infants, and Table 4.3 provides a compiled list of end-user requirements that express an overall goal or objective to be attained by designing, developing, and deploying an assistive technology for profoundly deaf parents with infants. As stated in section 4.2, the registered user stories express end-user requirements in a simple language. Therefore, in this section, the labelling of user stories done in Table 4.1 is changed from 'USn' to 'EURTn and EURPn'. 'EURT and EURP' stands for End-User Requirement for Technology and End-User Requirements for Parenting, and 'n' stands for the number (e.g., 01, 02…), respectively.

Table 4.2: End-User Requirements of an Assistive Technology for Profoundly Deaf parents with Infants.

End-User Requirements for Technology (assistive technology functions)
EURT01: As a deaf parent, I want to always be connected to the infant.
EURT02: As a deaf parent, I want to always feel the infant even when out of sight.
EURT03: As a deaf parent, I need to "hear" the infant even when they are out of sight.
EURT04: As a deaf parent, I would like a clearly visible alert when the baby monitor is not in my sight.
EURT05: As a deaf parent, I would like the device to not be affected by water because of my daily housework.
EURT06: As a deaf parent, I need to know when the infant is crying.
EURT07: As a deaf parent, I need to always be connected to the infant even if they are out of sight.
EURT08: As a deaf parent, I want to visually see the infant.
EURT09: As a deaf parent, I would like an alternative alert to audio.
EURT10: As a deaf parent, I would like an appropriate baby monitor.
EURT11: As a deaf parent, I would like products to have tactile alert.

End-User Requirements for Technology (assistive technology functions)
EURT12: As a deaf parent, I would like to receive a clear alert without checking the infant's room.
EURT13: As a deaf parent, I would like to know when noise made by myself causes the infant to cry.
EURT14: As a deaf parent, I would like to interpret sounds so that I can react accordingly.
EURT15: As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them.
EURT16: As a deaf parent, I would like to know when the infant is crying even if the infant is not in my presence.
EURT17: As a deaf parent, I would like to know when the infant makes sound because sounds made by infants are a form of verbal communication.
EURT18: As a deaf parent, I want to "hear" when the infant is crying.

Table 4.3: End-User Requirements Expressing an Overall Goal/Objective to be Achieved.

End-User Requirements for Parenting (parenting goal/objective to be achieved)
EURP01: As a deaf parent, I would like to create a normal environment for the infant.
EURP02: As a deaf parent, I would like to prove myself to the hearing world.
EURP03: As a deaf parent, I want to avoid putting my children at a disadvantage in society.
EURP04: As a deaf parent, I would like to parent independently.

End-User Requirements for Parenting (parenting goal/objective to be achieved)
EURP05: As a deaf parent, I would like to improve my quality of interaction with the infant.
EURP06: As a deaf parent, I would like to receive social support.
EURP07: As a deaf parent, I would like my deafness not to interfere with the development of the child.
EURP08: As a deaf parent, I would like my parents to not take over parental authority.
EURP09: As a deaf parent, I would like professionals to interact with me not bypass me because of my hearing status.
EURP10: As a deaf parent, I would like equal access to education on effective parenting.

4.4 End-User Requirements: User Stories Validation

After the user stories have been translated to end-user requirements of an assistive technology for profoundly deaf parents with infants, validation is required. The process validation will provide an understanding of the accuracy, relevance, completeness, and/or comprehensiveness of the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants. Therefore, in this section validation is done by evaluating the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants. Furthermore, evaluation is done by assessing existing and emerging assistive technologies with the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants.

In this section, only the 18 elicited end-user requirements expressing functions of an assistive technology for profoundly deaf parents with infants, compiled in Table 4.2, will be considered for evaluation. The 10 compiled list of end-user requirements in Table 4.3 will not be considered as they express an overall goal/objective to be achieved rather than a specific function of an assistive technology for profoundly deaf parents with infants. The evaluation is done to assess whether the 18 elicited end-user requirements

that express functions of an assistive technology for profoundly deaf parents with infants are present in the selected existing and emerging assistive technologies.

In Chapter 2 (section 2.3), categories of assistive technologies for deaf people have been provided in Table 2.3. The categories are: 1) assistive listening devices, 2) augmentative and alternative communication devices, and 3) alerting devices. Considering the context of this research, the focus is on alerting devices. Alerting devices are described as devices to alert a deaf person of an event that is taking place in a home environment or around them (National Institude on Deafness and Other Communication Disorders, 2019). Examples of alerting devices include a doorbell, telephone, alarm, blinking light, and infant monitoring device, among others.

In this section, existing and emerging infant monitoring assistive technologies for deaf parents are identified, selected, and assessed. In the context of this research, infant monitoring assistive technologies are products/devices for profoundly deaf parents to monitor infants. The term ‘existing assistive technologies’ refers to baby monitoring products/devices commercially available, that deaf parents with infants can buy and use. The term ‘emerging assistive technologies’ refers to any technologies under development that are specifically for the context of this research.

To conduct a thorough assessment, the specification and purpose of the selected products/devices, the understanding of the elicited end-user requirements, and the understanding of the research context, are key considerations. Table 4.4 provides a criterion description that is applied to assess existing and emerging assistive technologies with the elicited end-user requirements expressing functions of and assistive technology for profoundly deaf parents with infants.

Table 4.4: Assessment Criterion.

Criteria	Description	Representation letter
Product/device does not meet the end-user requirement.	This means all parts of the selected product/device do not meet the elicited end-user requirement.	No(N)

Criteria	Description	Representation letter
Product/device partially meets the end-user requirement.	This means some part of the selected product/device meets the elicited end-user requirement while the other part does not.	Partially (P)
Product/device meets the end-user requirement.	This means all parts of the selected product/device meet the elicited end-user requirement.	Yes(Y)

Sections 4.4.1 and 4.4.2 provide an assessment of existing and emerging products/devices for deaf parents with infants with the elicited end-user requirements expressing functions of an assistive technology for profoundly deaf parents with infants. It is important to note that to assess existing and emerging infant monitoring products/devices, no physical products/devices were used. This research makes use of online data and published literature on existing and emerging infant monitoring products/devices to assess if the elicited end-user requirements express functions of an assistive technology for profoundly deaf parents with infants are met, partially met, or not met. The selection criterion of existing and emerging products/devices was based on the understanding of the context and the products/devices description provided online or through academic literature.

4.4.1 Existing Products/Devices

Using the keyword ‘baby monitoring devices’ to search on Amazon, three infant monitoring products/devices for deaf parents with infants which provide sufficient detail for the assessment were identified and selected. Sections 4.4.1.1 to 4.4.1.3 assesses the selected existing infant monitoring products/devices for deaf parents with infants with the 18 elicited end-user requirements that express functions of an assistive technology for profoundly deaf parents with infants.

4.4.1.1 MonBaby

Table 4.5 provides an assessment of the MonBaby device to ascertain if it meets, partially meets, or does not meet the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants. The MonBaby is a small device that

can be attached to infant's clothes to monitor breathing and movement. The device alerts parents if there is any abnormality, and when the infant rolls over, through a mobile application. The mobile application uses images, text, and sound to alert parents. Figure 4.1 is an image of the MonBaby device to show its design.

Figure 4.1: MonBaby (Amazon, n.d.-b)

Table 4.5: Assessment of the MonBaby Device.

End-User Requirements	MonBaby	Comment
EURT01: As a deaf parent, I want to always be connected to the infant.	Y	The product consists of two devices, a monitoring device on the infant side and a smartphone application on the parent side. The two devices provide the parent-infant connection.
EURT02: As a deaf parent, I want to always feel the infant even when out of sight.	Y	Smartphones can be set to vibrate to allow deaf parents to feel the alerts.
EURT03: As a deaf parent, I need to "hear" the infant even when they are out of sight.	N	The primary function of the device is to monitor breathing and movement of the infant.

End-User Requirements	MonBaby	Comment
EURT04: As a deaf parent, I would like a clearly visible alert when the baby monitor is not in my sight.	Y	The monitoring device uses a smartphone application to provides text and images that are clear for deaf parents to know exactly what is wrong with the infant.
EURT05: As a deaf parent, I would like the device to not be affected by water because of my daily housework.	P	Some smartphones are water resistant. However, on the infant side, the monitoring device's online specification does not provide detail for assessment with the elicited end-user requirement.
EURT06: As a deaf parent, I need to know when the infant is crying.	N	The primary function of the device is to monitor breathing and movement of the infant.
EURT07: As a deaf parent, I need to always be connected to the infant even if they are out of sight.	Y	The product consists of two parts, a monitoring device on the infant side and a smartphone application on the parent side to monitor the infant. Smartphone and monitoring device can connect wirelessly with Bluetooth in a home environment.
EURT08: As a deaf parent, I want to visually see the infant.	N	The primary function of the device is to monitor breathing and movement of the infant.
EURT09: As a deaf parent, I would like an alternative alert to audio.	Y	The monitoring device's smartphone application provides text, vibration, and images as an alternative alert to audio.

End-User Requirements	MonBaby	Comment
EURT10: As a deaf parent, I would like an appropriate baby monitor.	N	The device does not meet the elicited end-user requirement as it does not meet with other elicited end-user requirements such as EURT03 and EURT06, among others.
EURT11: As a deaf parent, I would like products to have tactile alert.	Y	The monitoring device uses a smartphone which can be set to vibrate to provide tactile alert.
EURT12: As a deaf parent, I would like to receive a clear alert without checking the infant's room.	Y	The monitoring device uses a smartphone application that provides clear text and images to alert parents.
EURT13: As a deaf parent, I would like to know when noise made by myself causes the infant to cry.	N	The main function of the device is to monitor breathing and movement of the infant.
EURT14: As a deaf parent, I would like to interpret sounds so that I can react accordingly.	N	The main function of the device is to monitor breathing and movement of the infant.
EURT15: As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them.	Y	The monitoring device provides an alert when something is wrong with the infant such as stopping of breathing.

End-User Requirements	MonBaby	Comment
EURT16: As a deaf parent, I would like to know when the infant is crying even if the infant is not in my presence.	N	The main function of the device is to monitor breathing and movement of the infant.
EURT17: As a deaf parent, I would like to know when the infant makes a sound because sounds made by infants are a form of verbal communication.	N	The main function of the device is to monitor breathing and movement of the infant.
EURT18: As a deaf parent, I want to "hear" when the infant is crying.	N	The main function of the device is to monitor breathing and movement of the infant.

4.4.1.2 Vtech

Table 4.6 provides an assessment of the VTech product to ascertain if it meets, partially meets, or does not meet the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants. The Vtech product consist of two devices, a video camera for monitoring infants and a video feedback device. The product uses the video feedback device to alert parents if there is any abnormality with the infant through video and light for sound. The video feedback device provides video, text, and sound to alert parents. Figure 4.2 is an image of the Vtech monitoring product.

Figure 4.2: Vtech (Amazon, n.d.-c)

Table 4.6: Assessment of the Vtech Product.

End-User Requirements	Vtech	Comment
EURT01: As a deaf parent, I want to always be connected to the infant.	Y	The product consists of two parts, a video feedback device on the parent side and a video camera on the infant side to provide an alert.
EURT02: As a deaf parent, I want to always feel the infant even when out of sight.	N	The product uses audio and video as the primary/main alerting mechanism.
EURT03: As a deaf parent, I need to "hear" the infant even when they are out of sight.	Y	The product uses video as an alternative alerting mechanism for parents.
EURT04: As a deaf parent, I would like a clearly visible alert when the baby monitor is not in my sight.	N	The product uses audio and video as a primary/main alerting mechanism. Parents will need to be looking at the product to know the state of the infant.

End-User Requirements	Vtech	Comment
EURT05: As a deaf parent, I would like the device to not be affected by water because of my daily housework.	N	The product's online specification does not provide detail for assessment with the elicited end-user requirement. Therefore, the product is considered as not meeting the elicited end-user requirement.
EURT06: As a deaf parent, I need to know when the infant is crying.	Y	The product uses a video camera to monitor the infant and provides visual feedback. The visual feedback provides a way for parent to know when infants are crying.
EURT07: As a deaf parent, I need to always be connected to the infant even if they are out of sight.	Y	The product uses a wireless connected device to a video camera to provide visuals for parents to see their infant.
EURT08: As a deaf parent, I want to visually see the infant.	Y	The product uses a video camera to monitor the infant and provides visual feedback to a device.
EURT09: As a deaf parent, I would like an alternative alert to audio.	Y	The product uses video to provide visual feedback as an alternative to audio alerts.
EURT10: As a deaf parent, I would like an appropriate baby monitor.	N	The product does not meet the elicited end-user requirement as it does not meet with other elicited end-user requirements such as EURT02 and EURT04, to name a few.
EURT11: As a deaf parent, I would like	N	The product uses audio and video as the primary/main alerting mechanism.

End-User Requirements	Vtech	Comment
products to have tactile alert.		
EURT12: As a deaf parent, I would like to to receive a clear alert without checking the infant's room.	Y	The product uses video to provide visual feedback of the infant's room.
EURT13: As a deaf parent, I would like to know when noise made by myself causes the infant to cry.	N	The main function of the product is to provide visual feedback of the infant.
EURT14: As a deaf parent, I would like to interpret sounds so that I can react accordingly.	N	The main function of the product is to provide audio alert and visual feedback to parents.
EURT15: As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them.	Y	The product uses video to provide visual feedback of the infant.
EURT16: As a deaf parent, I would like to know when the infant is crying even if the infant is not in my presence.	Y	The product uses video to provide visual feedback of the infant.

End-User Requirements	Vtech	Comment
EURT17: As a deaf parent, I would like to know when the infant makes a sound because sounds made by infants are a form of verbal communication.	P	The product uses video to provide visual alert, however, visual alert alone is not effective.
EURT18: As a deaf parent, I want to "hear" when the infant is crying.	Y	The product uses video as an alternative alerting mechanism for parents to "hear".

4.4.1.3 HelloBaby

Table 4.7 provides an assessment of the HelloBaby product to ascertain if it meets, partially meets, or does not meet the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants. The HelloBaby product consist of two devices, a sound detection device, and a sound transmission device. The product uses sound and sound level lighting to alert parents if the infant is making sounds. The HelloBaby product also provides a two-way communication for parents. Figure 4.3 is an image of the HelloBaby sound monitoring product.

Figure 4.3: HelloBaby (Amazon, n.d.-a)

Table 4.7: Assessment of the HelloBaby Product.

End-User Requirements	HelloBaby	Comment
EURT01: As a deaf parent, I want to always be connected to the infant.	Y	The product consists of two parts, a device to record sounds made by infants, and another device to alert parents. The two devices provide connection between the parent and infant.
EURT02: As a deaf parent, I want to always feel the infant even when out of sight.	N	The primary function of the product is to provide audio alert.
EURT03: As a deaf parent, I need to "hear" the infant even when they are out of sight.	N	The primary function of the product is to provide audio alert.
EURT04: As a deaf parent, I would like a clearly visible alert when the baby monitor is not in my sight.	N	The product requires a parent to always be checking the monitoring device.
EURT05: As a deaf parent, I would like the device to not be affected by water because of my daily housework.	N	The product's online specification does not provide detail for assessment with the elicited end-user requirement. Therefore, the product is considered as not meeting the elicited end-user requirement.
EURT06: As a deaf parent, I need to know when the infant is crying.	Y	The product uses a sound level lighting signal to indicate the level of sound made by the infant.

End-User Requirements	HelloBaby	Comment
EURT07: As a deaf parent, I need to always be connected to the infant even if they are out of sight.	Y	The product uses two devices to provide connection between the parent and infant with a DECT 6.0 digital technology for wireless connection.
EURT08: As a deaf parent, I want to visually see the infant.	N	The primary function of the product is to provide audio alert.
EURT09: As a deaf parent, I would like an alternative alert to audio.	N	The primary function of the product is to provide audio alert.
EURT10: As a deaf parent, I would like an appropriate baby monitor.	N	The product does not meet the elicited end-user requirement as it does not meet with other elicited end-user requirements such as EURT02 and EURT05, to name a few.
EURT11: As a deaf parent, I would like products to have tactile alert.	N	The primary function of the product is to provide audio alert.
EURT12: As a deaf parent, I would like to receive a clear alert without checking the infant's room.	Y	The product uses sound level lighting to provide a clear alert when infants are in a different room.
EURT13: As a deaf parent, I would like to know when noise made	N	The primary function of the product is to monitor sounds made by the infant.

End-User Requirements	HelloBaby	Comment
by myself causes the infant to cry.		
EURT14: As a deaf parent, I would like to interpret sounds so that I can react accordingly.	P	The sound level lighting functionality of the product provides alert for different sound levels made by infants to assist parents in interpreting the sounds. However, the parent may not be able to interpret the sounds accurately and react accordingly.
EURT15: As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them.	Y	The sound level lighting functionality of the product provides alerts for different sound levels.
EURT16: As a deaf parent, I would like to know when the infant is crying even if the infant is not in my presence.	Y	The primary function of the product is to monitor sounds made by the infant.
EURT17: As a deaf parent, I would like to know when the infant makes a sound because sounds made by infants are a form of verbal communication.	Y	The primary function of the product is to monitor sounds made by the infant.

End-User Requirements	HelloBaby	Comment
EURT18: As a deaf parent, I want to "hear" when the infant is crying.	Y	The primary function of the product is to monitor sounds made by the infant.

4.4.2 Emerging Products/Devices

Using the keywords 'infant monitoring deaf parents' to search on Google Scholar, three emerging products/devices were identified and selected. Sections 4.4.2.1 to 4.4.2.3 assesses the selected emerging products/devices with the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants.

4.4.2.1 Fil'O Prototype

Table 4.8 provides an assessment of the Fil'O prototype to ascertain if it meets, partially meets, or does not meet the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants. The name Fil'O means "feel it all the time". The Fil'O prototype is an "interactive design project aiming to assist the parenthood of deaf couples and promote a high-quality parent-infant relationship with their hearing infant" (Ting et al., 2013).

The Fil'O prototype makes use of three devices to alert deaf parents with infants, these devices are: 1) a toy that holds the sensor/detector to record all sounds made by infants; 2) a wearable device that can connect to the sensor/detector; 3) a lamplight to provide more assistance to deaf parents to indicate when the infant is crying. Since deaf parents cannot hear sound, the Fil'O prototype makes use of colours and sound spikes to represent the multiple sounds made by the infant. According to the designers of the Fil'O, a blue wavelet represents a comfortable status while red signals an alarm. Figure 4.4 is a graphical representation of how the Fil'O prototype works.

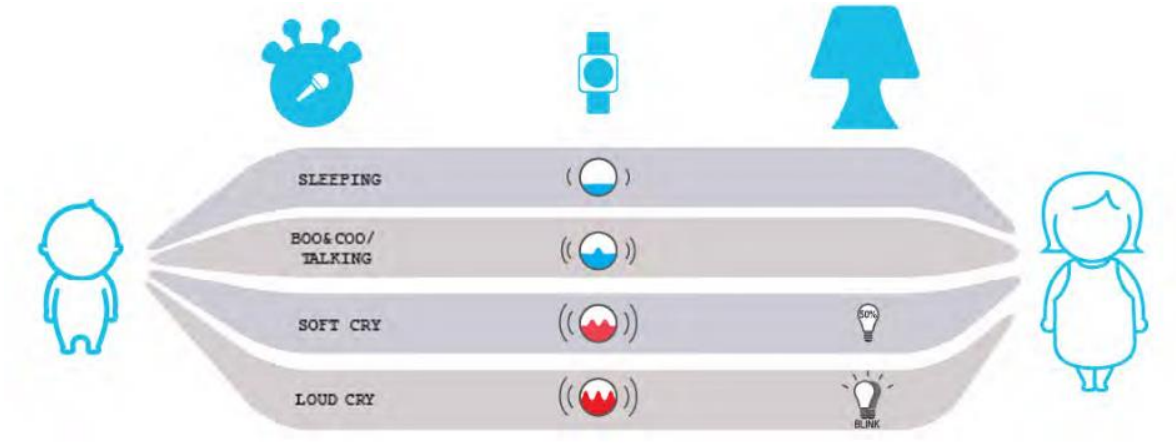

Figure 4.4: Fil'O Prototype Prompting and Alarming Mechanisms (Ting et al., 2013)

Table 4.8: Assessment of the Fil'O Prototype

End-User Requirements	Fil'O	Comment
EURT01: As a deaf parent, I want to always be connected to the infant.	Y	The prototype uses two devices (a sound detector and a wearable watch) to provide connection between the deaf parent and infant.
EURT02: As a deaf parent, I want to always feel the infant even when out of sight.	Y	The prototype uses a vibrating wearable watch for deaf parents to feel alerts.
EURT03: As a deaf parent, I need to "hear" the infant even when they are out of sight.	Y	The wearable watch provides vibration or tactile alert for deaf parents to "hear" when the infant makes sounds.
EURT04: As a deaf parent, I would like a clearly visible alert when the baby monitor is not in my sight.	Y	The prototype includes ambient lighting devices, and a wearable watch that uses different colours to alert deaf parents of different states of the infant.

End-User Requirements	Fil'O	Comment
EURT05: As a deaf parent, I would like the device to not be affected by water because of my daily housework.	P	The prototype consists of two devices. The wearable watch for the deaf parent is water resistant. However, the design description of the sensor/detector attached to the infant does not provide details regarding water resistance.
EURT06: As a deaf parent, I need to know when the infant is crying.	Y	The prototype's sensor/detector, ambient lighting devices, and wearable watch provide a signal alert for deaf parents to know if the infant is crying.
EURT07: As a deaf parent, I need to always be connected to the infant even if they are out of sight.	Y	The prototype uses two devices (a sound detector and a wearable watch) to provide a wireless connection between the deaf parent and infant through an XBee radio module.
EURT08: As a deaf parent, I want to visually see the infant.	N	The primary/main function of the prototype is to monitor sounds made by infants.
EURT09: As a deaf parent, I would like an alternative alert to audio.	Y	The prototype provides visual and tactile alerts as an alternative to audio.
EURT10: As a deaf parent, I would like an appropriate baby monitor.	P	The prototype partially meets the elicited end-user requirement but does not meet all elicited end-user requirements.
EURT11: As a deaf parent, I would like	Y	The prototype uses a vibrating wearable device to provide a tactile alert.

End-User Requirements	Fil'O	Comment
products to have a tactile alert.		
EURT12: As a deaf parent, I would like to receive a clear alert without checking the infant's room.	Y	The prototype provides a wearable, visual, and lighting signals as part of the alert system.
EURT13: As a deaf parent, I would like to know when noise made by myself causes the infant to cry.	N	The primary/main function of the prototype is to monitor sounds made by infants.
EURT14: As a deaf parent, I would like to interpret sounds so that I can react accordingly.	P	The prototype monitors different sounds made by infants and provides alerts based on sound levels. However, the parent may not be able to interpret the sounds accurately.
EURT15: As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them.	Y	The prototype provides an alert when the infant is making sounds.
EURT16: As a deaf parent, I would like to know when the infant is crying even if the infant is not in my presence.	Y	The prototype provides an alert when the infant is making sounds (includes crying).

End-User Requirements	Fil'O	Comment
EURT17: As a deaf parent, I would like to know when the infant makes a sound because sounds made by infants are a form of verbal communication.	Y	The prototype provides an alert when the infant is making sounds.
EURT18: As a deaf parent, I want to "hear" when the infant is crying.	Y	The wearable watch provides vibration or a tactile alert when the infant makes sounds.

4.4.2.2 Infant Monitoring System for Deaf Parents

Table 4.9 provides an assessment of the Infant Monitoring System for deaf parents to ascertain if it meets, partially meets, or does not meet the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants. The Infant Monitoring System for deaf parents is designed to identify the infant's cry by using a microphone and an Artificial Neural Network algorithm (Mohite & Jadhav, 2021). The system allows a deaf parent to be able to identify sounds, including sounds made by infants, and convert them to recognisable alerts such as messaging, LED lighting, and vibration. Figure 4.5 is a graphical representation of how the Infant Monitoring System for deaf parents works.

The Infant Monitoring System for deaf parents makes use of mobile phone and LED lighting within the system for alerts, with 2000 sound samples, and a speech recognition system. Furthermore, the Infant Monitoring System for deaf parents uses the Artificial Neural Network algorithm to interpret different sounds, especially sounds made by infants. The system can be used to alert deaf parents at "homes, day care centres, schools, and hospitals" to name a few (Mohite & Jadhav, 2021, p. 533).

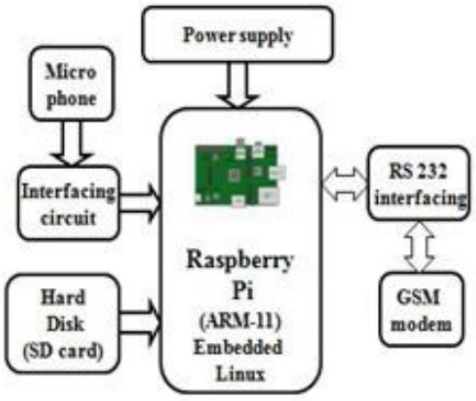

Figure 4.5: Infant Monitoring System for Deaf Parents (Mohite & Jadhav, 2021)

Table 4.9: Assessment of the Infant Monitoring System for Deaf Parents

End-User Requirements	IMSDP	Comment
EURT01: As a deaf parent, I want to always be connected to the infant.	Y	The prototype uses a device and a cell phone to provide an alert.
EURT02: As a deaf parent, I want to always feel the infant even when out of sight.	Y	The prototype uses a cell phone which the parent can use to receive alerts. Cell phones can be set to vibrate to provide deaf people with an alert.
EURT03: As a deaf parent, I need to "hear" the infant even when they are out of sight.	Y	The prototype's main functionality is to send a text message to deaf parents as an alert when the infant makes a sound. Cell phones can be set to vibrate to provide deaf parents with a way to "hear" infants.
EURT04: As a deaf parent, I would like a clearly visible alert when the baby monitor is not in my sight.	Y	The prototype sends clear text messages as an alert for deaf parents.

End-User Requirements	IMSDP	Comment
EURT05: As a deaf parent, I would like the device to not be affected by water because of my daily housework.	P	Some cell phones are water resistant. However, the design of the prototype for detecting sounds made by infants does not provide detail of whether it is water resistant.
EURT06: As a deaf parent, I need to know when the infant is crying.	Y	The prototype provides text as an alert to notify deaf parents when the infant is crying.
EURT07: As a deaf parent, I need to always be connected to the infant even if they are out of sight.	Y	The prototype uses a mobile phone and a device, connected by a GSM Modem for sending text.
EURT08: As a deaf parent, I want to visually see the infant.	N	The prototype's main function is to send a text message as an alert.
EURT09: As a deaf parent, I would like an alternative alert to audio.	Y	The prototype provides text as an alternative alert to audio.
EURT10: As a deaf parent, I would like an appropriate baby monitor.	P	The prototype partially meets the elicited end-user requirement but does not meet all elicited end-user requirements.
EURT11: As a deaf parent, I would like products to have a tactile alert.	Y	The prototype provides text messages as an alert through a cell phone number. Cell phones can be set to vibrate to provide tactile alerts.

End-User Requirements	IMSDP	Comment
EURT12: As a deaf parent, I would like to receive a clear alert without checking the infant's room.	Y	The text message provides a clear alert of what is wrong with the infant.
EURT13: As a deaf parent, I would like to know when noise made by myself causes the infant to cry.	N	The prototype's main function is to monitor sounds made by the infant.
EURT14: As a deaf parent, I would like to interpret sounds so that I can react accordingly.	Y	The prototype uses an Artificial Neural Network to interpret sounds made by an infant and sends a text message to deaf parents of what kind of sound the infant is making.
EURT15: As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them.	Y	The prototype uses an Artificial Neural Network to interpret sounds made by an infant and sends a text message to deaf parents of what kind of sound the infant is making.
EURT16: As a deaf parent, I would like to know when the infant is crying even if the infant is not in my presence.	Y	The prototype uses an Artificial Neural Network to interpret sounds made by an infant and sends a text message to deaf parents of what kind of sound the infant is making.
EURT17: As a deaf parent, I would like to	Y	The prototype uses an Artificial Neural Network to interpret sounds made by an

End-User Requirements	IMSDP	Comment
know when the infant makes a sound because sounds made by infants are a form of verbal communication.		infant and sends a text message to deaf parents of what kind of sound the infant is making.
EURT18: As a deaf parent, I want to "hear" when the infant is crying.	Y	The prototype's main functionality is to send a text message as an alert when the infant makes sounds.

4.4.2.3 Infant Care System

Table 4.10 provides an assessment of the "Infant Care System" for deaf parents to ascertain if it meets, partially meets, or does not meet the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants. The "Infant Care System" is a prototype developed on an Arduino Uno board. The prototype consists of sensors and hardware devices to display infants' condition. Furthermore, the prototype for the "Infant Care System" monitors infants' temperature, moisture content, and the infant's voice. To alert deaf parents, the "Infant Care System" prototype makes use of vibration and text. Figure 4.6 is a graphical representation of the prototype for the "Infant Care System".

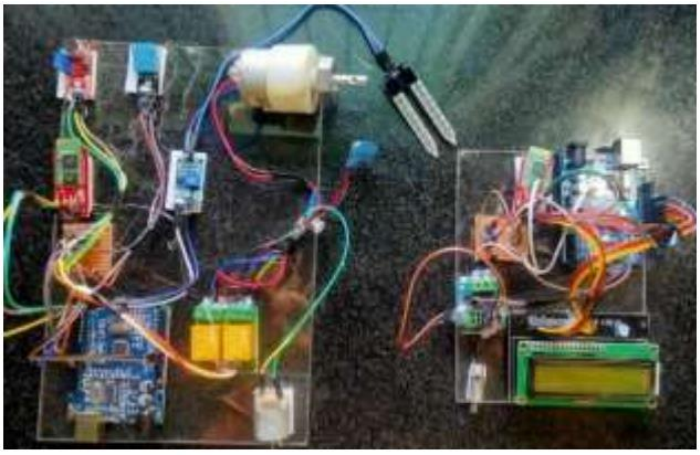

Figure 4.6: Infant Care System (Lakshmi et al., 2021)

Table 4.10: Assessment of the Infant Care System

End-User Requirements	ICS	Comment
EURT01: As a deaf parent, I want to always be connected to the infant.	Y	The prototype uses two devices connected wirelessly to provide an alert.
EURT02: As a deaf parent, I want to always feel the infant even when out of sight.	Y	The prototype uses two devices (transmitter on the infant side and receiver on the parent side) for alerts. The receiver can vibrate to allow deaf parents to feel an alert.
EURT03: As a deaf parent, I need to "hear" the infant even when they are out of sight.	Y	The prototype's main functionality is to provide a text and vibration to deaf parents as an alert when the infant is not in front of them
EURT04: As a deaf parent, I would like a clearly visible alert when the baby monitor is not in my sight.	Y	The prototype provides a clear text as an alert for deaf parents.
EURT05: As a deaf parent, I would like the device to not be affected by water because of my daily housework.	N	The product is still in a prototype stage developed on an Arduino Uno board.
EURT06: As a deaf parent, I need to know when the infant is crying.	Y	The Prototype provides text and vibration as an alert to notify deaf parents when the infant is crying.
EURT07: As a deaf parent, I need to always be connected to the infant	Y	The prototype uses two devices connected by Bluetooth.

End-User Requirements	ICS	Comment
even if they are out of sight.		
EURT08: As a deaf parent, I want to visually see the infant.	N	The prototype's main function is to send a text and provide vibration as an alert.
EURT09: As a deaf parent, I would like an alternative alert to audio.	Y	The prototype provides text and vibration as an alternative alert to audio.
EURT10: As a deaf parent, I would like an appropriate baby monitor.	P	The prototype partially meets the elicited end-user requirement, but it does not meet all elicited end-user requirements.
EURT11: As a deaf parent, I would like products to have a tactile alert.	Y	The product provides vibration as an alert.
EURT12: As a deaf parent, I would like to receive a clear alert without checking the infant's room.	Y	The text provides a clear alert of what is wrong with the infant.
EURT13: As a deaf parent, I would like to know when noise made by myself causes the infant to cry.	N	The prototype's main function is to monitor infants.
EURT14: As a deaf parent, I would like to	P	The prototype monitors sounds made by infants and will provides an alert based on

End-User Requirements	ICS	Comment
interpret sounds so that I can react accordingly.		sound levels. However, the parent may not be able to interpret the sounds accurately.
EURT15: As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them.	Y	The prototype provides an alert when there is something wrong with the infant or the infant is making sounds.
EURT16: As a deaf parent, I would like to know when the infant is crying even if the infant is not in my presence.	Y	The prototype uses two devices connected by Bluetooth to provide an alert for deaf parents.
EURT17: As a deaf parent, I would like to know when the infant makes a sound because sounds made by infants are a form of verbal communication.	Y	The prototype provides an alert when the infant is making sounds.
EURT18: As a deaf parent, I want to "hear" when the infant is crying.	Y	The prototype provides tactile alerts for deaf parents to "hear" when infant cries.

4.5 Discussion: Lessons Learnt

In the 'stories' registration and validation' step (Step 4) of the *User Stories* method, user stories are validated through a discussion between the usability and engineering teams. In this research, validation of user stories was not conducted due to the nature of data collection. However, as an alternative to validation of user stories, an evaluation of the elicited end-user requirements of an assistive technology for profoundly deaf parents

with infants was done by assessing existing and emerging assistive technologies. The assessment was done to provide an understanding of the completeness, accuracy, relevance, and/or comprehensiveness of the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants. The evaluation therefore contributes to the validation of user stories. Table 4.11 provides a summary of the assessment done for existing and emerging infant monitoring products/devices.

Table 4.11: Summary Assessment of Existing and emerging products/devices

End-User Requirements	MonBaby	Vtech	HelloBaby	Fil'O	IMSDP	ICS
EURT01: As a deaf parent, I want to always be connected to the infant.	Y	Y	Y	Y	Y	Y
EURT02: As a deaf parent, I want to always feel the infant even when out of sight.	Y	N	N	Y	Y	Y
EURT03: As a deaf parent, I need to "hear" the infant even when they are out of sight.	N	Y	N	Y	Y	Y
EURT04: As a deaf parent, I would like a clearly visible alert when the baby monitor is not in my sight.	Y	N	N	Y	Y	Y
EURT05: As a deaf parent, I would like the device to not be	P	N	N	P	P	N

End-User Requirements	MonBaby	Vtech	HelloBaby	Fil'O	IMSDP	ICS
affected by water because of my daily housework.						
EURT06: As a deaf parent, I need to know when the infant is crying.	N	Y	Y	Y	Y	Y
EURT07: As a deaf parent, I need to always be connected to the infant even if they are out of sight**.**	Y	Y	Y	Y	Y	Y
EURT08: As a deaf parent, I want to visually see the infant.	N	Y	N	N	N	N
EURT09: As a deaf parent, I would like an alternative alert to audio.	Y	Y	N	Y	Y	Y
EURT10: As a deaf parent, I would like an appropriate baby monitor.	N	N	N	P	P	P
EURT11: As a deaf parent, I would like products to have tactile alert.	Y	N	N	Y	Y	Y

End-User Requirements	MonBaby	Vtech	HelloBaby	Fil'O	IMSDP	ICS
EURT12: As a deaf parent, I would like to receive a clear alert without checking the infant's room.	Y	Y	Y	Y	Y	Y
EURT13: As a deaf parent, I would like to know when noise made by myself causes the infant to cry.	N	N	N	N	N	N
EURT14: As a deaf parent, I would like to interpret sounds so that I can react accordingly.	N	N	P	P	Y	P
EURT15: As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them.	Y	Y	Y	Y	Y	Y
EURT16: As a deaf parent, I would like to know when the infant is crying even if the infant is not in my presence.	N	Y	Y	Y	Y	Y
EURT17: As a deaf parent, I would like to	N	P	Y	Y	Y	Y

End-User Requirements	MonBaby	Vtech	HelloBaby	Fil'O	IMSDP	ICS
know when the infant makes sound because sounds made by infants are a form of verbal communication.						
EURT18: As a deaf parent, I want to "hear" when the infant is crying.	N	Y	Y	Y	Y	Y
Total (Y)	Y: 8	Y: 10	Y: 8	Y: 13	Y: 14	Y: 13
Total (N)	N: 9	N: 7	N: 9	N: 2	N: 2	N: 3
Total (P)	P: 1	P: 1	P: 1	P: 3	P: 2	P: 2

The total numbers of elicited end-user requirements not met by the selected existing products/devices (N: 9, N: 7, and N: 9) is higher than the total numbers of elicited end-user requirements not met by the 3 selected emerging products/devices (N: 2, N: 2, and N: 3). The high number of elicited end-user requirements not met by existing products/devices provides an understanding that existing products/devices were initially not developed for the context of deaf parents with infants. Furthermore, emerging products/devices have low numbers on elicited end-user requirements not met because the research conducted was specific to the context of deaf parents with infants. However, even though emerging products/devices identified are being researched for the context of deaf parents with infants, they still fall short of the elicited end-user requirements in this research.

In Table 4.11, one elicited end-user requirement (EURT13) was not met by all selected existing and emerging products/devices. EURT13 indicates: "as a deaf parent, I would like to know when noise made by myself causes the infant to cry". EURT13 in summary provides an understanding that profoundly deaf parents with infants want products/devices that will not only alert them of noises made by infants, but also alert

them of noises made by themselves which may cause the state of the infant to change. Furthermore, EURT13 provides insight on the importance of user involvement early in the development of new assistive technologies. The involvement of end-users will allow developers to gain an understanding of what users really need directly from them. This will improve the quality of requirements being elicited instead of using what Blackburn and Cudd (2012) describe as a 'common-sense' approach to understanding users' needs.

In Table 4.11, four elicited end-user requirements (EURT01, EURT07, EURT12, and EURT15) were met by all selected existing and emerging products/devices. EURT01 indicates: "as a deaf parent, I want to always be connected to the infant"; EURT07 indicates: "as a deaf parent, I need to always be connected to the infant even if they are out of sight", EURT12 indicates: "as a deaf parent, I would like a clear alert without checking the infant's room", and EURT15 indicates: "As a deaf parent, I would like to be aware of the state of the infant without having to constantly check up on them". The four elicited end-user requirements in summary provide an understanding that all deaf parents want to be connected to the infants at all times, even if the infant is not in their presence. Furthermore, deaf parents want a clear alert from the products/devices about the state of the infant. Since all selected existing and emerging products/devices meet four elicited end-user requirements, the four elicited end-user requirements can be considered as base end-user requirements of an assistive technology for profoundly deaf parents with infants.

In Table 4.11, a range between 8 to 14 elicited end-user requirements were met by existing and emerging products/devices, with the "Infant Monitoring System for deaf parents" meeting the most (14 out of 18) elicited end-user requirements among all selected products/devices. Therefore, the process fulfilled in this research to elicit end-user requirements resulted in an accurate, complete, relevant, and comprehensive set of end-user requirements of an assistive technology for profoundly deaf parents with infants.

In summary, the assessment revealed that baby monitors:

- Provide a way for deaf parents to always stay connected and alerted of the state of the infant, even when the infant is out of sight of the parent.

- Are an alternative to audio, which is not usable to profoundly deaf parents, to enable them to “hear” infants.

The assessment also revealed that baby monitors:

- Sometimes uses audio as the main prompting mechanism, which is not usable to profoundly deaf parents.
- Cannot differentiate sounds made by infants such as laughing, crying, and cooing.
- Cannot differentiate when the sounds are NOT being made by the infant (i.e., by the parent or someone else)
- Are not effective when the infant is out of sight of the parent.

4.6 Conclusion

Chapter 4 elicited end-user requirements of an assistive technology for profoundly deaf parents with infants by applying the recommended method in Chapter 2 with the *needs* and *challenges* extracted in Chapter 3 as input. Thereafter, Chapter 4 evaluated the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants to provide an understanding of the completeness, accuracy, relevance, and comprehensiveness of the elicited requirements. In Chapter 5, a conclusion to this research will be provided.

CHAPTER 5

5. CONCLUSION

In Chapter 4, end-user requirements of an assistive technology for deaf parents with infants were elicited. Thereafter, the elicited end-user requirements were evaluated by assessing existing and emerging assistive technologies to gain a better understanding of the completeness, accuracy, relevance, and comprehensiveness of the elicited end-user requirements. Chapter 5 will provide the research summary, discuss the achievement of objectives, limitations, and recommendations for further research.

Chapter 5 is structured as follows:

Section	Header
5.1.	Background
5.2.	Research Summary
5.3.	Achievement of Objectives
5.4.	Limitations
5.5.	Recommendation
5.6.	Future Research
5.7.	Conclusion

5.1 Background

In this research study, the problem identified is a lack of understanding of end-user requirements of an assistive technology for profoundly deaf parents with infants. The literature clearly identifies that existing assistive technologies are not suitable for the context of deaf parents with infants. Therefore, the main objective of this research was to compile end-user requirements on an assistive technology for profoundly deaf parents with infants. To achieve the main objective, the researcher first identified a method appropriate for eliciting end-user requirements for assistive technologies. Thereafter, the *needs* and *challenges* of profoundly deaf parents with infants were extracted; and finally, end-user requirements of an assistive technology for profoundly deaf parents with infants were elicited. Accordingly, the main objective and the problem identified were achieved and addressed.

5.2 Research Summary

In this section, the achievements of the research objectives are discussed and summarised. The summary is achieved by discussing what was done in each chapter.

5.2.1 Chapter 1: Introduction

In this chapter, a brief background and understanding on the disability of hearing impairment and assistive technologies was presented. The chapter also provided a discussion of the research context, problem identified, objectives, methodology, and dissertation structure.

5.2.2 Chapter 2: Requirements Elicitation for Assistive Technologies

In this chapter, an overview of the assistive technologies, from general understanding to the specific context of deaf people, was provided. The chapter also provided a discussion of the concept of technology abandonment, and the importance of user involvement when developing new assistive technologies. The chapter concluded by recommending a suitable end-user requirements elicitation method specifically for assistive technologies. Thereafter, the recommended end-user requirements elicitation method for assistive technologies was modified to fit the deaf context.

5.2.3 Chapter 3: Needs and Challenges of Profoundly Deaf parents with Infants

In this chapter, literature was identified to extract *needs* and *challenges* of profoundly deaf parents with infants. Through literature review, applying filtering options and

selection criteria, three academic papers were identified and selected to extract the *needs* and *challenges* of profoundly deaf parents with infants. The three selected academic papers were read multiple times to highlight and record the *needs* and *challenges* of profoundly deaf parents with infants. Thereafter, themes were constructed using the extracted *needs* and *challenges* of profoundly deaf parents with infants. The themes with repeating ideas that captured important data were further organised and grouped, which resulted in two main themes being created. The two main themes created were Technology and Parenting. The Technology main theme organises all the needs and challenges of profoundly deaf parents with infants that are technology related, and the Parenting theme organises all the needs and challenges of profoundly deaf parents with infants that are related to parenting an infant.

5.2.4 Chapter 4: End-User Requirements of an Assistive Technology for Profoundly Deaf Parents with Infants

In this chapter, end-user requirements for an assistive technology for deaf parents with infants are elicited. End-user requirements elicitation is done by applying the recommended end-user requirements elicitation method for assistive technologies in Chapter 2, with the *needs* and *challenges* of profoundly deaf parents with infants extracted in Chapter 3 as input. This process resulted in two categories of end-user requirements. The first category of elicited end-user requirements expresses functions of an assistive technology for profoundly deaf parents with infants, and the second category expresses an overall objective to be attained by profoundly deaf parents with infants.

For the purpose of this research, only the category of elicited end-user requirements expressing functions of an assistive technology for profoundly deaf parents with infants were considered for evaluation. The evaluation was done by assessing existing and emerging assistive technologies to provide an understanding of the comprehensiveness of the elicited end-user requirements of an assistive technology for profoundly deaf parents with infants.

5.2.5 Chapter 5: Conclusion

In this chapter, a summary of the research, how the objectives were achieved, trustworthiness of the research, limitations to the research, and recommendations for future research are discussed.

5.3 Achievement of Objectives

The main objective of this research was:

Main Objective
To determine end-user requirements of an assistive technology for deaf parents with infants.

To achieve the main objective, sub-objectives formulated were:

Sub-Objectives
Sub-objective 1: To identify method(s) for eliciting end-user requirements for assistive technologies. This sub-objective was achieved in Chapter 2 by conducting a literature review to understand the different approaches that are available to elicit end-user requirements for assistive technologies. With the use of logical argumentation, a method for eliciting end-user requirements from deaf people was recommended.
Sub-Objective 2: To extract the needs and challenges of profoundly deaf parents with infants. This sub-objective was achieved in Chapter 3 by conducting an integrative literature review to review, critique, and synthesise relevant literature, along with thematic analysis to analyse and organise the extracted needs and challenges of profoundly deaf parents with infants into themes.
Sub-Objective 3: To elicit end-user requirements of an assistive technology for profoundly deaf parents with infants. This sub-objective was achieved in Chapter 4 by applying the recommended method for eliciting end-user requirements for assistive technologies in Chapter 2, and the *needs* and *challenges* of profoundly deaf parents with infants extracted in Chapter 3 as input to elicit end-user requirements of an assistive technology for profoundly deaf parents with infants.

In conclusion, the main objective of this research was achieved.

5.4 Evaluating Trustworthiness of the Research

Researchers often talk about two types of research, quantitative and qualitative research. Quantitative research is considered as a type of research that deals primarily with numerical data to produce findings using statistical procedures (Golafshani, 2015; and Leung, 2015). Qualitative research is the opposite, it is considered as a type of research that seeks to understand the real-world by providing answers to the “how, where, when, who, and why” questions (Golafshani, 2015; Leung, 2015; and Shenton, 2004). In this research, a qualitative research paradigm was followed, no statistical procedures were used to produce findings; the main objective was to provide an understanding. In this research, the term ‘findings’ refers to both methods and results.

A good qualitative study helps to understand situations that are considered as difficult to interpret or that are confusing (Golafshani, 2015). Therefore, to persuade an audience that research findings are worthwhile, research should be based on 2 key concepts of reliability and validity (Cypress, 2017). Golafshani (2015) referred to Joppe’s definition of reliability and validity. Joppe defines reliability as a concept of evaluating the replicability and accuracy of the results over time, and explains validity as a concept of measuring the truthfulness of the results (Golafshani, 2015). However, while the concepts of validity concerns replicability of the results and validity concerns the means of measuring accuracy of the results, the two concepts are not relevant in qualitative research (Cypress, 2017; and Golafshani, 2015). Furthermore, the two concepts are treated separately in quantitative research, while in qualitative research the two concepts are linked(Golafshani, 2015).

Lincoln and Guba’s crucial work in the 1980s replaced the two concepts of reliability and validity with ‘‘trustworthiness’’ (Cypress, 2017). Trustworthiness refers to quality, authenticity, and truthfulness of findings to ensure that the research process is carried out correctly (Cypress, 2017). While the concepts of reliability and validity are crucial criteria to evaluate trustworthiness in quantitative research, Lincoln and Guba’s work from 1985 introduced credibility, transferability, dependability, and confirmability as criterion for evaluating trustworthiness in qualitative research (Shenton, 2004; and Nowell, Norris, White, & Moules, 2017). This research has also adopted the criterion introduced by Lincoln and Guba to evaluate its trustworthiness. This section defines the trustworthiness criteria and discusses how the researcher conducted trustworthy research.

5.4.1 Credibility

Lincoln and Guba's work from 1985 suggested several techniques to address credibility in research (Shenton, 2004). The following techniques for evaluating credibility of the research have been adopted in this research to provide evidence that the research is trustworthy.

5.4.1.1 The adoption of well-established research methods

To ensure credibility, methods for data collection and analysis should be derived from those that have been successfully employed (Shenton, 2004). In this research, methods employed to obtain the desired data are derived from existing methods discussed in literature, and have been successfully employed in different contexts. Chapter 3 and Chapter 4 identified, discussed, and employed these well-established methods suitable for the research context.

5.4.1.2 Triangulation

To ensure credibility, the strategy of triangulation can be employed. Triangulation is "the combination of two or more data sources, investigators, methodologic approaches, theoretical perspectives, or analytical methods within the same study" (Thurmond, 2001, p.253). Furthermore, Denzin's work on triangulation in 1970 identified four types of triangulation (Carter, Bryant-Lukosius, Dicenso, Blythe, & Neville, 2014; and Thurmond, 2001). The 4 types of triangulation are data sources, investigator, methodologic, and theoretical triangulation (Carter et al., 2014; and Thurmond, 2001). Table 5.1 provides further detail on the types of triangulation as discussed by Carter et al., (2014) and Thurmond (2001).

Table 5.1: Types of Triangulation (Carter et al., 2014; and Thurmond, 2001, p. 254)

Type	Description
Data Sources	Involves the use of multiple data sources to gain multiple perspectives and validation.
Researcher	Involvement of multiple researchers in one study.
Methodologic	The combination of multiple data collection methods about the same phenomenon. Methodologic triangulation refer to "either data collection methods or research designs".

Type	Description
	Furthermore, methodologic triangulation can "be classified into two types: within-method triangulation and between- or across-method triangulation". within-method triangulation combines data collection methods, quantitative or qualitative, but not both. Between- or across method triangulation combines both quantitative and qualitative data collection methods.
Theoretical	The use of different theories to analyse and interpret data.

This research employed three methods of triangulation, 1) data source triangulation, 2) researcher triangulation, and 3) within methodologic triangulation. To ensure credibility of the research from the beginning, researcher and supervisor had constant meetings. In Chapter 3 (section 3.1, 3.2, and 3.4), data source and within methodologic triangulation were employed due to a lack of published literature on this topic, and to benefit from all selected methods due to their individual limitations.

5.4.1.3 Frequent debriefing sessions

Frequent discussion between the researcher and supervisor or project director is another way of ensuring research credibility (Shenton, 2004). In this research, frequent discussions with the research supervisor ensured that researcher bias was minimised, and relevant methods were employed for collecting, analysing, and interpreting data. Therefore, in Chapter 2 and Chapter 3, after multiple discussions between the researcher and supervisor, suitable methods for the context of this research were identified and employed.

5.4.1.4 Use of reflective commentary by researcher

To ensure credibility, evaluation of the research as it develops can be done through a reflective commentary (Shenton, 2004). Furthermore, part of reflective commentary may be "devoted to the effectiveness of the techniques that have been employed" (Shenton, 2004, p.68). In Chapter 4 (section 4.3), reflective commentary on the effectiveness of the methods employed in Chapter 3, is provided. Furthermore, the use of a researcher diary to take notes as the research progressed, and during the frequent debriefing sessions with the supervisor, was another form of reflective commentary. This diary

forms part of the audit trail (Shenton, 2004), which is a part of trustworthiness in qualitative research.

5.4.1.5 Thick description of the phenomenon under scrutiny

To ensure credibility, a detailed description of the research context to provide insight for readers is required to evaluate the extent to which the findings convey the actual situation investigated (Shenton, 2004). Throughout this research, detailed descriptions of the context, decisions made, and reporting are provided. Chapter 1 and Chapter 2 provided a detailed discussion to understand the context of the research. Furthermore, Chapter 2 and Chapter 3 provided detailed insight for readers to understand the actual situation being investigated. Finally, Chapter 2, Chapter 3, and Chapter 4 provided detailed discussion for readers to evaluate the trustworthiness of the findings.

5.4.1.6 Examination of previous research findings

To ensure credibility, the ability of the researcher to relate the research findings with existing knowledge is crucial (Shenton, 2004). In Chapter 1, previous research findings were used to provide an understanding of the research background and context, to formulate an appropriate research question and objectives. In Chapter 2 and 3, previous research findings were used to identify and discuss suitable methods for the context of this research. Furthermore, previous research findings in Chapter 2 and 3 were used to provide a better understanding of the research context to assist the researcher in identifying and selecting appropriate methods. Thereafter, in Chapter 3 and 4, appropriate methods suitable for the context of this research were selected and employed to achieve research objectives. In Chapter 4, previous research findings were also used to compare the findings of this research and to provide an understanding of the trustworthiness of the results.

5.4.2 Transferability

One of the key criteria for transferability in research is external validity, which “is concerned with the extent to which the findings of one study can be applied to other situations” (Shenton, 2004, p.69). This research is specific to a segment of the group of people under study and their specific situation. This includes how the data was collected, analysed, interpreted, and recorded. However, part of the findings discussed in Chapter 4 (section 4.5), can be generalised beyond the research context and the group under study. Furthermore, the methods identified can also be generalised to similar contexts and situations. In Chapter 2, the method identified which was employed

in Chapter 3 and Chapter 4, can be employed in other contexts involving the group of people under study. In Chapter 3, the alternative methods identified for data collection and analysis can be generalised to other studies with similar situations. The detailed reporting of the research process ensures that other researchers can evaluate the transferability of the research.

5.4.3 Dependability

Dependability refers to the detailed reporting of what was done to enable future researchers to repeat the research (Shenton, 2004). In Chapter 2 (section 2.7), a suitable method for the context of this research was identified. Thereafter, to allow future researchers to repeat the research, detailed reporting of what was done step-by-step is provided in Chapter 3 and Chapter 4. Furthermore, Chapter 3 identified suitable methods for data collection and analysis which were discussed in detail, including what was done in each step, which can assist future researchers to repeat the study. The detailed reporting provided in this research is not concerned with the dependability of the methods employed, it also pertains to the results of the study. Therefore, the findings of this research can be applied in a similar context. Furthermore, if the research is repeated under the same conditions, future researchers should be able to compare their results with the results of this research study to evaluate dependability.

5.4.4 Confirmability

Confirmability helps to ensure that the research findings represent the experiences and ideas of the people involved in the study and assists to reduce researcher bias (Shenton, 2004). The research study was conducted during the challenging period of the Covid-19 pandemic. Therefore, as described in Chapter 3, alternative methods were employed to ensure that the experiences and ideas of the people under study were incorporated without direct engagement. Chapter 3 provides a detailed step-by-step discussion of how the data was collected and analysed. In Chapter 4, due to the nature of the data collection in Chapter 3, an alternative method was employed to compensate the shortcomings in the final step of the method identified in Chapter 2. The use of triangulation and frequent debriefing sessions with the supervisor opened a discussion to ensure that the methods selected were relevant to the context of the research and that researcher bias was reduced to enable results that are trustworthy.

5.5 Limitations

Due to the outbreak of Covid-19, this research study did not involve any participants. The data used was extracted from literature. Therefore, the delimitation identified in section 1.5 limited the nature of data that could be considered in this research. This limitation can be addressed in future research as discussed in section 5.8.

5.6 Recommendation

To minimise assistive technology abandonment by the intended users, assistive technology developers/manufacturers must fit the user to the technology instead of attempting to fit the technology to the user. Therefore, the lessons learnt from this research will need to be communicated to assistive technology developers/manufacturers to yield an impact to future devices. The assessment done in this research can be useful to deaf parents to assess an assistive technology as choose the one that meets their needs best.

5.7 Contribution

The contribution of this research project provides an approach for eliciting and documenting end-user requirements where: 1) the focus is on assistive technologies, 2) participant interaction is not possible, 3) literature review is the only data collection method, 4) the researcher's aim is to understand the experiences and reality of the selected group of participants, and 5) where there is dearth of published literature. This approach consists of 1) a *User Stories* method as a new approach to elicit and document end-user requirements for assistive technologies, 2) an integrative literature review as a guide to document the literature review process in an area where there is dearth of published literature, and 3) thematic analysis of the data. The contribution also provides a useful assessment tool for deaf parents to choose assistive devices that best suits their needs. Furthermore, the main objective of this research provided baseline end-user requirements that assistive technology developers/manufacturers can implement in future assistive devices to accommodate profoundly deaf parents with infants. The assessment of existing and emerging products done in this research can be useful to deaf parents.

5.8 Future Research

The elicited end-user requirements can be used to develop a prototype which profoundly deaf parents with infants can assess the efficacy. The elicited end-user

requirements can also be used to develop programmes targeted at deaf parents with infants.

5.9 Conclusion

The focus of this research is on assistive technologies as a tool to assist profoundly deaf parents with infants. A commonly available solution used in this context is the is a baby monitoring device. However, current available baby monitoring devices were initially not developed for profoundly deaf parents with infants. Therefore, may mis important requirements to fit into the deaf context.

The objective of the research was to compile end-user requirements of an assistive technology for profoundly deaf parents with infants. The research made use of the *User Stories* method as a suitable approach for eliciting end-user requirements when developing assistive technologies. The *User Stories* method provided a rich description of the context of profoundly deaf parents looking after infants based on literature, to provide insight into the lived experiences and reality of profoundly deaf parents with infants. The assessment of baby monitoring solutions provides a useful tool for deaf parents to assess an assistive device based on their needs. The results of this research are also useful to developers/manufacturers of assistive devices for deaf parents with infants. Additionally, deaf parents with infants may now feel empowered to function like a hearing parent when parenting their infants.

REFERENCE LIST

Al-Megren, S., & Almutairi, A. (2019). Analysis of user requirements for a mobile augmented reality application to support literacy development amongst hearing-impaired children. *Journal of Information and Communication Technology*, *18*(1), 97–121. https://doi.org/10.32890/jict2019.18.1.8283

Amazon. (n.d.-a). *HelloBaby Audio Monitor*. Retrieved November 12, 2021, from https://www.amazon.com/Hello-Monitor-Technology-Crystal-One-Way/dp/B08JYP16N8/ref=sr_1_3?keywords=HelloBaby+sound+baby+monitor&qid=1636490775&qsid=140-6476477-8992932&sr=8-3&sres=B08JYP16N8%252CB07MZ1J93Y%252CB07SR98HFB%252CB07NRPN8W9%252CB083L5DY5S%252CB

Amazon. (n.d.-b). *MonBaby Baby Breathing Monitor*. Retrieved November 12, 2021, from https://www.amazon.com/MonBaby-Monitors-Temperature-Breathing-Movement/dp/B07V4NJ38S

Amazon. (n.d.-c). *VTech Video Baby Monitor*. Retrieved November 12, 2021, from https://www.amazon.com/VTech-VM3252-Digital-Full-Color-Automatic/dp/B0799CLC5D

Blackburn, S., & Cudd, P. A. (2012). A discussion of systematic user requirements gathering from a population who require assistive technology. *Technology and Disability*, *24*(3), 193–204. https://doi.org/10.3233/TAD-2012-0352

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Carrera, Á., & Iglesias, C. A. (2015). A systematic review of argumentation techniques for multi-agent systems research. *Artificial Intelligence Review*, *44*(4), 509–535. https://doi.org/10.1007/s10462-015-9435-9

Carter, N., Bryant-Lukosius, D., Dicenso, A., Blythe, J., & Neville, A. J. (2014). The use of triangulation in qualitative research. *Oncology Nursing Forum*, *41*(5), 545–547. https://doi.org/10.1188/14.ONF.545-547

Cohn, M. (2004). *User Stories Applied for Agile Software Development*. Addison-Wesley.

Colclasure, D. (2004). *Life as a Deaf Mother*. https://www.mothering.com/threads/life-as-a-deaf-mother.1621814/

Cook, A. M., & Polgar, J. M. (2015). *Assistive Technologies: Principles and Practice Fourth* (4th ed.). Elsevier Inc. https://linkinghub.elsevier.com/retrieve/pii/S2405471217300108

Cypress, B. S. (2017). Rigor or reliability and validity in qualitative research: Perspectives, strategies, reconceptualization, and recommendations. *Dimensions of Critical Care Nursing*, *36*(4), 253–263. https://doi.org/10.1097/DCC.0000000000000253

Felman, A. (2018). *Deafness and hearing loss : Causes, symptoms, and treatments*. https://www.medicalnewstoday.com/articles/249285

Golafshani, N. (2015). Understanding Reliability and Validity in Qualitative Research. *The Qualitative Report*, *8*(4), 597–606. https://doi.org/10.46743/2160-3715/2003.1870

HearCanada. (n.d.). *Types and Causes of Hearing Loss*. Retrieved October 10, 2019, from https://hearcanada.com/hearing-loss/types-and-causes-of-hearing-loss

Hersh, M. A., & Johnson, M. A. (2003). *Assistive Technology for the Hearing-impaired, Deaf and Deafblind* (M. A. Hersh & M. A. Johnson (eds.)). Springer-Verlag. https://doi.org/10.1007/b97528

Lakshmi, P., Lalitha, G. K., Malashree, D., Mohana Priya, D., & Singh, M. (2021). Design and Development of Infant Care System Using Arduino Technology. *Proceedings of the 2nd International Conference on Electronics and Sustainable Communication Systems, ICESC 2021*, 790–796. https://doi.org/10.1109/ICESC51422.2021.9532999

Lenneberg, E. H., Rebelsky, F. G., & Nichols, I. A. (1965). The vocalizations of infants born to deaf and to hearing parents. *Human Development*, *8*(1), 23–37. https://doi.org/10.1159/000270229

Leung, L. (2015). Validity, reliability, and generalizability in qualitative research. *Journal of Family Medicine and Primary Care*, *4*(3), 324. https://doi.org/10.4103/2249-4863.161306

Marti, P., & Recupero, A. (2019). Is Deafness a Disability? *Proceedings of the 2019 on*

Creativity and Cognition, 133–143. https://doi.org/10.1145/3325480.3325491

Mohite, A., & Jadhav, D. (2021). Infant Monitoring System for Deaf Parents. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, *7*(3), 527–534. https://doi.org/10.32628/CSEIT2173163

Nathan, S. S., Hussain, A., & Hashim, N. L. (2016). Deaf mobile application accessibility requirements. *AIP Conference Proceedings*, *1761*(August 2016). https://doi.org/10.1063/1.4960938

National Institude on Deafness and Other Communication Disorders. (2019). *Assistive Devices for People with Hearing , Voice , Speech , or Language Disorders*. https://www.nidcd.nih.gov/health/assistive-devices-people-hearing-voice-speech-or-language-disorders

Newell, A. F., Gregor, P., Morgan, M., Pullin, G., & Macaulay, C. (2011). User-Sensitive Inclusive Design. *Universal Access in the Information Society*, *10*(3), 235–243. https://doi.org/10.1007/s10209-010-0203-y

Nierling, L., Maia, M. J., Hennen, L., Wolbring, G., Bratan, T., Kukk, P., Čas, J., Capari, L., Krieger-Lamina, J., & Mordini, E. (2018). Assistive technologies for people with disabilities - Part III: Perspectives on assistive technologies. In *European Parliamentary Research Service* (Issue January). Science and Technology Options Assessment (STOA). https://doi.org/10.2861/11162

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, *16*(1), 1–13. https://doi.org/10.1177/1609406917733847

Olivier, M. S. (2009). *Information Technology Research: A practical guide for Computer Science and Informatics.* (3rd Editio). Van Schaik.

Phillips, B., & Zhao, H. (1993). Predictors of Assistive Technology Abandonment. *Assistive Technology*, *5*(1), 36–45. https://doi.org/10.1080/10400435.1993.10132205

Shahrestani, S. (2017). *Internet of Things and Smart Environments*. Springer International Publishing. https://doi.org/10.1007/978-3-319-60164-9

Sharp, H., Finkelstein, A., & Galal, G. (1999). Stakeholder identification in the

requirements engineering process. *Proceedings. Tenth International Workshop on Database and Expert Systems Applications. DEXA 99*, 387–391. https://doi.org/10.1109/DEXA.1999.795198

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, *22*(2), 63–75. https://doi.org/10.3233/EFI-2004-22201

Singleton, J. L., & Tittle, M. D. (2000). Deaf Parents and Their Hearing Children. *Journal of Deaf Studies and Deaf Education*, *5*(3), 221–236. https://doi.org/10.1093/deafed/5.3.221

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Thurmond, V. A. (2001). The point of triangulation. *Journal of Nursing Scholarship*, *33*(3), 253–258. https://doi.org/10.1111/j.1547-5069.2001.00253.x

Ting, L. W., Hao, J., & Ching-chiuan, Y. (2013). Designing a communication device for deaf parents and a hearing infant. *Consilence and Innovation in Design - 5th International Congress of International Association of Societies of Design Research*, 3579–3589.

Torraco, R. J. (2005). Writing Integrative Literature Reviews: Guidelines and Examples. *Human Resource Development Review*, *4*(3), 356–367. https://doi.org/10.1177/1534484305278283

Vaismoradi, M., Jones, J., Turunen, H., & Snelgrove, S. (2016). Theme development in qualitative content analysis and thematic analysis. *Journal of Nursing Education and Practice*, *6*(5). https://doi.org/10.5430/jnep.v6n5p100

Vanderheiden, G. C. (1998). Universal Design and Assistive Technology in Communication and Information Technologies: Alternatives or Complements? *Assistive Technology*, *10*(1), 29–36. https://doi.org/10.1080/10400435.1998.10131958

Wautelet, Y., Heng, S., Kolp, M., & Mirbel, I. (2014). Unifying and Extending User Story Models. In *Advanced Information Systems Engineering* (Vol. 8484, pp. 211–225). Springer, Cham. https://doi.org/10.1007/978-3-319-07881-6_15

World Health Organization. (2021a). *Deafness and hearing loss*. https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss

World Health Organization. (2021b). *Infant and young child feeding*. https://www.who.int/news-room/fact-sheets/detail/infant-and-young-child-feeding

Writing Stories. (2010). In *User Stories Applied for Agile Software Development* (pp. 17–29). Addison Wesley.

Zacharias, I. C. S., Campese, C., dos Santos, T. B., da Cunha, L. P., & Costa, J. M. H. (2019). User Stories Method and Assistive Technology Product Development: A New Approach to Requirements Elicitation. *Proceedings of the Design Society: International Conference on Engineering Design*, *1*(1), 3781–3790. https://doi.org/10.1017/dsi.2019.385

Zhang, Z. (2007). Effective requirements development - A comparison of requirements elicitation techniques. *Software Quality Management XV: Software Quality in the Knowledge Society, British Computer Society*, 225–240.

Zowghi, D., & Coulin, C. (2005). Requirements Elicitation: A Survey of Techniques, Approaches, and Tools. In *Engineering and Managing Software Requirements* (Issue July, pp. 19–46). Springer-Verlag. https://doi.org/10.1007/3-540-28244-0_2