Touchless interfaces for healthcare communication

Exploring touchless interfaces to support healthcare workers when communicating on mobile devices

Master's thesis in Computer science and engineering

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Cover: Illustration of a healthcare worker surrounded by various elements related to this thesis.

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Abstract

In healthcare, efficient communication is crucial for delivering proper patient care. The utilisation of individual communication devices for healthcare workers is growing more widespread to optimise workflows and address alarm fatigue. With this change comes challenges, considering the high demand for infection control and the many hands-on tasks performed by healthcare workers. Touchless interfaces have emerged as a possible solution to face these challenges. Therefore, the purpose of this thesis is to answer the following research question: *What should be considered when designing touchless interfaces to support healthcare workers when communicating on a mobile device?* To address the research question, a pre-study followed by an iterative design process was conducted.

Five separate visits to hospitals took place to observe and identify the unique needs of healthcare workers and the problems they face. These visits resulted in 12 problem areas exemplifying areas where touchless interfaces could be beneficial. Subsequently, requirements were formulated based on the pre-study and user studies, indicating what should be considered when designing touchless interfaces. Through the requirements, it became evident that eye tracking was not a suitable option for healthcare workers. However, both voice user interface and gesture-based interface emerged as viable alternatives. Two prototypes were developed to exemplify different approaches to implementing the requirements. The prototypes *Myco Mini* and *Myco Main* are two compact devices that assist healthcare workers in various situations by enabling interactions using a voice user interface and a gesture-based interface. The evaluation of the prototypes showed that the voice user interface was more approved, both in terms of its ease of use and social acceptance. Therefore, additional studies are needed to research gesture-based interfaces before implementing them for communication purposes in healthcare environments.

Keywords: Interaction design, touchless interfaces, voice user interface, gesture-based interface, healthcare

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Olivia Jarl & Amanda Olsby, Gothenburg, June 2024

Contents

Glossary

Alert - An audible or visual signal in hospitals, for example, indicating when a patient needs immediate assistance from healthcare workers. (Swedish: Kallelse)

Emergency department - Hospital department providing immediate medical care for urgent conditions. There are emergency departments that specialise in specific fields. For example, gynaecological emergency departments specialise in the care of women's reproductive organs, and pediatric emergency departments specialise in the care of children. (Swedish: Akutmottagning)

Infection department - Hospital department focused on preventing, diagnosing, and treating infectious diseases. (Swedish: Infektionsavdelning)

Intensive care unit - Specialised unit for critically ill patients with close monitoring and care. There are specialised intensive care units. One example is neuro intensive care units, which provide care to patients who have suffered from acute diseases and injuries related to the nervous system. (Swedish: Intensivvårdsavdelning)

Medical department - Hospital department for admitted patients where they diagnose and treat diseases in internal organs. (Swedish: Medicinavdelning)

Neonatal department - Hospital department specialising in care for newborn infants. (Swedish: Neonatalavdelning)

Practical nurse - A healthcare worker who assists nurses and doctors with patient care tasks such as taking vital signs, administering medications, and helping patients with daily activities and personal hygiene. (Swedish: Undersköterska)

Speciality residents - Doctors who are undergoing advanced training in a specific medical speciality, such as anaesthesia or surgery. (Swedish: ST-läkare)

Telemetry - The remote monitoring of a patient's vital signs and medical data using telecommunication technology. (Swedish: Telemetri)

1
Introduction

This master's thesis addresses the challenges healthcare workers face when conventional mobile devices, such as phones and pagers, prove impractical. Touchless interfaces are explored as possible solutions for these challenges. Touchless interaction requires no physical contact between the user and any component of an artificial system (de la Barré et al., 2009). There are several types of touchless interfaces, such as voice control, gesture tracking and eye tracking (Iqbal & Campbell, 2021).

This thesis is in collaboration with the company Ascom, and they formulated the initial track of the project. Ascom globally supplies the healthcare industry with information and communication technologies and mobile workflow solutions (Ascom, n.d.-a). One of Ascom's product categories is mobile devices, and they provide feature phones (non-smartphones), pagers and smartphones (Ascom, n.d.-f). There are many benefits of mobile communication devices in a hospital environment. For example, they enable communication on the go, and they can direct information to the intended recipients instead of distributing it to the entire department. However, their current form makes it impractical to access the device in some situations, such as when performing tasks that require both hands. Furthermore, healthcare workers carry out many unclean tasks which complicates the interaction with the mobile devices. The most common transmission of pathogens is contact transmission by hand (Vårdgivarguiden, 2024), and the phone can become a source of bacteria if not appropriately sterilised (Foong et al., 2015). According to Pillet et al. (2016) mobile phones can also carry viruses, and therefore, good hand hygiene and frequent cleaning of the phone is recommended to minimise the spread.

In this project, user studies will be performed to identify situations where touchless interfaces could support healthcare workers. The hospital context brings several challenges that the project needs to address. For example, hygiene routines and social acceptance need to be considered. The first chapter of this report establishes a foundation for the research and contains the research question, aim, deliverables, delimitations, and ethical considerations.

1.1 Aim

This thesis aims to research and identify areas where conventional mobile communication devices can be complemented with alternative, touchless interfaces in time-sensitive hospital environments. These interfaces should improve efficiency for nurses while communicating and accessing information from the device. The findings from this research will support the development of prototypes.

1.2 Deliverables

The deliverables of this master thesis are the following:

- Problem areas of identified situations within hospital departments that could benefit from touchless interfaces.
- Requirements that support the integration of touchless interfaces within at least one of the problem areas.
- Prototypes utilising touchless interfaces that meet the formulated requirements.

1.3 Research question

For this master thesis, the following research question was formulated:

What should be considered when designing touchless interfaces to support healthcare workers when communicating on a mobile device?

1.4 Delimitations

All user studies will be executed in Sweden; consequently, the findings may not apply to healthcare in other countries. Additionally, observations and interviews will be conducted in close vicinity to Gothenburg. The user studies will primarily take place in high-paced hospital departments due to the assumed high demands on the communication systems. Examples of such departments are intensive care and emergency units. The studied users are nurses and doctors working in these environments; no patients will be interviewed. The technologies considered for the prototypes should be currently available and established, avoiding futuristic and theoretical ideas.

1.5 Ethical considerations

There are ethical aspects that need to be considered during the project. Firstly, the user studies will take place in hospitals where patients may be in vulnerable positions. Therefore, patients will only be observed from afar, and no patients will be approached during the hospital visits. The lack of patient perspectives may result in a gap in the insights received from the research, which can affect how well a final product could be integrated into a real hospital setting. Confidentiality agreements will be signed, to reassure the parties involved that no sensitive patient information will be disclosed.

Secondly, the primary studied users are nurses and doctors at hospitals, and all participants will be informed of the purpose of the study before participating. Additionally, all interviews and observations will follow GDPR, the participants will be informed that the data will be anonymised, and all potential recordings will be deleted at the end of the project. They also have the right to withdraw at any point. Since healthcare workers often work under significant time constraints, the observations will be conducted to minimally disrupt their responsibilities.

Finally, should Ascom decide to implement the findings derived from this thesis and integrate them into future products, it could affect the work of healthcare workers. Therefore, the quality of care will be influenced, emphasising our responsibility not to negatively impact patient care or disadvantage any individuals in the healthcare system.

2
Background

This chapter provides a background to the research area. It includes a description of the company Ascom with a selection of their current products and an explanation of the research problem this thesis will tackle. Related work will also be covered in this chapter.

2.1 Ascom

This project is done in collaboration with the company Ascom, which provides information and communication technologies for healthcare and mobile workflow solutions globally (Ascom, n.d.-a). Their target group is users working in highly mobile and time-sensitive environments who demand near real-time solutions. Besides healthcare, Ascom targets multiple types of organisations and industries, such as hospitality, retail, manufacturing and high-security establishments (Ascom, n.d.-e).

This master thesis is limited to the healthcare industry, and Ascom provides both software and hardware solutions for hospital environments. Their portfolio of mobile devices includes smartphones, pagers and cordless phones (Ascom, n.d.-f), see Figure 2.1. Their devices have several features that make them suitable for hospital environments. Their latest smartphone model, Myco 4, has a tough chassis and screen, and can be cleaned and disinfected (Ascom, n.d.-b). Its battery has a hot-swap procedure, which allows swapping the battery without the smartphone shutting down.

Ascom's software products are developed to be used specifically with Ascom hardware, but they can also be combined with third-party devices (Ascom, n.d.-c), such as iPhones. One of their software products is called Ascom Unite, which is a workflow orchestration platform (Ascom, n.d.-d). Ascom Unite uses events and data from source systems to orchestrate these as alerts, chats and tasks. In the software, recipients of an alert can be assigned, and the recipients can be arranged in a prioritisation list. If a primary recipient rejects the alert or does not reply within a predefined time limit, the alert is automatically redirected to the secondary recipient. Not letting everyone get all alerts decreases the sensory load on staff, and the environment becomes calmer.

Figure 2.1: An Ascom smartphone, DECT phone and pager. *Mobilenheter för vården* [Image], by Ascom (n.d.-g)[1].

According to a clinical consultant at Ascom, Ascom products can be found in most Swedish hospitals. However, only two hospital organisations are working with Ascom smartphones; the other organisations are using other types of mobile devices. The most common Ascom product in Sweden is a bedside call module that patients and healthcare workers use to call for help. A typical scenario in Swedish hospitals is that a patient calls for help by pressing a button on the bedside call module, which creates an event that Ascom Unite registers. This event is treated like an alert that is sent to the predefined primary recipient. The recipient can either accept or reject the alert, and the accept-action signifies that they will go and check on the patient. An alert can only be turned off in the patient's room by pressing a button on the bedside call module.

Ascom's existing products utilise interfaces dependent on physical contact between the user and the device. The Research and Development (R&D) department at Ascom Sweden formulated the initial track of this master thesis, and they believed there were potential benefits of integrating touchless interfaces into their products.

2.2 Research problem

In recent years, the integration of smartphones into healthcare environments has brought many advantages. By using Ascom products, healthcare workers can access near real-time patient information at all times. Additionally, smartphones can work as a communication tool within the workforce, improving communication and

[1]https://www.ascom.com/globalassets/assets/global/gmc/healthcare-2021/phone_collection-copy.png?width=640&format=webp

information exchange between co-workers (Fiorinelli et al., 2021). Despite the many advantages, there are disadvantages worth considering. The use of smartphones in healthcare can pose a distraction and lead to errors, compromising patient safety (Fiorinelli et al., 2021). Additionally, this limits the workers' ability to engage and connect with their patients.

Ascom stated that there are situations where the use of phones is impractical, namely when wearing protective clothing or, in other ways, being physically constrained. According to Cronin and Doherty (2018), there is a need for touchless control in hands-busy settings at hospitals, such as when holding tools or handling patients. In a situation where an alert goes off on a device using Ascom's system and the worker is occupied with other tasks, the alert will continue to sound for a predefined time or until the worker is available to turn it off. Continuous and repetitive alerts are common in hospital settings and can result in alarm fatigue in the workers (Jones, 2014). This overwhelming feeling can make it more likely for the workers to ignore the alerts and have trouble distinguishing between them.

Cronin and Doherty (2018) also found sterility as a motivation for integrating touchless control. A study (Foong et al., 2015) examining 226 mobile phones belonging to healthcare workers during a twelve-month period found that 74% of these devices were contaminated with bacteria. A part of the bacteria was potentially pathogenic, and this finding highlights the potential risk of pathogen transmission through these devices. Pillet et al. (2016) state a strong correlation between the use of phones and the presence of viruses in hospitals. To address this issue, they recommend frequent handwashing and regular sterilisation of phones.

There may be situations in hospital environments where an alternative solution to conventional phones is more suitable. A solution that enables the workers to interact with a device without needing to physically touch it. Therefore, this thesis will explore this topic and focus on examining problem areas where the phone can be complemented by a touchless interface to better fit the workers' needs.

2.3 Related work

Related work will be covered in this section, including information about touchless interfaces in both hospitals and other industries. The aim is to show how others have tackled problems similar to those previously mentioned and the opportunities that exist.

2.3.1 Touchless interfaces in healthcare

The use of touchless interfaces in hospitals is not a completely unexplored area. There are situations where they are used to make tasks easier and more efficient for the workers. As stated in a literature review on touchless modalities in hospitals by de Camargo et al. (2021), the most common departments for these technologies were physical therapy, surgery and radiology. Microsoft Kinect and Leap Motion were the most used touchless technologies in these departments. Kinect is a line of motion sensing input devices controlled by gestures and spoken commands that was originally released for the XBOX 360 gaming console (Hsu et al., 2017, p. 12). The Leap Motion controller by Ultraleap is a hand-tracking device that enables the user to interact with the system without the need for touchscreens or wearables (Ultraleap, n.d.-d). Both of these sensors for gesture-based interfaces have been used in surgery as a tool to interact and manipulate medical images without breaking the sterile environment (de Camargo et al., 2021).

HoloLens 2 is a mixed reality headset by Microsoft that incorporates several different touchless tracking systems (Microsoft, n.d.-a). Mixed reality is the meeting between real and virtual environments (Milgram & Kishino, 1994). HoloLens 2 features hand tracking without the need for external controllers, enabling users to manipulate holograms with natural movements. Additionally, it incorporates eye tracking technology that adjusts the holograms based on the user's gaze direction. In situations where the hands are occupied, the headset can also be controlled with voice commands. It utilises spatial mapping to map the environment around the user and to lock holograms to physical surfaces. This headset is applied across different industries, including healthcare, and is used for activities such as remote consultation and viewing 3D images.

Another touchless technology emerging in healthcare is Alexa, a cloud-based voice service developed by Amazon (Amazon, n.d.-b). According to (Espinoza-Hernández et al., 2023), Alexa is used in healthcare for various reasons, including answering questions, alerting about critical health statuses, making video calls and taking on small tasks. Additionally, mobile devices with integrated touchless interfaces are available, with Vocera being one example. Vocera are hands-free communication devices that help healthcare workers communicate using voice control (Stryker, 2023). It ensures that workers can quickly access help in emergencies, and it is also possible to use the devices under protective equipment to reduce contamination risks.

2.3.2 Touchless interfaces in other contexts

One example of a widely adopted voice user interface in households is the previously discussed voice assistant Alexa. Alexa serves multiple purposes, including controlling lights and televisions (Amazon, n.d.-d), offering hands-free voice and video calls (Amazon, n.d.-a) and keeping users updated on the latest news (Amazon, n.d.-c). Other similar digital voice assistants are Siri by Apple and Google Assistant. Another example of a touchless interface is Google's Camera Switches. Google allows users to control their smartphones using facial gestures (Google Help, n.d.). This is used by having the phone securely mounted and the camera directed towards the user's face. It is possible for the user to record their own gestures to use as shortcuts for quickly accessing frequently used functions or commands.

A newly released device that incorporates touchless functionalities is Ai Pin by

Humane (Humane, n.d.). This wearable screenless device is pinned to the user's sweater or other clothes and is an alternative to conventional smartphones. It is controlled with the use of touch, voice and gestures and to interact with it, the user starts by touching a touchpad on the device. It can be used as a virtual assistant and can answer questions, take pictures, send messages and comment on items held in front of it. The user's hand operates as a display using the "Laser Ink Display" on the device. Information such as the time, weather and music is projected onto the palm, and the interface can be maneuvered by tilting the hand and moving the fingers.

Another device that recently became available is Apple Vision Pro, a mixed reality headset that extends the interface to the space around the user (Apple, n.d.). It is controlled by the user's eyes, hands and voice. With Vision Pro, it is possible to view the information normally viewed on a screen in a new format while still staying aware of the world around. It can be used instead of a computer screen or smartphone to, for instance, view movies, make video calls or browse the web.

The previously mentioned devices HoloLens 2 by Microsoft and Leap Motion by Ultraleap, serve multiple industries beyond just healthcare (Microsoft, n.d.-b) (Ultraleap, n.d.-d). The headset HoloLens 2 is incorporated into manufacturing, engineering and construction industries to increase efficiency (Microsoft, n.d.-b). Additionally, it is used in education to show complex systems. Ultraleap (n.d.-d), the creator of Leap Motion, describes the hand tracking device as universally accessible: designed for anyone and anywhere. The compact and adaptable device can be attached to VR headsets, computers, or other digital interfaces. The touchless software can be used in various contexts, such as museums (Ultraleap, n.d.-e), quick-service restaurants and retail (Ultraleap, n.d.-b) to enhance user experience and promote hygiene. It can also be used for training purposes to simulate a specific scenario (Ultraleap, n.d.-c) and in VR arcades (Ultraleap, n.d.-a). Another virtual reality headset with similar applications is Meta Quest Pro (Meta, n.d.).

Touchless interfaces can be found in the automotive industry. BMW has a feature that lets users operate functions by making hand gestures in front of a display located under the rear mirror (BMW, 2019). For example, they can change the volume and accept a phone call. Furthermore, Jaguar has developed a feature where users can open and close the tailgate by performing a kick gesture under the rear bumpers (Jaguar, 2018). Another touchless approach in cars is voice control, and Mercedes-Benz has in a beta-version integrated ChatGPT into their voice assistant (Mercedes-Benz Group, 2022). The integration intends to expand the tasks the voice assistant can respond to and make users experience a more natural dialogue.

3

Theory

This chapter includes theory about common touchless interfaces and their advantages and disadvantages compared to conventional touch user interfaces. Haptic and multimodal interfaces will also be covered. Moreover, the term usability will be described.

3.1 Touchless interfaces

This section exemplifies touchless interfaces. These can also be described as natural user interfaces, which enable users to intuitively and naturally interact with a system using body movements, gestures and voice (Hsu et al., 2017, p. 10).

3.1.1 Voice user interface

Voice user interfaces (VUI) are interactive systems that utilise speech recognition technology to enable users to input commands and communicate with a device solely through spoken language (Hsu et al., 2017, p. 10). The system interprets the commands, making it possible to interact without using both hands and eyes (Interaction Design Foundation, 2016). A specific type of VUI is auditory interface, in which not only input but also output solely consists of sounds (Cohen et al., 2004, p. 6). The user inputs speech and the system outputs speech and other nonverbal audio such as music, background sounds and earcons. Earcons are auditory icons whose purpose is to convey specific messages.

A notable advantage of VUI is the hands-free capability. In situations where the user is physically occupied, it is more practical to speak rather than interact with a screen (Pearl, 2016, pp. 3-4). Speech is also a quick and efficient way of conveying time-sensitive information. In addition, VUI:s are intuitive since they can be used by anyone capable of speaking, without the need for a complex interface. However, when considering using a VUI, it is important to be aware of the disadvantages. Using them in public spaces may not always be suitable, both considering privacy reasons and the potential for unintended disruptions (Pearl, 2016, p. 5). Concerns can arise not only for the privacy of what the users are saying but also fear regarding the disclosure of sensitive information by the system.

According to Easwara Moorthy and Vu (2014), the social acceptability of using VUI varies depending on the situation and the information being exchanged. Their study investigated voice-activated personal assistance in smartphones and compared the exchange of private and non-private information in a home and a restaurant location. The findings showed that the users preferred the VUI for non-private information in a home setting. In public spaces among strangers, the users found it inappropriate to display personal information. Voice user interfaces can also be challenging to use in noisy situations since the surrounding sounds can interfere with the sounds interpreted (de Camargo et al., 2021). In these situations, subvocal recognition is an option. This system uses external sensors placed on the user's throat to capture nerve signals when a person silently or aloud articulates words (Yonck, 2010). The technology can be utilised in noisy environments and situations requiring silence.

Utilising auditory interfaces, where both input and output are managed through sound, presents its own set of challenges. The system's output is transient, preventing users from accessing information at their preferred pace (Cohen et al., 2004, p. 6). Once the sound is emitted, it is no longer available for the user, compared to a screen where information can stay longer. Because of this, the output places a heavy cognitive load on the user, particularly on their memory.

3.1.2 Gesture-based interface

Gesture-based interfaces rely on movements from the user as their source of input. The user interacts with the interface by moving their hands, head or other body parts and these gestures are captured and organised into a sequence of commands (Hsu et al., 2017, pp. 10-11). A specific type of gesture-based interface is touchless gesture interface, which operates without the need for physical touch. Touchscreens is an example of a gesture-based interface, but is not a touchless gesture interface. Since gestures are a communication form that humans use naturally with each other, this type of interface can be intuitive. However, this is only true as long as the gestures are simple and not too numerous. Gestures can be challenging for the user if they are complex, physically challenging or hard to remember (Vatavu, 2023). Furthermore, interacting with screenless interfaces by using gestures can result in a lack of appropriate feedback (Rise & Alsos, 2020). According to Rempel et al. (2014), gestures used in sign language for letters and numbers are distinct and easy to recall, and image capture recognises them more easily. Therefore, these can be considered in the design of gestures for HCI. Moreover, the authors claim that sign language interpreters can advise which hand gestures are comfortable due to their extensive experience.

The healthcare domain is one area that could benefit from the use of gesture-based interfaces since it can ensure a sterile environment and focused attention (Wachs et al., 2018), as well as assist workers when traditional interfaces may prove insufficient (Rise & Alsos, 2020). Depending on the type of gesture, the technique can be more or less socially acceptable to use. Montero et al. (2010) divided gestures into four categories to study the social acceptance of gestures based on what the user thinks about the interaction and how the observer perceives it. The categories used in the study were originally proposed by Reeves et al. (2005) to describe different approaches to designing public interfaces, and these were secretive, expressive, magical and suspenseful interactions. These categories differ based on whether the manipulation and effect of the interaction are revealed to or concealed from the observer, and this is illustrated in Figure 3.1. In the study by Montero et al. (2010), it was established that suspenseful gestures, where the gesture is obvious but the effect is not, were the least socially acceptable. The other three categories were equally accepted. These results show that the use of both small and hidden gestures and large and obvious gestures can be accepted, depending on whether the effect is clearly distinguishable or not to the public.

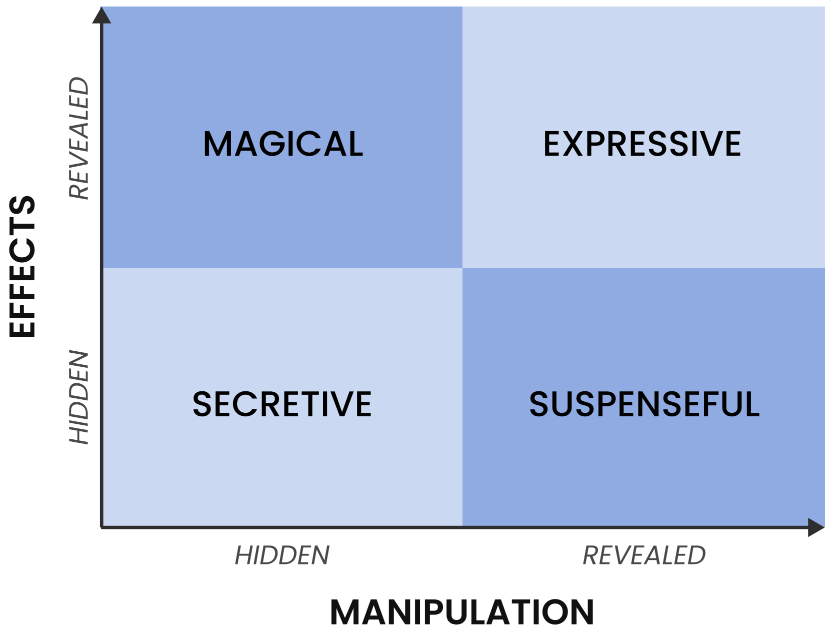

Figure 3.1: A visualisation of different approaches to designing public interfaces.

3.1.3 Eye tracking Systems

Eye tracking is a technology that monitors the movement and position of the user's eyes to identify their focus and attention (Punde et al., 2017). There are two general types of eye trackers, one of which is remote eye trackers. These trackers use screens, cameras or sensors that are placed in a limited area and detect eye movements. The other type is mobile eye trackers which are placed near the eyes of the user and allow them to move around without restrictions.

Using the eye as an input device is faster than the more conventional method of using a mouse to interact with computer systems (Sibert & Jacob, 2000). This approach also proves to be a practical solution in situations where the hands of the user are occupied. Despite these advantages, this technique can present challenges since eye movements often are unconscious and the system needs to differentiate between intentional and unintentional viewing (Majaranta & Bulling, 2014). If the eye tracking device is worn on the head and covers the eyes, it can also affect the healthcare worker's ability to maintain eye contact with their patients. Eye contact is important during communication to fully understand the intention and message being conveyed (Davidhizar, 1992). The lack of eye contact can be perceived as being disinterested and uncaring.

3.2 Haptic interface

Haptic interfaces mediate communication between humans and machines by touch (Hayward et al., 2004). To provide information, haptic interfaces produce mechanical stimuli that affect the human's perception of touch and proprioception. Proprioception refers to a human's ability to perceive body position, movement and weight. Vibrotactile sensation is a term for perceiving vibrating objects in contact with the skin. According to Schneider et al. (2017), vibrotactile feedback is the most common haptic technology and can be found in smartphones. Usually, haptic feedback is most effective in combination with other modalities (MacLean, 2000), and haptic interfaces can be helpful when other modalities are overloaded (Osvalder & Ulfvengren, 2015, p. 369). The resolution of the haptic modality is relatively low, leading to few values that can be clearly distinguished from each other (Hoggan, 2013).

3.3 Multimodal interface

A system qualifies as a multimodal interface if it incorporates two or more input modalities, like voice and gestures, along with multimedia outputs (Oviatt, 2007, pp. 414-418). These interfaces have many advantages compared to single modality interfaces. They can be used by a wide range of users and in scenarios where one input mode is unavailable, allowing users to switch to alternative input methods. Furthermore, the interfaces tend to be easier to learn and use, resulting in users preferring them in various situations.

3.4 Usability

The International Organization for Standardization (2018) defines usability as: "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (ISO 9241-210, section 3.13). Effectiveness can be described as the degree to which the user's goal can be achieved, and efficiency refers to how much effort is needed to achieve the goal (Jordan, 1998, pp. 5-7). Satisfaction is more subjective than the other two aspects and can be harder to measure. It includes how well the product meets the user's needs and expectations in terms of cognitive, physical, and emotional aspects (International Organization for Standardization, 2018, ISO 9241-210, section 3.10). According to Nielsen (2012), usability refers to how easy an interface is to use, while utility refers to the functionality of the design. The two attributes combined determine the usefulness of an interface. Jordan (1998, pp. 25-38) listed ten principles of usable design that are associated with usability, and they are described below:

Consistency
Similar tasks within the product should be performed similarly.

Compatibility
How tasks are accomplished should correspond to the user's expectations based on their experience with other products.

Consideration of user resources
The interaction should consider the demands placed on the user's cognitive and physical resources.

Feedback
Any actions performed by the user should be acknowledged, and information about the results of the actions should be provided.

Error prevention and recovery
Minimise the likelihood of user errors, and if an error occurs, provide easy and quick recovery.

User control
Give the users as much control as possible over the actions taken by the product and the state the product is in.

Visual clarity
Information should be displayed for easy and fast access without causing any confusion.

Prioritisation of functionality and information
The most essential functionality and information should be easily accessible.

Appropriate transfer of technology
Apply appropriate technology developed in other contexts to enhance the usability of a product.

Explicitness
Provide cues for the product's functionality and method of operation.

4
Methodology

This chapter starts by explaining the concepts of Research through Design and wicked problems. Then, it describes design methods, which are organised in the stages of the iterative process of Design thinking.

4.1 Research through Design

Methods and processes of design practice can be applied to produce new knowledge through an approach called Research through Design, abbreviated RtD (Zimmerman & Forlizzi, 2014). While commercial design practice aims to make a successful commercial product, a valuable outcome of RtD can be a more comprehensive understanding of a challenging problem. Furthermore, RtD is more well-documented than design practice. Except for RtD, there is also Research for design and Research into design, and it was Frayling (1993) who suggested the three categories of design as research: Research into art and design, Research for art and design, and Research through art and design. He argued that research is essential for the teaching and practice of design and art. Research for design aims to improve the practice of design, while Research into design includes research on the human activity of design (Zimmerman & Forlizzi, 2014).

4.2 Wicked problems

According to Churchman (1967), Rittel described wicked problems as "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing” (p. B-141). Rittel and Webber (1973) compared wicked problems to problems in natural sciences, which they call tame problems. Unlike wicked problems, tame problems are definable, have an enumerable set of solutions, and the correctness of the solution is assessable. They also listed the properties of a wicked problem, including that it is unique, can be described first after solutions are developed, has no stopping rule, and has no true or false answers. Buchanan (1992) argues that designers have to handle wicked problems since they conceive and plan what has not yet been created. Moreover, he suggests a non-linear design thinking model as an appropriate approach to wicked problems due to the lack of definitive conditions and limits.

4.3 Design thinking

Design thinking is a human-centred and iterative process used to gain insights into user experiences, define problems and discover opportunities that can lead to innovative solutions (Interaction Design Foundation, 2016). Stanford University's Hasso Plattner Institute of Design suggests the following five stages for a design thinking process: Empathise, Define, Ideate, Prototype and Test. See Figure 4.1 for an illustration of the design process. These stages are not always done in a straightforward sequence but instead partially executed simultaneously and repeated as the need arises. This section explains the five stages and methods that can be conducted during each of them.

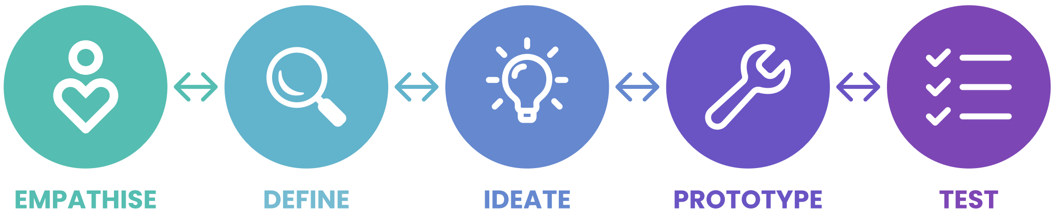

Figure 4.1: Illustration of a Design thinking process.

4.3.1 Empathise

During the Empathise stage of the design process, the goal is to understand the users and their decisions, needs and thoughts within the design context (Hasso Plattner Institute of Design, n.d.). To be able to solve a design problem, it is important to empathise with the intended user and not focus on one's own opinions. Interviews, focus groups and observations can be performed to enhance the understanding of the users. Before conducting user studies, the participants should be informed about their rights, the purpose of the data gathering, and how the collected data will be used and stored (Sharp et al., 2019, p. 262). In addition to these methods that involve users, data can be gathered from literature and by analysing the current market.

Pilot study

A pilot study can be carried out to ascertain that the planned method is applicable before starting the main study (Sharp et al., 2019, p. 265). A pilot study serves as a small test run of the main study, where potential issues can be found and adjusted beforehand. Participants in the pilot study should not participate in the main study since their knowledge can distort the results.

Interviews

One common data gathering method is interviews, which can be categorised into three types: unstructured, semi-structured and structured (Sharp et al., 2019, pp.

268-304). What an interview is classified as depends on how much control the interviewer has over the interview process. The most controlled type is structured interviews, where the interviewer follows a preplanned set of questions. Structured interviews often consist of closed-ended questions, which implies that the interviewee chooses an answer from a predetermined set of alternatives. On the other end of the spectrum, there are unstructured interviews. These are more similar to a conversation and explore a subject more in-depth. For unstructured interviews, open-ended questions are suitable which have no specific format or predetermined answers. Semi-structured interviews are a combination of structured and unstructured interviews. The interviewee should follow a guide with preplanned questions to ensure the same topics are included in all interviews.

Interviews can also be conducted in groups, and one form of group interview is focus group (Sharp et al., 2019, pp. 271-272). Usually, three to ten people participate, and the selection of participants should reflect the target group. The session is guided by a facilitator, who should follow a predetermined agenda. Besides guiding the discussion, the facilitator is responsible for letting every participant have their say. If the focus group is successful, the participants can help each other recall situations, and hence a participant can sometimes share more experiences than in a one-to-one interview (Unger & Chandler, 2012). However, the group setting can also lead to exaggerated statements.

Observations

Observations in the intended context are useful for gathering data that might be difficult to obtain from conversations with the user (Hasso Plattner Institute of Design, n.d.). For example, explaining accurately how you perform a task can be challenging (Sharp et al., 2019, p. 288). There are several approaches to conducting an observation. An observation can either be direct or indirect, depending on whether the investigator is the one watching and recording the activities on the spot or not (Bernard, 2011). Observations can take place in the field where the users perform their daily tasks, or they can take place in a controlled environment where the users perform specified tasks (Sharp et al., 2019, pp. 287-289). Before conducting an observation, it is recommended to make a framework for structuring and focusing the observation.

Literature reviews

In a literature review, information from published sources is gathered to lay a foundation for the current project (Hanington & Martin, 2019, pp. 148-149). The selected sources should be relevant to the project, and they can be organised by topic to structure the review.

Benchmarking

Benchmarking is a process of evaluating and comparing the achievements of a company's products and work with those of its competitors (Fridley et al., 1997). A benchmark helps the company to make knowledgeable decisions. The process starts by determining what to benchmark and selecting comparative companies. Data will then be collected from the companies and later analysed to understand the differences and opportunities. The findings can later be implemented in the company.

4.3.2 Define

The aim of the Define stage is to draw conclusions from the data gathered in the Empathise stage (Hasso Plattner Institute of Design, n.d.). The purpose is to clarify and define the scope of design possibilities and limitations, setting the direction for the following work and making it possible to tackle a meaningful challenge. The design space is defined by finding patterns in the gathered data and drawing conclusions. In this section, the methods affinity diagram, Hierarchical Task Analysis, requirements, persona, and scenario will be presented.

Affinity diagram
The purpose of an affinity diagram is to examine data and identify themes (Sharp et al., 2019, p. 324) and to help designers base their solutions on data (Hanington & Martin, 2019, p. 12). The building blocks of an affinity diagram are insights written on notes (Sharp et al., 2019, p. 324). Each note is compared to the others to find similarities, and notes with a common theme are clustered. Affinity diagrams can also be used to analyse data from usability testing, and by colour-coding each participant, recurring problems can be identified (Hanington & Martin, 2019, p. 12).

Hierarchical Task Analysis
To thoroughly describe how a task is performed, a Hierarchical Task Analysis (HTA) can be conducted (Stanton et al., 2017, pp. 40-44). An HTA is based on collected data regarding the task, including data about the steps, the human-machine interaction and how decisions are made. The elements of a HTA are organised hierarchically, and the overall goal of the task should be placed at the top. This goal is decomposed into several subgoals, which in turn can be broken down into meaningful subgoals. The subgoals at the bottom have associated operations, which are the actions the agent needs to perform to reach the subgoals. The HTA also contains plans that describe how the subgoals are reached. For example, a plan can say if a step depends on another step, in which order the steps should be performed or if a step should be repeated until a criterion is reached. One disadvantage of the method is that it requires much time and effort for large and complex tasks.

Requirements
A requirement specifies the functionality or performance of an intended product, and capturing requirements is important for defining the product (Sharp et al., 2019, pp. 385-417 & p. 19). The formulation of requirements can be based on the results from data gathering methods, such as interviews, observations and questionnaires. Requirements can be categorised into different types, and below are six types of requirements:

- Functional requirements - Specify what the product will do.
- Data requirements - Specify characteristics of the required data that the product will handle.

- Environmental requirements - Specify the operational environment in terms of physical, social, organisational and technical aspects.
- User characteristics - Specify the attributes of the user group.
- Usability goals - Specify usability criteria regarding efficiency, effectiveness, safety, utility, learnability and memorability.
- User experience goals - Specify the nature of the user experience.

Persona & scenario
Two methods often used together that help to bring requirements to life are persona and scenario (Sharp et al., 2019, p. 403). Personas describe typical users of the developed product extensively and help to communicate user characteristics and goals within the design team (Cooper, 1999, as cited in Sharp et al., 2019, p. 403). Personas are based on real users who participated in the data gathering and describe the user's behaviour, attitudes, activities and environment. Additionally, it includes the user's goals relating to the design inquiry. A persona is seldom longer than one page, including a name and an image of the person (Hanington & Martin, 2019, p. 170).

Carroll (1997) defines scenarios as narrative descriptions of what people do and experience when using the product under development. A scenario is built around a user's perspective and includes descriptions of the actions taken, the intention of these actions and the outcomes in terms of the user's motivations and expectations. Scenarios concretise the use and, thus, help developers to create results that support human activities.

4.3.3 Ideate

After defining the design space in the previous stage, the next stage is Ideate. The goal of this stage is to generate solutions for the identified problems by combining rational and imaginary ideas (Hasso Plattner Institute of Design, n.d.). Evaluating the ideas should be avoided during the ideation process to not hinder creativity and imagination. The purpose is not to immediately pinpoint an optimal solution but rather to generate a wide range of ideas that later, through user testing, can result in a suitable solution. There are several different methods for ideation, including brainstorming, brainwriting, braindrawing, SCAMPER and Six thinking hats.

Brainstorming, brainwriting & braindrawing
According to Wilson (2013), brainstorming is a method that can be used for many purposes, for example, to generate ideas, to find solutions to problems and to explore new design spaces. In brainstorming, participants shout out ideas on a predefined topic as quickly as possible. Quantity is prioritised higher than quality, and many generated ideas characterise a successful session. Wilson also mentions the methods brainwiriting and braindrawing as alternatives to brainstorming. In brainwriting, participants write down their ideas within a time limit and then pass them to another participant, who should continue elaborating on them (Brahm & Kleiner, 1996). Braindrawing also includes participants passing their ideas to each other, but the

ideas are sketched instead of written down (Wilson, 2013).

SCAMPER

Ideas from earlier ideation sessions can be further developed using SCAMPER (Wikberg Nilsson et al., 2017, pp. 132-133). In this method, the same questions are asked for each idea, and Dam and Teo (2024) describe the questions as follows:

- Substitute - What can be substituted in the idea?
- Combine - What can be combined to enhance synergy?
- Adapt - What parts of the idea can be adapted to solve the problem?
- Modify, Magnify, Minify - What in the idea can be modified or emphasised to a lesser or greater extent?
- Put to another use - How can the idea be used elsewhere?
- Eliminate - What can be eliminated or reduced in the idea?
- Rearrange - How can the idea be reordered or reversed?

There are guiding subquestions available for each question to facilitate the process.

Six thinking hats

Six thinking hats is a method that helps a team to separate thinking into six distinct functions (The de Bono Group, n.d.). The functions are represented by one hat each that is mentally worn, and de Bono (2017) describes the hats as follows:

- The White Hat focuses on objective facts.
- The Black Hat highlights the weaknesses of an idea.
- The Yellow Hat brings up the positive aspects of an idea.
- The Red Hat provides an emotional perspective.
- The Green Hat is creative and proposes new ideas.
- The Blue Hat ensures that the method is carried out right.

This method helps to systematically reflect on issues, decisions and opportunities (The de Bono Group, n.d.). Furthermore, it can be conducted to generate more and better ideas.

4.3.4 Prototype

After ideation, one typically moves on to the Prototype stage. In the early stages, the prototypes should be quickly created, and later on in the process, they should be more detailed (Hasso Plattner Institute of Design, n.d.). Sharp et al. (2019, pp. 422-428) describe prototypes as manifestations of ideas. They allow designers to communicate their ideas, both within the design team and to other stakeholders, and to explore their suitability. Prototypes can be discussed in terms of fidelity, where the higher fidelity a prototype has, the closer it is to the final product.

Low-fidelity prototyping

To explore ideas early in the development, low-fidelity prototypes are suitable since they are simple, quick and cheap to produce and modify (Sharp et al., 2019, pp. 426-428). Low-fidelity prototypes do not have the same functionality and look as the final product. One type of low-fidelity prototyping is storyboarding. In a storyboard, a series of sketches or scenes are used to show how a user could perform a task using the product. Wizard of Oz is another low-fidelity prototyping method that is useful for software-based prototypes. In Wizard of Oz, the software-dependent response is simulated by a human.

High-fidelity prototyping
Compared to low-fidelity prototypes, high-fidelity prototypes have more functionality and a closer visual resemblance to the final product (Sharp et al., 2019, pp. 428-429). Existing hardware and software components can be integrated to create high-fidelity prototypes. A high-fidelity prototype can also exist in digital form, for example, as a computer-aided design model (Hanington & Martin, 2019, p. 176). Users can evaluate high-fidelity prototypes to provide feedback on aesthetics, form, interaction and usability.

4.3.5 Test

The Test stage is executed after defining a problem and creating prototypes by letting stakeholders interact and give input on the developed product or concept (Hasso Plattner Institute of Design, n.d.). The purpose is to find opportunities for improvement and to refine the solutions, but also to learn more about the user. In this section, the methods of Pugh matrix, opportunistic evaluation, heuristic evaluation and usability testing are described. Data gathering methods, such as interviews, observations, and questionnaires, can also be used for evaluation purposes (Sharp et al., 2019, p. 520).

Pugh matrix
To compare design ideas and evaluate which best meets the defined criteria, a Pugh matrix can be utilised (Cervone, 2009). This method ensures that the opinions remain objective and that the result stays consistent. The process starts by listing design ideas in the matrix's first column and the criteria across the matrix's first row. One idea is selected to be the baseline, and all other ideas will be compared against it. Based on the comparisons to the baseline a "+" (better), "-" (worse), or "S" (same) is recorded against each criteria. The total score for each idea is then calculated by adding up the pluses and minuses, and the higher the score the better the result. The ideas with the worst results will be eliminated, resulting in one or a few optimal ideas.

Opportunistic evaluation
In the early stages of the design process, opportunistic evaluation can be executed in order to receive knowledge and input on a design idea (Sharp et al., 2019, p. 507). These evaluations are often informal and done by asking questions to the users about their opinions and receiving their feedback. By conducting this type of early evaluation, it is still possible to easily improve the design before investing too much time. Additionally, it clarifies if it is worth proceeding with an idea and creating prototypes with higher fidelity.

Heuristic evaluation

Heuristic evaluation is an inspection method that aims to identify problems in an interface (Sharp et al., 2019, pp. 549-552). It can be conducted together with an expert, which is someone who possesses knowledge about interaction design and the users' needs and behaviour. In a heuristic evaluation, an interface is evaluated against heuristics, which is a set of guidelines, and the evaluators list design aspects that do not follow these (Moran & Gordon, 2023). Which set of heuristics to use depends on what is to be assessed. People tend to identify different problems, and thus, it is beneficial to involve several evaluators (Nielsen, 1994). A heuristic evaluation can be made early in the development (Nielsen & Molich, 1990).

Usability testing

Usability testing is a method for identifying issues and possible improvements in a design and understanding the intended user's preferences (Moran, 2019). The user performs predefined tasks, and performance measures are collected, such as the time it takes to complete a task (Sharp et al., 2019, pp. 517 & 524-525). "Think aloud" is a common approach during usability testing, which implies that the participants are encouraged to say what they are thinking and doing out loud. To gather information on the user's impression of the interaction, a user satisfaction questionnaire and interview can follow. Similar to user studies, the participants should be informed before the test starts about how the test will be conducted and how the data will be collected and used. Moreover, they should be informed about their rights, and one common right is the right to withdraw from the study.

5

Planning

This project starts in mid-January and will proceed until early June, and its Gantt schedule can be seen in Figure 5.1. The problem this project addresses can be considered wicked since its formulation is not definitive and will be more defined as the project progresses. It will be tackled by conducting an iterative Design thinking process, and the intention is to carry out the five stages described in Section 4.3: Empathise, Define, Ideate, Prototype and Test. Meetings are planned every other week with the supervisor and every week with the mentors at Ascom. These meetings are an opportunity to receive continuous feedback and to discuss how the work could proceed.

The first four weeks of the project are primarily dedicated to writing the planning report. Simultaneously, a pre-study will be conducted, including a literature review of touchless interfaces and a benchmarking of products using touchless interfaces. The Empathise stage will start in the middle of February and continue until the middle of March. This stage will be emphasised greatly due to the complex use context involving several actors performing critical tasks. Moreover, the users are experts with knowledge and experiences that people in general don't possess. Several hospital departments will be visited to gain an understanding of this unfamiliar area, and the focus of the visits is to study the interaction between healthcare workers and communication devices.

The Define stage will start with structuring all gathered data to identify problem areas that could benefit from touchless interfaces. In mid-March, the plan is to choose one of the problem areas to centre the subsequent stages around. Requirements for this problem area will be written and complemented with a persona and a scenario to concretise the user group and situation. When the problem area is outlined, the Ideate stage can start by performing one or more ideation methods. The ideas need to be evaluated and reduced in number before proceeding to the Prototype stage, which will start at the beginning of April. The selected ideas will influence the selection of prototyping methods, although they will likely be low-fidelity prototyping methods because of the time constraint. This stage will be shortly followed by the Test stage to receive early feedback on the prototypes.

Due to the iterative nature of the design process, several methods will be revisited during the project. For example, complementary data gathering will be needed to fill gaps of knowledge discovered later in the project, and insights from evaluations will support the making of new, better prototypes. The intention is to write the master thesis report continuously during the project. However, in May, the main focus will be completing the report. The goal is to finalise the master thesis in June.

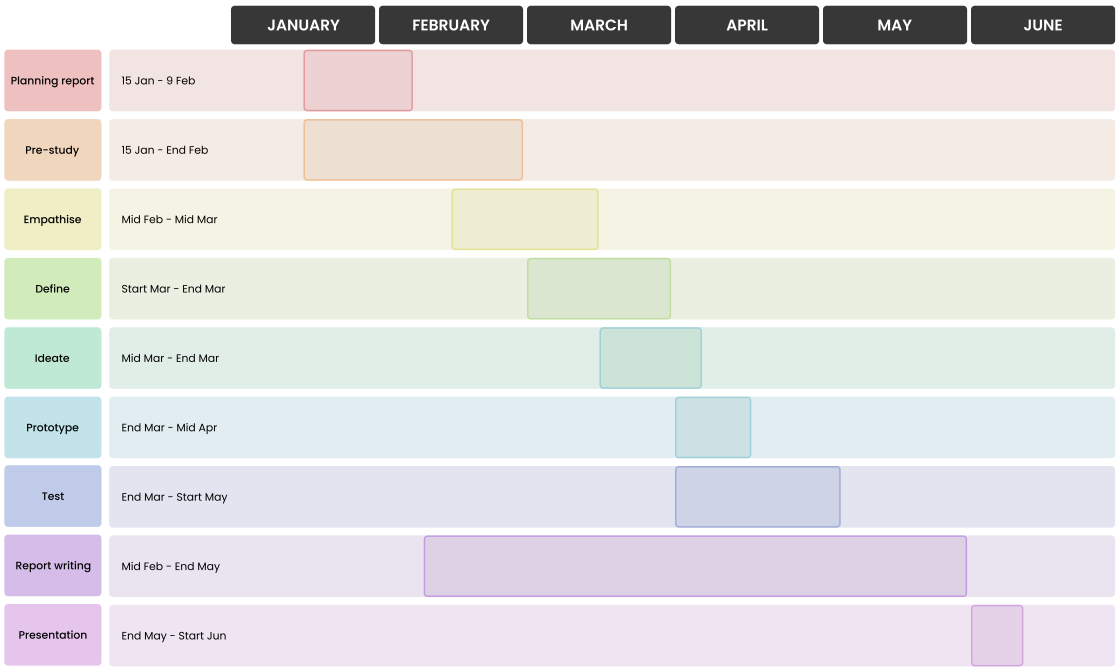

Figure 5.1: The project represented in a Gantt chart.

6
Execution

This chapter chronologically presents the execution of the thesis project and starts by describing the pre-study. Subsequently, it covers the design process, which followed the stages of Design thinking. For every stage, the execution and results of the applied methods are described. Since Design thinking is an iterative process, some stages appear more than once. See Figure 6.1 for an illustration of the process.

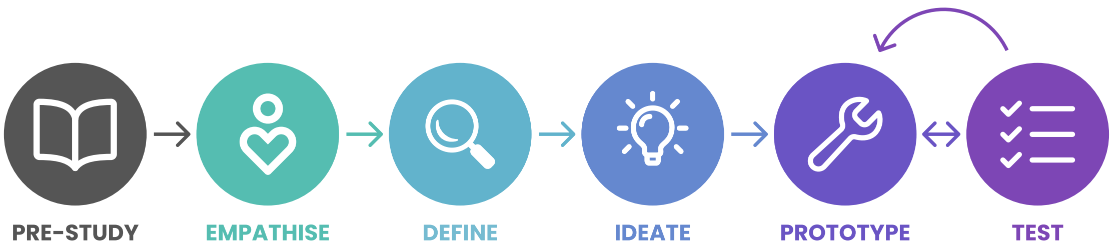

Figure 6.1: Illustration of the process.

6.1 Pre-study

The pre-study consisted of a literature review and a benchmarking. It was an opportunity to gather knowledge about touchless interfaces and how they are utilised today, Ascom's product portfolio and previous work related to this project.

6.1.1 Literature review

A literature review was conducted on touchless, haptic and multimodal interfaces, which provided knowledge of what they imply, their benefits and drawbacks, and the social aspects when using them. The studied touchless interfaces included eye tracking, voice user interfaces and gesture-based interfaces. These findings were supposed to support the upcoming solution development and evaluation, and they can be found in Section 3. In addition, literature on touchless interfaces in healthcare was studied, and these findings are presented in Section 2.3.1. This review aimed to gain insight into what has been investigated prior to this thesis and what conclusions others have drawn.

6.1.2 Benchmarking

To gain inspiration on how touchless technologies can be applied, a benchmarking of products utilising this was carried out. The benchmarking was not limited to solutions within healthcare but also those utilised in other industries, such as the automotive industry. Examples of studied products include Vocera, Humane Ai Pin, Leap Motion and HoloLens 2. The findings from the benchmarking can be seen in section 2.3.

Familiarising ourselves with Ascom's products was also crucial for this project. A clinical consultant at Ascom held a demo of their product portfolio, showcasing some of their hardware and software solutions. The primary focus was to demonstrate how Unite, the system where alert chains can be created and executed, worked. In the demo, the alerts were sent to the users' smartphones, where they could decide whether to reject or confirm an alert. By attending this demo, an understanding was gained of how the products are supposed to be used. This knowledge was important since the intended use does not always correspond with how users actually use them.

6.2 Empathise

During this stage, user studies were performed to investigate whether healthcare could benefit from touchless interfaces and, in that case, in which situations. In addition, the user studies aimed to collect data on what to consider when integrating touchless interfaces in a hospital environment. Firstly, a pilot study was conducted, followed by interviews and observations at hospital visits and an interview with a nurse. A focus group was not conducted because it would have been challenging for the visited departments to spare several healthcare workers simultaneously without affecting patient safety. Another alternative would have been to find healthcare people willing to participate in the study in their spare time, which would also have been difficult.

6.2.1 Pilot study

Before the visits to the hospital departments were conducted, an observation guide and interview questions were prepared. A pilot study including two interviews was conducted to assess the suitability of the interview questions. Two recently graduated doctors were interviewed over the phone, one at a time. Before the interviews, they were informed that the gathered data would be used for this master's thesis and that they could withdraw from the interviews. All the interview questions were asked, and the answers were written down along with reflections about the questions. The most significant finding of this study was that the alert and communication setup at hospitals often differ from the setup Ascom explained during the demo. In the demo, alerts were managed through an individual alert system on smartphones. The participants said that Ascom's DECT phones are used for almost all communication, and that was also common in their previous occupations at other hospitals. This information prepared us for the fact that many hospitals may not have transitioned to newer technology.

6.2.2 Interviews & observations

Five hospital departments were visited during this stage. The mentors at Ascom proposed intensive care, emergency, infection, and neonatal departments as potential interesting places to visit due to their high pace and need for sterility. Departments were contacted by mailing contact persons on hospitals' information pages, which resulted in three visits to different emergency departments and one to a neurological intensive care unit. After the first visits, we realised it would be interesting to visit one more department with inpatients. Therefore, a medical department was contacted via Ascom. This department was also interesting since they used smartphones for handling alerts, which differed from the other departments that used DECT phones and collective alert systems. In addition to the hospital visits, a nurse who worked at another medical department was interviewed.

Before the visits, an information sheet was emailed to the contact persons to be handed out to the personnel. It included the title of the project, the research question, the goal of the project, the purpose of the visits, and what their participation implied. Four out of five visits began with changing into scrubs (medical uniforms) to blend in better during any patient meetings. During the fifth visit, no patient meetings were attended; thus, no scrubs were needed. At the hospital departments, direct observations were made of how the communication and alert systems were set up and how the healthcare workers interacted with different devices. Since all the interviewees were working, most interview questions were asked on the go when appropriate. Observations and interview answers were recorded in a notebook, and the notes were transcribed to a text document after the visits. The hospitals have photo restrictions, and hence, no photos were taken. Below is a summary of a more extensive logbook containing insights gathered from each visit and the interview with the nurse.

Emergency department
A visit to an emergency department was conducted to assess their use of and demand for communication devices. During this visit, interviews were held with one practical nurse responsible for managing external and internal communication, two doctors specialised in emergency care and two nurses. Explanations of the different professions can be found in the Glossary. Additionally, the practical nurse and one of the nurses were observed during their work, and a general observation of the department was conducted. The department was equipped with an alert system linked to each patient room, with the alert information displayed in the corridors. See Figure 6.2 for an illustration of a hospital corridor. The nurses and the practical nurses collectively managed these alerts. Due to this system, the work environment was noisy, and continuous beeping sounds were in the corridors. Despite this, several workers preferred collective responsibility over a system involving individual alert units. They believed they had clear procedures for managing the alerts and found the information easily accessible. Only workers with specific leadership responsibili-

ties and doctors carried DECT phones during their shifts; the rest did not have their own units. Since the doctors' expertise is sometimes needed in other departments, it was highly prioritised to answer calls in all situations. They described scenarios in which they were unable to answer their phone, needing to either cancel their current task to answer or rely on someone else to respond on their behalf. During point-of-care tasks, answering the phone was often inconvenient. In such instances, someone would respond only to verify the urgency of the matter, and if deemed non-critical, they would end the call.

Figure 6.2: An illustration of a hospital corridor with an alert system.

Pediatric emergency department

During the visit to a pediatric department, interviews were held with two speciality residents, one nurse with extra responsibilities and one doctor with extra responsibilities. A general observation of the work environment was carried out, which focused on shadowing the interviewed nurse throughout her work assignments. The department primarily used DECT phones, and its different teams had one phone each. All doctors and workers with specific leading roles were equipped with at least one phone at all times. Similarly to the previously visited emergency department, alerts of different severity levels were managed through a system in the hospital corridors. Information about the type of alert and room number was shown on wall and ceiling displays. The interviewees expressed that they had become accustomed to the frequent sounds in the corridor and seldom reflected on it unless it was an emergency. The interviews and observations revealed that there was a need to communicate via devices simultaneously while performing two-handed tasks. Several of these tasks involved assisting patients, but also while using a computer, and managing medications. One of the speciality residents had requested a voice-controlled device worn around the neck for such situations but had not received it.

Gynaecology emergency department

A gynaecology emergency department was also visited. During this visit, multiple nurses and practical nurses were shadowed and asked questions. One longer interview was held with one of the nurses. This department utilised alert and phone call systems similar to those in the previously examined emergency departments. Many patient meetings in this department touch on sensitive topics; hence, using phones during these meetings was avoided whenever possible. Occasionally, phones were left outside patient rooms to avoid disturbances, and nurses often answered calls on behalf of the doctors during examinations. Each worker in the department had a personal safety alarm that was supposed to be worn on the clothes and used in threatening situations. However, most workers did not frequently wear these wearable devices. They often forgot it or did not feel the need to wear it since the threatening situations were very rare.

Neurological intensive care unit
A visit was made to a neurological intensive care unit, where the workers and patients had unique needs compared to the previously observed emergency departments. The visit involved conducting observations in three rooms, where nurses and practical nurses monitored and assisted the patients at all times. Collectively, six nurses were observed. Furthermore, interviews were held with a practical nurse, a nurse, a nurse with leading responsibilities and an anesthesiology resident. Similar to the previous observations, this unit had alert systems in the corridors. These alerts sounded in all rooms, including the patient rooms. Since the patients admitted to this unit need intensive care, they are monitored intensely. The monitoring of the patient's vitals and medication infusion resulted in frequent alert sounds. The interviewed practical nurse pointed out that the sounds could disturb the patients, especially since they could experience intense headaches. Each room had a DECT phone, for which the room team was collectively responsible. All doctors and other workers with special responsibilities had their own phones.

Following hygiene routines was important in the neurological intensive care unit. Therefore, they frequently used gloves and aprons when assisting the patients. The use of these protective equipment affected their use of communication and monitoring devices. During an observation, one nurse received a phone call while wearing gloves. To answer, they first had to interrupt what they were doing, then remove one glove, pick up the phone and cradle it between the shoulder and ear. At the same time as they answered the call, they removed the remaining glove. Several instances of touching displays to turn off monitoring alerts with gloves on were also observed, even though it does not follow the routines. The inconvenience of managing alerts and phone calls when wearing protective clothes resulted in the workers not always adhering to hygiene routines, potentially increasing the risk of transmission of pathogens between patients.

Medical department
The final observation of the initial user studies was conducted in a medical department. Interviews were held with one nurse and one practical nurse; beyond this, three additional nurses and three practical nurses were asked questions for further insights. Each nurse and practical nurse carried their own Ascom smartphone to manage alerts and phone calls and an additional smartphone that monitored the patient's vitals. Furthermore, they had displays in the corridors and lights outside

each room indicating where an alert had been triggered. Unlike all previously visited departments, the alerts in the corridors were silent. The only sound caused by an alert originated from the workers' smartphones, resulting in a quieter environment. It was clear that the workers did not use the smartphone's alert system as intended. Instead of accepting an alert on the phone, they only viewed the information on the phone or in the corridor and proceeded to the patient room, where they turned it off. Similarly, when they could not take on an alert, they did not use the reject option on the smartphone, causing the phone to continue sounding until someone else deactivated it at the source. The practical nurse expressed that they did not fully understand the alert app and were unsure about the outcomes of using these functions. Others had not formed the habit of using them but thought they should start since it would ease the work for themselves and their colleagues.

Several workers also described situations where handling the phone was inconvenient, such as wearing gloves and assisting patients. In these situations, the continuous sound of the phone could disturb the meeting with the patient. The workers expressed how patients sometimes commented: "Now they want to reach you" and "You have a lot to do". All interviewed workers expressed that they thought the smartphone was too heavy and big and desired a smaller version. When they were asked about their opinions of carrying an additional device with touchless features, they were not enthusiastic. This department had previously used an earlier version of an Ascom smartphone that had a small additional display on the top for easy information access. They all missed this version and explained that the two main functions needed on the phone were to manage alerts and phone calls and that other features were often redundant.

Interview with nurse

A small interview was held with a nurse who shared their experience with communication devices in their department. They worked in a medical department where the nurses had their own phones. Each nurse was responsible for six to seven patients, and all calls regarding their patients were directed to them. According to the nurse, incoming phone calls could disturb their work, for example, when they cannot answer a call and the phone keeps ringing. This type of situation can happen when they have occupied hands or unclean gloves, such as performing a jaw thrust, inserting a venous catheter, and administrating an injection. During the evening, night and weekend shifts, one of the nurses needed to carry the department phone in addition to their own phone. Since phone calls often interfere, the nurses argue about who should take the department phone. The department utilised an alert system in the corridor, and the nurse did not find this system disturbing. However, they said that reaching the assistance button sometimes can be troublesome when they have to be close to the patient.

6.3 Define

The purpose of this stage was to organise, understand and summarise the findings from the pre-study and the Empathise stage. It started by making an affinity diagram, whose results were used to write problem areas and requirements. Thereafter, two personas and scenarios were created.

6.3.1 Affinity diagram

All the gathered data was categorised in an affinity diagram to identify problem areas that could benefit from touchless interfaces and systematically map the users' needs. The affinity diagram included data from the visits, the interview and the literature review, assigning each source a unique colour to track the source of an insight. After each visit, the insights were written on notes in Figma and organised in preliminary categories together with the data from previous visits. When the last insights were assigned a category, the content of each category was revisited. Several iterations of recategorising resulted in the final affinity diagram in Figure 6.3, which includes the following categories:

- Challenges - This category included identified challenges that might benefit from integrating touchless interfaces. The challenges were divided into sub-categories, such as Interference with hygiene routines and Hands-occupied in point-of-care. Examples of insights:
  - "Hard to reach the assistance button when needing to be close to the patient"
  - "Sometimes they let the phone ring if they are wearing gloves and call back later."
- User experience - Several subjects were included in this category, such as Social aspects, Usability and Work environment. Examples of insights:
  - "You want to touch the mobile phone as little as possible."
  - "Healthcare workers believe that patients sometimes feel guilty when the phone makes sounds."
- Physical aspects - In this category, insights about how the physical design of the current devices affects healthcare workers are gathered. Moreover, it contains insights related to workwear and personal protective equipment. Examples of insights:
  - "The aprons cover all pockets."
  - "Heavy objects in the pockets of the shirt cause the shirt to move forward when bending over."
- Alarm - This category gathered insights regarding different types of alerts and alarms, including alert systems, monitor systems and emergency alarms. The insights covered needs, attitudes and functionalities related to the various kinds of alerts. Examples of insights:
  - "The healthcare workers do not carry the personal safety alarm because it is seldom used."
  - "Due to the many alerts in the corridor, some are filtered out, increasing the risk of important alerts being overlooked."
- Communication - The insights of this category were related to communication at the hospital departments, which mainly occurred over phone calls or by looking up someone. Example of insights:

- “To know who is calling, you have to check the screen and usually also answer.”
- “Calls to the doctor’s phone always need to be answered.”

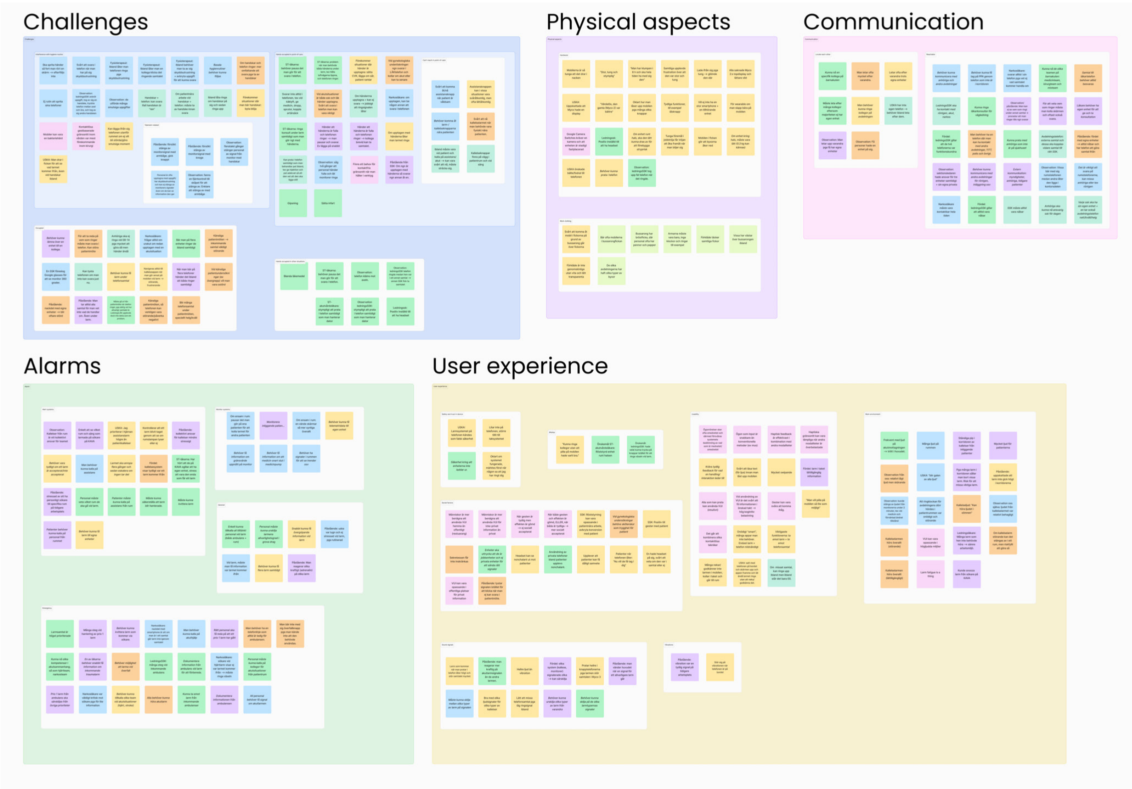

Figure 6.3: The final affinity diagram.

6.3.2 Problem areas

The problem areas were formulated by summarising and dividing the key findings from the research. Most of these originated from the category Challenges in the affinity diagram. In total, 12 problem areas were written, and they all had a similar structure, including a background to the problem, the problem itself, and its effect. The content of the problem areas is also alike, and only some factors differentiate them from one another. These factors result in different circumstances, so it was important to distinguish them. For example, when a healthcare worker follows hygiene routines, their hands can be free to interact with a device as long as they do not touch anything, compared to when their hands are occupied during two-handed tasks. Moreover, the procedures for handling calls differ from those for handling alerts. The titles of all problem areas are listed below, and their explanations can be found in section 7.1.

- P1. Following hygiene routines while responding to alerts
- P2. Following hygiene routines while managing incoming calls
- P3. Following hygiene routines while accessing information
- P4. Following hygiene routines while managing telemetry

- P5. Responding to alerts during two-handed, point-of-care tasks
- P6. Managing incoming calls during two-handed, point-of-care tasks
- P7. Access information during two-handed, point-of-care tasks
- P8. Initiate calls during two-handed, point-of-care tasks
- P9. Call for assistance while physically restrained
- P10. Managing calls during two-handed, non-point-of-care tasks
- P11. Workflow deviations when confirming alerts
- P12. Workflow deviations when rejecting alerts

The initial intention was to choose one problem area to focus on for the upcoming work. However, since many of the problem areas were related to each other, it felt overly restrictive to narrow the focus to just one. The decision was then made to exclude the problem areas P4 and P10. P4 involved telemetry, which Ascom is not a provider of and was therefore out of the scope. The choice to exclude P10 was based on the recognition that addressing the problems in the other problem areas would also cover those in P10. Furthermore, it was decided to narrow the target group to nurses and practical nurses, excluding doctors from the main focus. Nurses and practical nurses face similar problems regarding calls as doctors but also face additional challenges with alerts. Therefore, solving the nurses' and practical nurses' problems will inherently solve the doctors' problems as well.

6.3.3 Requirements

The formulation of the requirements began by reviewing the data organised in the affinity diagram. Each note in the affinity diagram was reviewed to ensure all important information relevant to the selected problem areas was included. The requirements were then categorised into different types. As an initial attempt, the requirements were divided into the types suggested in Section 4.3.2 in the methodology chapter. However, new types were created after realising they were not the most suitable for this project, and the new types are:

- Hardware
- Social aspects
- General functionalities
- Alert functionalities
- Call functionalities
- Usability

These requirements laid the foundation for a new requirement recommending what types of touchless interaction should be utilised in the solution. It was decided that voice user interfaces and gesture-based interfaces should be recommended, not eye tracking systems. Afterwards, the two new types listed below were added, and these included requirements regarding what to consider when utilising voice user interfaces and gesture-based interfaces for communication and information devices in a hospital environment.

- Voice user interface

- Gesture-based interface

Eye tracking was not recommended because it conflicted with requirements regarding comfort and the patient's perception of healthcare workers' facial expressions. A more extensive explanation for why eye tracking was excluded can be found in section 7.2, together with all the requirements.

6.3.4 Persona & scenario

Two personas and scenarios were crafted as the final step of the Define stage. These were derived from the information gathered on the healthcare workers who participated in the interviews and observations. Since the chosen focus was on nurses and practical nurses, one persona and scenario were created for each role. The aim was to aid the upcoming Ideate stage and to ensure a similar understanding of the users and their behaviours, needs, and challenges was achieved.

Persona 1
Name: Emma
Age: 35
Occupation: Nurse at a medical department

Emma has worked as a nurse for ten years and has been employed at the medical department for four years. Her daily tasks include assessing patients' health conditions, administering medications, performing medical procedures and speaking to patients' relatives on the phone. In her scrub pockets, the smartphone is accompanied by a few pens, a watch, several cheat sheets and an ID card. Every day, Emma strives to balance being present and engaged during patient meetings while remaining available for phone calls. She often feels frustrated over the constant interrupting phone calls, forcing her to start over with her tasks repeatedly.

Scenario 1
Emma walks towards Room 3 in the long hospital corridor. She feels how the weight of everything in her pockets is dragging her shirt down, and she pulls it up to its correct position. Today, she works the evening shift and is responsible for yet another phone along with her assigned work phone. Emma arrives at the room and greets her patient, who is lying in bed. While telling the patient she will set an IV with a new medication, she disinfects her hands and puts on gloves. As she is about to insert the needle in the patient's skin, one of the phones starts to ring in her pocket. She sighs quietly, puts the needle down, apologises to the patient, and quickly removes one glove before reaching for the correct phone in her pocket. She

fumbles for a second, then picks up the phone and cradles it between her shoulder and ear as she answers. With her bare hand, she proceeds to remove the other glove. On the other end of the line is a worried son of one of their other admitted patients, wondering about his father's current state of health. She excuses herself to the patient and walks out of the room to take the call. Right as the man is expressing his concerns, an alert starts beeping in her ear, and Emma pulls away from the sudden sound and quickly grabs the phone before it falls from her shoulder to the ground. She asks the man to repeat what he said and then ensures him that his father is stable. After the call, she notices someone else has managed the alert and returns to her patient. She repeats the disinfection of her hands and finally sets the IV.

Persona 2
Name: Anna-Maria
Age: 50
Occupation: Practical nurse at a medical department

One year ago, Anna-Maria started working at the medical department. She has worked as a practical nurse for 30 years and has experienced many different departments throughout the years. During a workday, she assists the patients with their daily needs, such as personal hygiene and meals, and performs some medical procedures. For Anna-Maria, it is important that her patients feel at home and seen during their hospital stay, even on stressful days. Here at the medical department, it is her first time using her own device to manage alerts. She appreciates the quieter environment the devices have resulted in but has not fully built a habit of using them as intended.

Scenario 2
"Beep beep beep", Anna-Maria hears while feeling the familiar vibration in her pocket. She looks up towards the ceiling, sees that the patient in room 7 is calling and starts walking towards the room. Actually, she should pick up her smartphone and confirm the alert to inform that she is responding to it, but since she is already on her way, she will turn it off in the room instead. The room is at the other end of the corridor, and the beeping sound starts once again before she enters the room. She smiles at the patient and asks what she can help with. The patient says that it looks like his wound dressing has started leaking, and after looking, Anna-Maria sees that it needs to be changed. To ensure sterility, changing wound dressing is a long process and involves disinfecting your hands at least six times. When Anna-Maria removes the old wound dressing, she receives a new alert. She

pulls the pocket containing the smartphone forward with her pinky finger to get a glance at the screen, and she thinks she can distinguish the word Room 8, or was it Room 9? The phone keeps beeping as she continues with the procedure. “You have much to do.”, the patient says, and Anna-Maria seems to hear a hint of guilt in his voice. Maybe it would have been better if she had left the phone outside the room.

6.4 Ideate

The next step of the project was to make design suggestions for how the requirements could be implemented. This process began in the Ideate stage, where the methods of brainwriting, braindrawing and SCAMPER were used. During SCAMPER, it became evident that many issues had already been thoroughly discussed, allowing us to proceed to the next stage. Therefore, the method of Six thinking hats was skipped.

6.4.1 Brainwriting & braindrawing

The first ideation session was done using the methods of brainwriting and braindrawing by writing down and drawing ideas connected to each problem area, one at a time. Some ideas were easier to explain by writing than drawing, and vice versa; therefore, combining the methods supported all ideas. Each round started with three minutes to generate ideas about one problem area on paper individually. After this, the papers were switched to continue elaborating on the other person’s ideas for three more minutes. Finally, all ideas were discussed before moving on to the next problem area. After ideating for all problem areas, the ideas were refined by discussing possible improvements and challenges. Each idea was described in writing and sketched to make it easier for others to understand. Here, aspects such as size and functionality were decided. A large number of ideas were generated, and to select which ones to move forward with, the ideas were evaluated against the requirements. The ideas that did not meet the requirements were eliminated, except one. This idea utilised eye tracking, which the requirements do not recommend, and it was kept due to curiosity about the healthcare workers’ opinions about using a device similar to the current mixed-reality headsets. In total, seven ideas progressed to the next stage.

6.4.2 SCAMPER

To further elaborate on the ideas and ensure that no improvements were overlooked, the method of SCAMPER was employed. The intention was to ask and discuss all questions from SCAMPER for each idea. However, after a few iterations, it became clear that all these questions had already been discussed during the previous ideation session. The decision was then made to move on to the next step of the process. Even though most of the discussion was repetitive, it became even clearer that feedback is important when interacting with touchless interfaces, such as using sounds, vibrations and possibly animations.

6.5 Prototype I

The first iteration of the Prototype stage was performed to communicate the ideas from the previous stage, both within the team and with users. During this stage, different types of low-fidelity prototyping methods were used.

6.5.1 Low-fidelity prototyping

The purpose of the first prototypes was to explore the ideas further and, later in the process, to receive early feedback. Therefore, low-fidelity prototyping was selected as an appropriate method. The ideas differed in their technical feasibility; some leaned more toward unconventional concepts, while others relied on more common technology. Consequently, the prototypes showed this diversity. For two of the seven ideas, digital illustrations and cardboard prototypes were created to provide an understanding of the dimensions and shapes. For the two most unconventional ideas, the *projecting headphone* and *smart glasses*, images of how they could look and be utilised were employed. Due to the technical limitations of these ideas, creating physical prototypes was considered too early at this stage of the process. The three remaining ideas were communicated by showing illustrations and trying out similar existing products borrowed from the Ascom office. All ideas utilised both voice control and gesture control.

Wearable with top display and integrated earbud
This wearable device is intended to be worn on the chest pocket (see Figure 6.4 for illustrations of the device). The user can interact with the device using voice, hand gestures, and touch. It has a touch-sensitive top display, letting the user quickly view the active output by tilting their head down. The user can choose to receive auditory information on command. To support the user in various situations, the user can choose to receive information through the speaker on the device or by wearing the integrated earbud. When wearing the earbud, the device automatically directs all auditory output to it, such as phone calls. This way, sensitive information can be withheld from the public. Only one earbud is provided to ensure that the user still remains present with patients and can hear sound from their surroundings. The earbud needs to fit both ears since a user can have hearing deficiencies in one ear. If the user engages in a phone call using the earbud, a phone icon on the front of the device will indicate that a call is in progress. When the user does not want to use the earbud, it will be placed in the dedicated holder on the side of the device, minimising the risk of it being misplaced and always being within reach. The earbud is kept in place with magnets and protected by a magnetic cap.

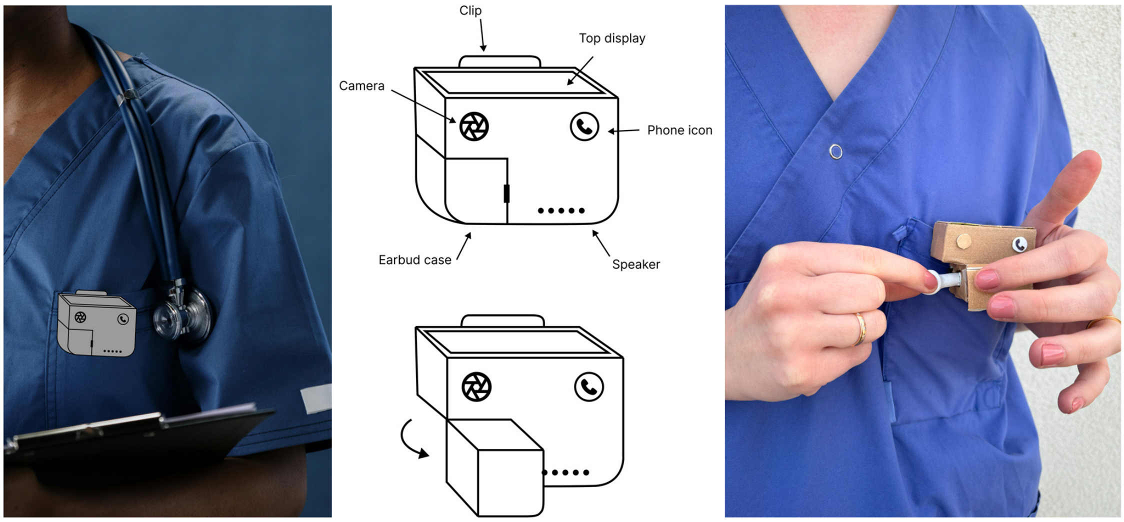

Figure 6.4: Prototypes and illustrations of the *wearable with top display and integrated earbud.*

MiniWearable

The *MiniWearable* is a small and lightweight device attached with a clip to the neckline of the shirt or to the chest pocket. See Figure 6.5 for an illustration of the device. It is to be carried together with and connected to a smartphone that utilises Ascom's systems. The device is controlled using voice and gestures, and some frequently used features are also available using buttons. All information from the device is provided by audio and vibrations. If the user wants to view visual output, they can access it through the smartphone.

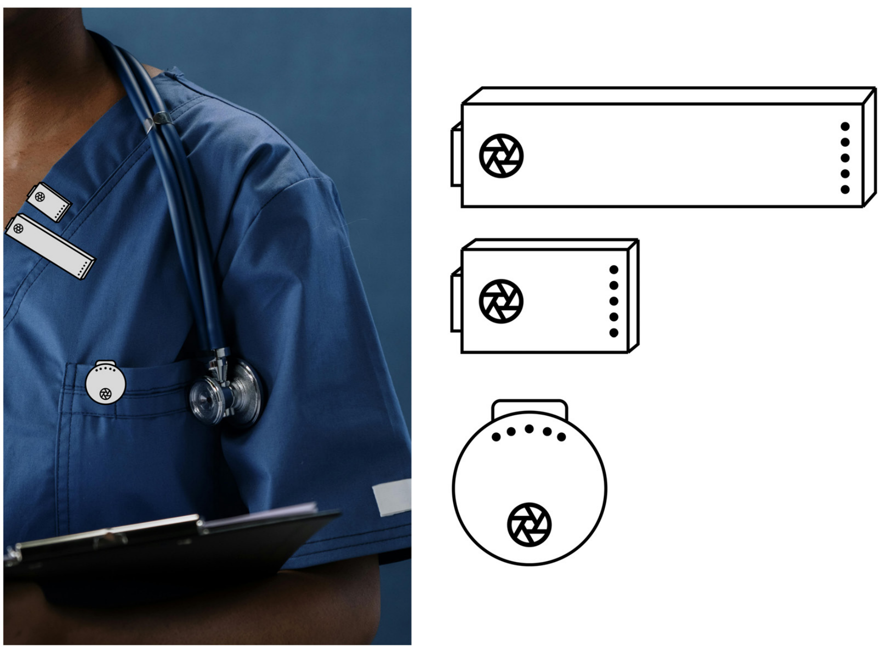

Figure 6.5: Illustrations of the MiniWearable, showing three different suggestions on the physical shape.

Wearable with top display and front display
This device is inspired by a previous Ascom device, Myco 2, and has two displays. It looks like a small version of a smartphone but with an additional small display on the top of the device. See Figure 6.6 for a visualisation of the prototype. The device is intended to be carried outside the chest pocket, with the top display visible when glancing down. When there are pending alerts, they will be displayed on the top display one at a time, alternating between them. If the user wants to get further information about the alerts, they can either ask the device to read the information out loud or view it on the front display. They can access the front display by tilting the phone upward or by removing it from the chest pocket and holding it in their hand. The features available on the device are limited to alert management and phone calls. Besides voice and gesture control, they can also interact with it via the touchscreen on the front of the device and a few buttons.

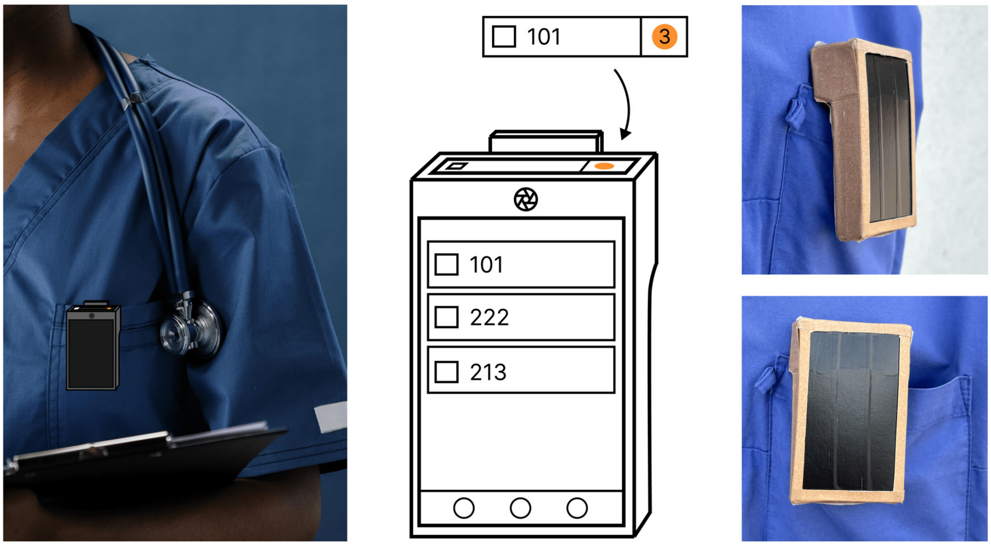

Figure 6.6: Prototypes and illustrations of the *wearable with top display and front display*.

Myco 4 with voice control and gesture control
This idea revolved around the already existing device Myco 4 but with the added utilisation of voice and gesture control. To be able to utilise the gesture control, the camera on the device needs to be visible. Today, the fabric of the shirt pocket occasionally covers the camera due to the position of the clip on the device being too high. The clip needs to be lowered so that the camera sticks out of the pocket. The images below in Figure 6.7, show a Myco 4 carried in different ways.

Figure 6.7: Images of how Myco 4 can be worn.

Bone conduction headphone

The *Bone conduction headphone* have the same functionality as the *MiniWearable*, but with the additional possibility of receiving all auditory information directly in your ear instead of on the speaker. The headphone is wrapped around the top of the user's ear and transmits sound waves directly to the bones. Therefore, it does not cover the ear canal. See Figure 6.8 for an illustration of this. Additionally, only one headphone will be worn. As a result, it is possible to still hear conversations and be aware of the surroundings. The front of the device features a small indicator light with a phone icon that is lit during a call. This enables observers to discern whether the user is engaged in a call or not. When the user interacts with the device by making gestures, they will be performed with hand movements near the ear.

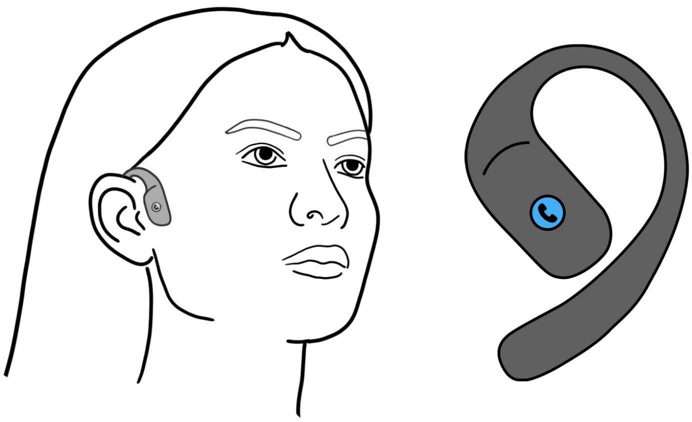

Figure 6.8: An illustration of the *bone conduction headphone*.

Projecting headphone

The *Projecting headphone* is a bone-conduction headphone similar to the previous idea. On the other hand, this device enables the user to view visual output from the device by projecting it on the palm of the hand. The device will detect when their hand is held in a specific position diagonally below their face, slightly away from their body, and project the information on it. The user should then be able to interact with gestures and voice to change the output. This device could in many situations be worn independently, without the need for an additional smartphone, making it a lightweight solution. Figure 6.9 shows an illustration of this prototype.

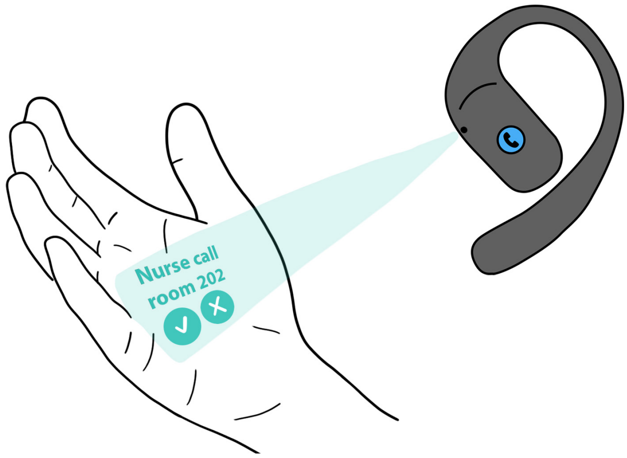

Figure 6.9: An illustration of the *projecting headphone*.

Smart glasses

This device is a pair of smart glasses that allows the user to view information in their field of view instead of on a screen. On the frames, close to the ears, there are speakers so that the user can hear auditory information as well. In addition to gesture and voice control, this device also utilises eye tracking. Below in Figure 6.10 is an illustration of the *Smart glasses*.

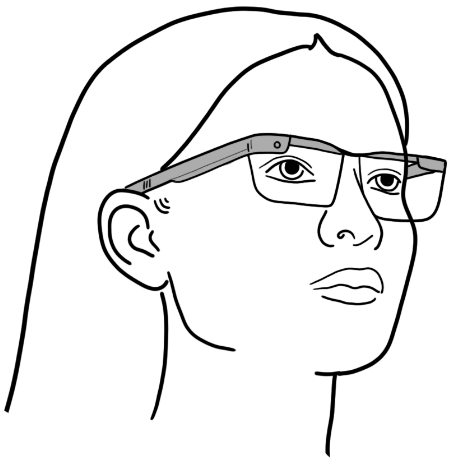

Figure 6.10: An illustration of the *smart glasses*.

6.6 Test I

During the first iteration of the Test stage, healthcare workers participated in an opportunistic evaluation where they interacted with existing products and the prototypes from the previous stage. This method aimed to gain a deeper insight into healthcare workers' thoughts on different touchless interfaces and what hardware they would prefer for a product integrating touchless interfaces. Since users were available, an opportunistic evaluation was chosen instead of a heuristic evaluation. The opportunistic evaluation was followed by another evaluation using a Pugh matrix. Lastly, the results of the two evaluations were used to decide which ideas to continue elaborating on.

6.6.1 Opportunistic evaluation

During a second visit to the medical department, a first evaluation was conducted with healthcare workers by letting them express their opinions and thoughts about the developed prototypes. Two practical nurses and one nurse were interviewed. In addition to the prototypes, they tried out existing products to experience and understand functionality that could be utilised in the prototypes. Among these products were a pair of bone-conduction headphones and a wearable smart assistant attached to clothes, utilising voice control. Besides these, they interacted with a Myco 4 smartphone through gestures.

The evaluation began by briefly describing the three existing products and letting the participants try them out one by one. For the wearable smart assistant, they were tasked with making a phone call using their voice. With the bone conduction headphones, they experienced listening to music while maintaining a conversation. As for the Myco 4, they were instructed to hang the phone on their chest pocket and pretend to accept an alert by gesturing with a thumbs-up in front of it. After each test, they were asked about their willingness to integrate the product into their work routine and its potential impact. After these questions, the evaluation moved on to the developed prototypes by showing the models and illustrations, explaining their features and asking for their opinions. At the end of the evaluation, they were asked to rank the prototypes from their favourite to least favourite for use in work.

Wearable with top display and integrated earbud
The participants viewed illustrations and a cardboard model of the idea during the evaluation of *Wearable with a top display and integrated earbud*. The reactions were mostly positive but with one major drawback: the earbud. They addressed concerns about sharing an earbud with others and said they would have liked to have a personal earbud for this wearable. They also said that it would be easy to drop the earbud and lose it. Besides this, they liked that it was small and easy to carry with them.

MiniWearable
The participants assessed *MiniWearable* by viewing illustrations, and their opinions

about it were positive. They thought the device was convenient and could benefit them in their work. Before the evaluation, a hypothesis was that this device would not be as well-received as it was, as previous user studies revealed a reluctance to carry additional devices. This turned out not to be an issue when asked this time. This prototype had quite similar expressions and features to the wearable smart assistant that they were able to try out earlier in the evaluation. They liked how this product was fastened to the clothes using a silicon strap with a magnet instead of a plastic clip. The material felt comfortable against the skin and less likely to break if accidentally dropped. Additionally, they appreciated its compact size and lightweight.

Wearable with top display and front display

The idea *Wearable with top display and front display* was presented to the participants by showing an illustration and a cardboard model. When summarising the ranking of the ideas for the three participants, this wearable ended up in the first place. The top display on the wearable was something they found appealing. They were all familiar with the Myco 2 phone, which featured a top display. This prior experience led them to desire the same feature again, which can be the reason for its high ranking. They were also positive about its small size and low weight, but one expressed that it could be slightly bigger. One of them compared it to their current phone, the Myco 3, which they felt was too large and heavy.

Myco 4 with voice control and gesture control

The participants assessed this idea by viewing illustrations and interacting with the Myco 4 that registered gestures through the camera. When the participants tried the gesture-based interaction, it became evident that some challenges were present. For example, it was not straightforward where the hand needed to be held so the camera could detect it. The direction of the camera varied depending on how they positioned the phone on their clothes and whether they were sitting or standing. Additionally, all participants initially made the gestures too close to the camera, so it could not detect them. Despite these challenges, they believed that using gestures could be helpful in certain situations. For example, during conversations, a gesture can be more convenient than a voice command to avoid interruptions in the conversation. Concerns were raised about gestures possibly not functioning properly while wearing an apron and the fabric of the shirt pocket could potentially obstruct the camera. Other opinions about the phone were that it was large and heavy and that they would rather use a smaller device.

Bone conduction headphone

This idea was presented to the participants by showing illustrations and letting them try a pair of bone conduction headphones. The feedback on the bone conduction headphones was positive and they liked that they could hear their surroundings simultaneously with the sound from the headphones. All three participants tried on glasses while wearing the headphones, which did not pose any issues. However, it’s worth noting that they only tested this setup for a limited time, which may have affected their response. Since this device is carried on the ear, it must be comfortable and secure. According to the participants, compared to in-ear headphones, these felt more secure and were perceived as less unhygienic when shared among coworkers. One participant expressed that it would be great to incorporate voice control in a headphone. During the evaluation, it was discussed whether the alert sounds should be played out loud or if only the user would hear them. Both approaches had pros and cons, so more research would be needed if this idea were further developed.

Projecting headphone
The opinions about the *Projecting headphone*, presented through illustrations, were mixed. One participant chose this idea as their favourite and said they would have taken it immediately. Another participant thought it was too futuristic and that they would rather have a screen than a projection.

Smart glasses
Similar to the *Projecting headphone*, this *Smart glasses* was demonstrated through illustrations. When summarising the participants' ranking, it was their least favourite. One expressed concerns about how the patients would perceive it and also questioned how it would be for those wearing regular glasses. Another participant only shook their head about the concept. The last one was quite positive, and they thought it would be cool to use but did not think all patients would accept it.

Summation
The participants ranked the prototypes, which were printed on paper, from most to least favourite, and the summation of all rankings is listed below. The prototype Myco 4 with voice control and gesture control was left out of the ranking session by mistake, probably because there were no printed pictures of this idea. However, since it utilised the same interactions as the other prototypes but had physical properties the participants found too large and heavy, one can assume that it would not be ranked at the top. Before proceeding to the next step, the prototype that performed the worst, namely the smart glasses, was eliminated.

1. Wearable with top display and front display
2. MiniWearable
3. Projecting headphone
4. Bone conduction headphone
5. Wearable with top display and integrated earbud
6. Smart glasses

6.6.2 Pugh matrix

A Pugh matrix was used to evaluate the prototypes further before eliminating any more. In the matrix, the most important requirements and wishes were selected as criteria. These can be read below:

- The solution should be perceived as lightweight.
- The solution should have a high social acceptability.

- The solution should prevent the need for excess devices to handle calls and alerts.
- The system should inform about missed calls when requested.
- The solution should be comfortable to use for a full shift.
- The solution should not negatively affect the quality of the patient-healthcare worker relationship.
- The solution should be able to manage alerts and calls that occur simultaneously.
- The solution should provide an overview of the current situation.
- The solution should withstand physical impact.
- The solution should not disclose confidential information to unauthorised people.
- The solution should consider hygienic aspects to ensure that the healthcare workers feel comfortable sharing it with one another.

Three rounds of the Pugh matrix were conducted. In the initial round, the prototype that had received the best reviews from the participants was selected as the reference, which was the *Wearable with a top and front display*. All other prototypes were compared to the reference for each criterion. In the second round, the prototype that had received the second best results in the previous round was chosen as the reference, namely the *Wearable with a top display and integrated earbud*. The last round was conducted only on two prototypes to clarify their differences since they received the same score during the evaluation with users and had quite similar features. The results from each round of the Pugh matrix are shown below in Table 6.1. The prototype that received the lowest number was deemed the most successful, and the one with the highest number was the least successful.

	Wearable with top display and integrated earbud	Mini Wearable	Wearable with top and front display	Myco 4 with voice and gesture control	Bone conduction headphone	Projecting headphone
Round 1	2	3	1	5	5	4
Round 2	2	4	1	5	5	3
Round 3	N/A	1	N/A	N/A	2	N/A

Table 6.1: Result from the Pugh matrix.

6.6.3 Result of Test I

With the collective results from the evaluation with potential users and the Pugh matrix, two ideas were selected for further work. The selected prototypes were of varying complexity to accommodate the diverse needs of different workplaces. By recognising that the reliance on third-party apps varied between departments, the decision was made to support this difference. The necessity of a larger screen to accommodate the demands of third-party apps conflicts with the needs derived from the user studies to reduce the weight and size of the device. For users who do not have a significant need for third-party apps and want to reduce the size and number of features on the phone, a replacement smartphone was chosen. This device would be independent and not rely on other devices to function. It would only include the most essential features. To support these users, the prototype chosen was the *Wearable with a top and front display*. This prototype received the best results during both evaluations.

For users who regularly need to use a large number of features on the smartphone, a small additional device that would be carried together with the smartphone was chosen. This device would reduce the number of interactions needed with the phone and make their work more efficient in situations where third-party apps would not be required. The prototype chosen for this was the *MiniWearable*. This prototype received the second-highest score during the evaluation with users and relatively high ratings during the Pugh matrix as well.

6.7 Prototype II

After deciding to continue with the two ideas *Wearable with top display and front display* and *MiniWearable*, time was spent further developing them. During the second Prototype stage, they were renamed *Myco Main* and *Myco Mini*. High-fidelity prototypes were made in the form of images of CAD models and 3D-printed models. Moreover, the method of Hierarchical Task Analysis was used as a prototyping method to discuss and explore interaction flows. Thereafter, storyboarding was used to explain some of these interaction flows. The results from this stage is further described in Section 7.3.

6.7.1 High-fidelity prototyping

With the feedback from the users in mind, the physical shape and look were explored. Several sketches were made using pen and paper, followed by illustrations in Figma (see Figure 6.11 and 6.12). Different shapes and sizes were also cut out of paper and placed in their intended positions on a shirt to understand them better. After deciding on the dimensions and shapes, 3D models for both devices were created using the CAD software Autodesk Alias to visualise their designs in greater detail. Additionally, basic 3D models were generated using another CAD software, Autodesk Fusion 360, specifically for the purpose of 3D printing. The models were 3D-printed for the final evaluation, enabling participants to better understand their sizes and dimensions.

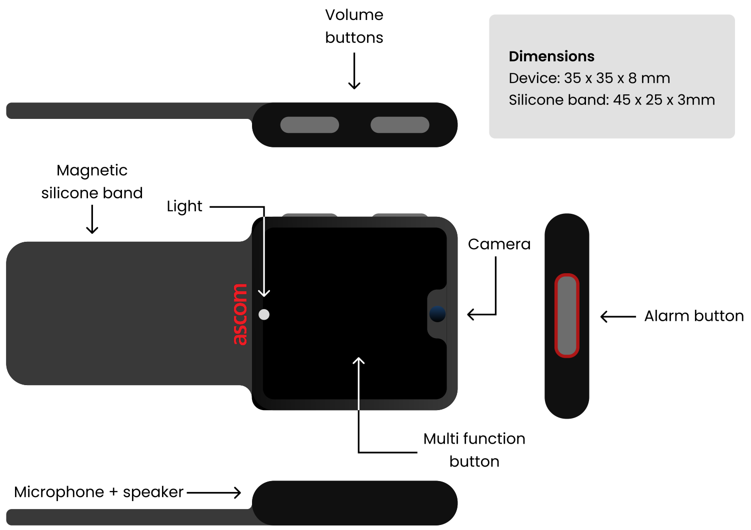

Figure 6.11: Illustration of the MiniWearable.

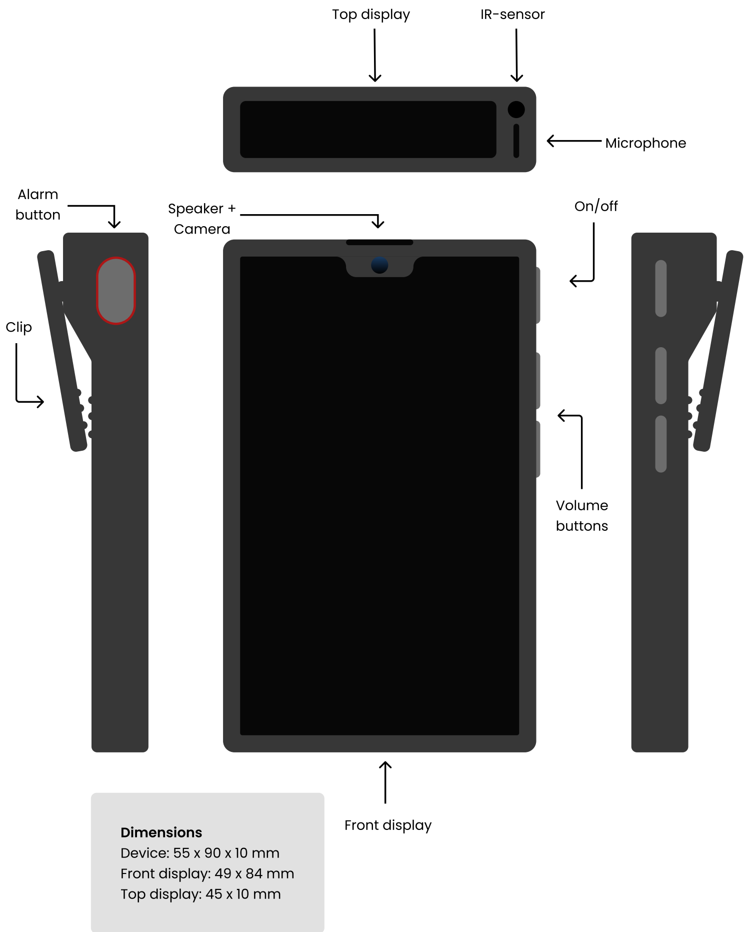

Figure 6.12: Illustration of the Wearable with top display and front display.

6.7.2 Low-fidelity prototyping

During this time, the features and interaction flows were also explored and decided. The method used to create the flow was loosely based on a hierarchical task analysis (HTA), dividing the interactions into goals, subgoals, and operations. The goals that were included are listed below. The interaction flows were reviewed together with the mentors at Ascom to validate them and get valuable input. The complete interaction flows can be found in Appendix A.

- Managing incoming alerts
- Create alerts
- Managing incoming calls
- Initiating calls
- Turn on the "do not disturb" mode
- Regulate volume

Decisions had to be made regarding when to employ voice control, gesture control, buttons, or a combination of these features. A combination of both controls was desired for most features to support users with different preferences. Thanks to the intuitive nature of voice control and that detailed information can be entered in a fast and easy way, it was enabled for all features. It was decided that the user should have the flexibility to express commands in various ways, and the device should be able to interpret them. It should also remember ongoing conversations. If information is missing for the device to be able to complete a request, it should ask the user to add information or clarify their intention. To support users in situations where sounds need to be kept to a minimum, gesture control will be available. However, it was decided to limit the number of available gestures, considering that learning gestures requires time and can be challenging to remember. Time was spent discussing whether feedback following gestures on the device should be entirely silent. While gestures offer a silent mode of interaction compared to voice commands, it was decided against keeping the feedback completely silent. This decision was made because the interface primarily relies on auditory cues, and removing them would risk crucial information being missed. A few buttons are available for commonly used features as a third way of interacting with the device.

Many of the interaction flows include several alternative interactions, and storyboarding was selected as an appropriate method to visualise these alternatives. The following interaction flows were explained by storyboards:

- Accept an alert using *Wearable with top display and front display*
- Reject an alert using *MiniWearable*
- Answer a call using *MiniWearable*
- Decline a call using *MiniWearable*

6.8 Test II

The last stage of the project was another iteration of Test, during which users evaluated the final designs. This evaluation validated how well the design met the users' needs and provided valuable insights that could be used during future design iterations. Furthermore, a brief evaluation of a gesture-based interface took place.

6.8.1 Usability testing - Gestures

A short evaluation was conducted at the Ascom office, where our mentors and we tried out a gesture-based interface developed by an Ascom colleague. This interface enabled users to answer and decline phone calls through the gestures of thumbs up and thumbs down. During the evaluation, the participant wore a hospital shirt, placed the gesture-enabled smartphone in the chest pocket, and tried the interactions of answering and declining a call. Both the front and back cameras of the device were tested by attaching the phone to the outside and inside of the pocket using the clip. Afterwards, the phone was placed in one of the lower pockets, and the tasks were repeated.

It became evident that the tested gestures were not optimal for the various positions the phone could be placed. Wearing the phone in the lower pockets and gesturing a thumbs down in the right location for the camera to register was very challenging because the hand needed to be held in a strained and uncomfortable position. When the phone was placed in the chest pocket, both gestures became easier to perform, although executing the thumbs-down gesture remained more challenging compared to the thumbs-up. Similarly to Test I, it was also difficult to know where and how close to the camera the hand needed to be held for the device to recognise the gestures.

6.8.2 Usability testing - Myco Mini & Myco Main

A final evaluation was conducted at the medical department, which had been visited twice before. The evaluation started with introducing the devices, where the participants could view the visualisations and hold and wear the 3D-printed prototypes. Then, the participants were asked to perform predefined tasks, similar to the method of usability testing. However, no performance measures were collected; instead, the participants were interviewed about their experiences. In the tasks, the participants tried the following features of the voice user interface: accept an alert, reject an alert, ask for more information about an alert and answer a call. Each task started with a description of the situation, where one of the situations was that they were in the corridor being ready to go on an alert. The description for the other three tasks was that they were performing an unclean task wearing unclean gloves. During these three tasks, the participants were also instructed to string beads while performing the voice control to imitate their hands being occupied, see Figure 6.13. Since the 3D printings had no integrated technology, a Wizard of Oz method was used to simulate alert notification sounds, a ringtone and responses to their voice commands. The simulation was achieved by connecting a laptop and a smartphone to a Teams meeting, where the laptop shared its sounds. The sounds were played by the smartphone, placed near the participant, and controlled by the computer. Lastly, the participants were asked about their opinions of the gesture-based interaction and the suggested gestures that can be seen in Section 7.3.2.

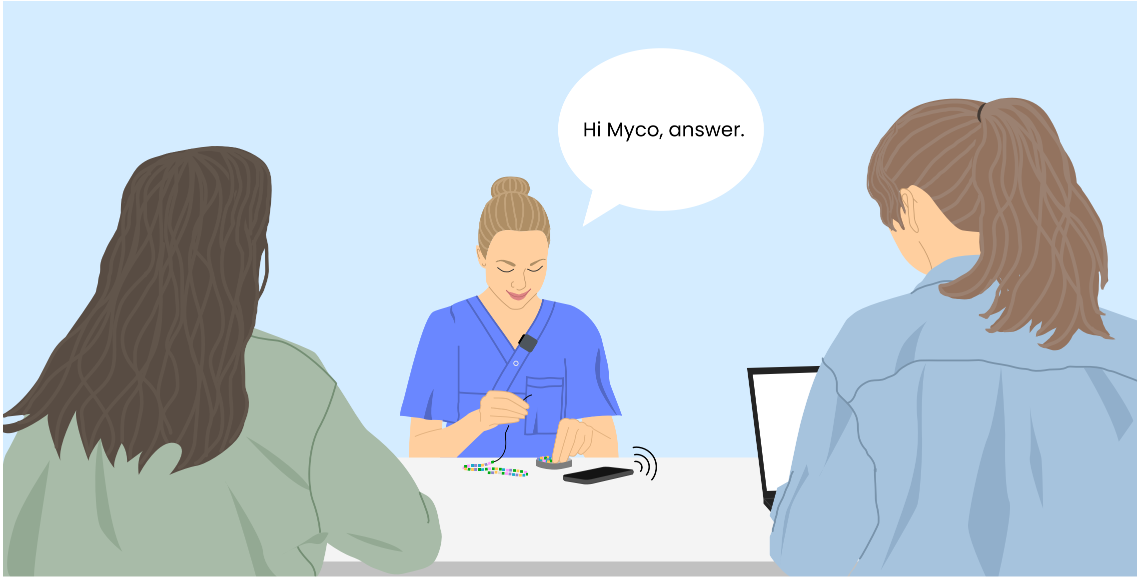

Figure 6.13: Illustration of the usability testing.

Two practical nurses and one nurse participated in the evaluation. When they were asked to wear the 3D-printed prototypes, they all positioned *Mini* on the V-neck of the shirt. They were okay with carrying around *Mini* with a smartphone since it is small. One said it was so discreet that one could easily forget it was there, and another participant actually forgot to remove *Mini* when leaving the evaluation. Two participants positioned *Main* hanging on one of the lower pockets of the shirt, mostly inwards, and the third one placed it in the breast pocket. They thought that the size of *Main* was appropriate, and they appreciated the top display. As previously mentioned, their department had previously had Myco 2, which they missed, so the top display was a welcome sight. Two additional practical nurses provided feedback on the devices, but did not perform the tasks.

In general, the participants were very optimistic about the voice user interface. They all thought that it could simplify their work since they are often in situations when they cannot respond to their smartphones, for example, when helping a patient to shower or when wrapping a leg. They believed that they would be comfortable using this in front of patients and that the patients would not find the interaction too strange. However, one of the participants did not like the interaction of accepting an alert in the corridor. Firstly, they thought accepting an alert was unnecessary since they could walk directly to the room and turn it off. Secondly, they did not see the point of accepting the alert in a touchless manner when they had free hands. Lastly, patients could perceive the voice commands in the corridor as strange behaviour. The participant said using voice commands when having occupied hands in a patient room makes more sense and would be much more comfortable. The other participants were more positive about accepting alerts in the corridor but said that it would take time to get used to the interaction.

When testing voice control for calls, the participants were asked about the provided feedback when the call began. In the current interaction, the user is informed that they can start to talk when the ringtone stops ringing. Two out of three thought it was clear enough, and one felt that additional feedback was needed. The auditory design of the alert notification was also discussed with the participants. An alternative to just using a sound as an alert notification is to let a voice read out information about the alert, for example, what type it is and where it comes from. The participants leaned towards the alternative of including information in the notification since this removes the extra steps of asking for more information. This would allow them to decide whether to accept or reject the alert faster. For example, some patients have an increased risk of falling, and when you receive an alert regarding them, it is important to check on them quickly. Other helpful information to include would be if a patient calls from the WC or their bed since this also affects the decision. One mentioned concern was that a more extensive notification would be more disturbing for the patients, but a participant said that if the information were concise, it would probably work. Many patients at the department are connected to telemetry systems that alert in case of abnormal values. According to a participant, sound notifications can make patients nervous over whether their values are causing the alert. Therefore, the participants said that more informative notifications might stress the patients less.

The gesture-based interface did not receive the same appreciation as the voice user interface. Two participants said they would not be comfortable using this with patients since the interaction is not as clear as the voice user interface. The patients would probably understand the voice commands but not the meaning of the gestures. Furthermore, there is a risk of them finding the gesture-based interaction disrespectful. A participant said they would prefer more hidden gestures, such as movements in front of the device. Another participant found the gestures more complicated to recall than the voice commands since the voice is more intuitive. Nevertheless, one participant did not find gesture control socially strange and thought it was a good complement to voice control for situations where you want to avoid interrupting an ongoing conversation.

7

Results

In this chapter, the deliverables of this thesis are presented. First, the problem areas are listed and described. These are followed by a section presenting and explaining the requirements that should be considered when integrating touchless interfaces in healthcare communication. Lastly, the final designs of *Myco Main* and *Myco Mini* are presented, including descriptions of their hardware and interactions.

7.1 Problem areas

Below are the problem areas of situations that could possibly benefit from touchless interfaces, which spring from the findings of the user studies. Three overarching themes can be identified in the problem areas: following hygiene routines, being physically constrained, and workflow deviations. Moreover, most of the problem areas either involve calls or alerts, which are two commonly used device features.

P1. Following hygiene routines while responding to alerts
In a medical department, the necessity for nurses to follow hygiene routines while performing point-of-care tasks wearing gloves, conflicts with the need to respond to smartphone alerts. Nurses have to decide whether to let the alert remain or to respond to the alert by cancelling the task, removing their gloves and disinfecting their hands. This conflict disrupts patient care and workflow efficiency as well as impairs the patient experience.

P2. Following hygiene routines while managing incoming calls
In hospital departments, the necessity for healthcare workers to follow hygiene routines while performing point-of-care tasks wearing gloves, conflicts with the need to manage incoming calls. Healthcare workers have to decide whether to let the phone ring, let someone else handle it for them, or manage themselves by cancelling the task, removing their gloves, and disinfecting their hands. This conflict disrupts patient care and workflow efficiency as well as impairs the patient experience.

P3. Following hygiene routines while accessing information
In hospital departments, healthcare workers encounter difficulties accessing all necessary information from the device while following hygiene routines wearing gloves. This is due to the screen of the device being out of their field of view. They need to decide whether to not access all information or access the information by cancelling the task, removing their gloves and disinfecting their hands. These difficulties result

in the healthcare worker lacking the information needed to make informed decisions.

P4. Following hygiene routines while managing telemetry
In an intensive care unit, the necessity for nurses to follow hygiene routines while performing point-of-care tasks wearing gloves conflicts with the need to respond to telemetry warnings. Nurses have to decide whether to let the warning remain or to respond to the warning by cancelling the task, removing their gloves and disinfecting their hands. This conflict disrupts patient care and workflow efficiency as well as impairs the patient experience.

P5. Responding to alerts during two-handed, point-of-care tasks
In a medical department, healthcare workers occasionally receive an alert while performing point-of-care tasks that require both hands. They need to decide whether to let the alert continue ringing or to respond to the alert by cancelling the task. This situation disrupts patient care and workflow efficiency as well as impairs the patient experience.

P6. Managing incoming calls during two-handed, point-of-care tasks
In hospital departments, healthcare workers occasionally receive a phone call while performing point-of-care tasks that require both hands. They need to decide whether to let the phone ring, let someone else handle it for them, or manage themselves by cancelling the task. This situation disrupts patient care and workflow efficiency as well as impairs the patient experience.

P7. Access information during two-handed, point-of-care tasks
In hospital departments, healthcare workers encounter difficulties accessing all necessary information from the device while performing point-of-care tasks that require both hands. This is due to the screen of the device being out of their field of view. They need to decide whether to not to access all information or access the information by cancelling the task. These difficulties result in the healthcare worker lacking the information needed to make informed decisions.

P8. Initiate calls during two-handed, point-of-care tasks
During major traumas, doctors occasionally need to initiate a phone call to a consultant while performing point-of-care tasks that require both hands. To address this, they have to interrupt the task and occasionally resort to cradling the phone between the shoulder and ear to continue with the patient. This situation disrupts patient care and workflow efficiency.

P9. Call for assistance while physically restrained
In hospital departments, healthcare workers occasionally need to call for assistance while being physically occupied with the patient and thus unable to reach the call module. This results in the healthcare worker needing to shout for help which may not be heard or exposing oneself and the patient to unnecessary risks.

P10. Managing calls during two-handed, non-point-of-care tasks

In hospital departments, healthcare workers occasionally need to initiate or answer a phone call while performing non-patient-related tasks that require both hands. To address this, they have to interrupt the task and occasionally resort to cradling the phone between the shoulder and ear to continue. This situation disrupts workflow efficiency and compromises physical ergonomics.

P11. Workflow deviations when confirming alerts

In a medical department, the nurses don't follow the intended workflow when receiving alerts on the smartphone. Instead, when they hear the alert, they glance at the ceiling display to obtain the information and proceed directly to the patient's room to deactivate the alert and assist the patient or colleague. The intended workflow includes retrieving the phone from the pocket, unlocking it, confirming the alert, and then proceeding to the patient's room to deactivate the alert. The alternative workflow can be more convenient for the responder but results in unawareness of the alert's status in the other recipients and a noisy environment.

P12. Workflow deviations when rejecting alerts

In a medical department, the nurses don't follow the intended workflow when receiving alerts on the smartphone. When they hear the alert and are occupied, they don't reject the alert as intended. Instead, they let the alert continue ringing until it is handled by another recipient. This approach results in an extended delay before the patient or colleague receives assistance and a noisy environment.

P1 to P4 cover situations where the hygiene routines restrict the handling of the device. Adhering to hygiene routines is critical in a hospital environment to avoid transmitting pathogens, and an unclean task often includes several glove changes and disinfections of hands to ensure sterility. If a healthcare worker needs to handle the device during an unclean task, they have to pause the task, remove their gloves and disinfect their hands. This approach is inefficient and time-consuming. However, if they decide not to respond to the device, it will still disturb the situation by continuing to beep. P3 highlights the issue of the devices often being carried in the healthcare workers' pockets, causing the screens to be out of sight. The healthcare worker must pick up the device to access information, which is cumbersome during unclean tasks. The challenges underlying P1 to P4 were primarily identified in departments with admitted patients since they frequently perform unclean tasks.

The challenges of interacting with devices during two-handed, point-of-care tasks are presented in P5 to P8. Similar to P1 to P4, the healthcare workers need to interrupt their tasks to manage the device. In P5 to P6, the healthcare workers need to decide whether to respond to the device or not. The user study participants said this could happen, for example, when maintaining a jaw thrust, casting or inserting a central venous catheter. P7 is very similar to P3, but the cause of the problem is occupied hands instead of following hygiene routines. P8 originated from one of the visits to the emergency departments. A doctor said that during some emergencies, they need to call a medical consultant when performing two-handed, point-of-care tasks to know how to proceed with the treatment. Today, they must cancel the task to initiate the call and then cradle the device between the shoulder and ear to resume the task. Healthcare workers also perform two-handed tasks when patients are not nearby. During these tasks, situations can arise where handling the device becomes inconvenient, and P10 represents these. Examples of such situations from the user studies include receiving a phone call while mixing medications or if you want to make a call while typing on the computer.

P9 originates from healthcare workers' experiences of the assistance button not being within reach. A healthcare worker at the gynaecological emergency department mentioned that one time, a patient passed out while sitting in the gynaecological chair and fell with her head caught between the seat and one of the leg supports. The healthcare worker, who needed to be next to the patient, could not reach the assistance button on the wall. Moreover, the neurological intensive care unit patients can occasionally behave violently, and the healthcare workers have trouble reaching the assistance button simultaneously while managing the situation. Today, healthcare workers handle these situations by shouting for help, hoping a colleague will hear them.

The last two problem areas emerged from observed workflow deviations when handling alerts on Ascom smartphones. These deviations are due to several factors, including the fact that some workers lack the knowledge of what the available actions "Accept" and "Reject" result in. Furthermore, the healthcare workers expressed that the current interaction required a lot of swiping. Solutions to these issues do not necessarily need to be touchless since healthcare workers have free and clean hands. However, they could still benefit from touchless interfaces if these interfaces make the interaction faster and more convenient.

7.2 Requirements

This section lists requirements that aim to answer the research question by showing what qualities a healthcare communication device utilising touchless interfaces must possess. These are based on the pre-studies and user studies of the project and consider every problem area except P4 and P10, as explained in section 6.3.2. The requirements consider individual alert systems that contribute to a quieter environment compared to open alert systems in the corridors. The list also includes some wishes, marked with a W, and the solution is not required to fulfil these but if it does, it is favourable. The requirements are intended for people who design healthcare communication devices with integrated touchless interfaces, and there are several fundamental requirements regarding mobile communication devices. The list is organised into the types of Hardware, Social aspects, General functionalities, Alert functionalities, Call functionalities, Usability, Voice user interface and Gesture-based interface.

7.2.1 Hardware

The following requirements regard the physical properties that a solution should possess.

1.1 The solution should not be worn on the arms below the elbows.

1.2 The solution should be compatible with the healthcare workers' uniforms.

1.3 The solution should be easily attachable and detachable to the healthcare workers' uniforms. (W)

1.4 The solution should be compatible with gloves.

1.5 The solution should be compatible with aprons.

1.6 The solution should be able to be disinfected.

1.7 The solution should be mobile.

1.8 The solution should be comfortable to use for a full shift.

1.9 The solution should not result in bodily harm.

1.10 The solution should be perceived as light weighted. (W)

1.11 The solution should have a continuous power supply for a full shift.

1.12 The solution should withstand physical impact.

1.13 The solution should be waterproof.

1.14 The solution should include hardware that enables the utilised touchless interfaces.

There are several requirements regarding healthcare workers' scrubs and the basic hygiene routines. At all visits, the healthcare workers wore a short-sleeved top with a v-neckline, one breast pocket and two lower pockets, and pants with varying types of pockets. When following hygiene routines, they are not allowed to wear anything on their forearms and hands, and they wear gloves and aprons during unclean tasks. Moreover, reusable equipment must be able to be disinfected. The hospital environment can be demanding, so the solution must withstand physical impacts, such as being dropped to the floor. It also needs to be waterproof since the they perform wet tasks, for example, helping patients shower.

A healthcare worker needs their device in many different places, so the solution must be mobile. They can use their device for an entire shift, which the power supply of the solution must manage. Since they carry their device for many hours, the solution must be comfortable and preferably lightweight. For example, an interviewee who occasionally uses two phones said that carrying them in the lower pockets of the shirt caused a shoulder ache. Lastly, the solution's hardware must support some touchless interfaces to fulfil the listed functionalities below.

7.2.2 Social aspects

The requirements in this section cover how the user's surroundings perceive the usage of the solution.

2.1 The solution should not negatively affect the quality of the patient-healthcare worker relationship.

2.2 The solution should not hinder the patient from seeing the healthcare worker's facial expressions.

2.3 The solution should be perceived as hospital equipment.

2.4 The use of the solution should be perceived as professional by the observer.

2.5 The solution should not disclose confidential information to unauthorised people.

2.6 The solution should have a high social acceptability. (W)

Healthcare workers at the medical department said they could have trouble turning the alerts off during patient meetings due to occupied hands or unclean gloves. Occasionally, the continuous alert sounds can make the patients feel guilty for taking up their time. The interviewed nurse who worked at another medical department said they would rather work without the phone because it disturbs patient meetings. However, that is impossible because they need to be reachable. The solution should be designed so that patient meetings are less disturbed. In addition, the solution should not affect the visibility of the healthcare worker's facial expressions. For example, eye contact is important for the patient to understand the message from the healthcare worker, and the patient can perceive a lack of eye contact from the healthcare worker as a sign of disinterest (Davidhizar, 1992). The solution should also clearly communicate that it is hospital equipment. Otherwise, using the device can appear to be ignorant to the observers, as mentioned by a nurse at an emergency department. Confidential information is often exchanged on the devices, while healthcare workers are surrounded by people who should not access this information, such as other patients and patient relatives. To make the solution usable in these contexts, confidential information must not be disclosed to everyone around.

According to some healthcare workers, the social acceptance of technology will come many years later in hospitals than for consumer products. In addition, most visited departments used older technology such as feature and landline phones, indicating a longer adaption time for new technology. Therefore, implementing touchless interfaces in a hospital environment may present social challenges and the solution having a high social acceptance is formulated as a wish. That being said, striving for high social acceptability when integrating touchless interfaces is important.

7.2.3 General functionalities

This section includes functionalities of the solution that are not exclusive to either calls or alerts.

3.1 The solution should not include excessive functionality.

3.2 The solution should prevent the need for excess devices to handle calls and alerts. (W)

3.3 The solution should ensure uninterrupted work during a limited time period.

3.4 The solution should direct information to the intended users.

3.5 The solution should be able to manage alerts and calls that occur simultaneously.

3.6 The solution should facilitate the localisation of colleagues. (W)

3.7 The solution should utilise at least one of the following touchless interfaces: voice user interface and gesture-based interface.

3.8 The solution should allow for multimodal input. (W)

3.9 The solution should include touch-based interfaces.

The healthcare workers at the medical department complained that there were many applications on smartphones that they had no use for. According to them, handling alerts and calls are the two most essential functionalities, and sometimes, a calculator and alarm clock can be helpful. Therefore, the solution should only include functionalities that the users request. In addition, the healthcare workers at the medical department said that they would not like to add a new device since they always carried two smartphones, and this opinion resulted in a wish.

A practical nurse at the medical department mentioned that they left the smartphone outside the patient's room when performing a time-consuming task to avoid being disturbed by alerts. If the solution provides a Do Not Disturb function, the healthcare workers don't have to put it away. To prevent unnecessary disturbances, information should only be directed to the intended users. For example, if a patient's room has an assigned nurse, the alerts should be primarily directed to that nurse.

An alert can occur during a call and vice versa. Considering the importance of both functionalities, the solution should be able to handle these situations conveniently. Moreover, at several departments, the healthcare workers spent time looking for each other. Hence, it would be beneficial if the solution would facilitate the localisation of colleagues.

The solution should use voice user interfaces, gesture-based interfaces, or both for touchless interaction. The decision to exclude eye tracking systems from the requirement was based on the fact that using eye tracking contradicts some requirements. The solution should be mobile, and today's mobile products using eye tracking, cover large parts of the face, such as HoloLens 2 (Microsoft, n.d.-a) and Apple Vision Pro (Apple, n.d.). Therefore, if eye tracking had been utilised, it would have contradicted the requirement saying that the solution should not hinder the patient from seeing the healthcare worker's facial expression. There is also a risk that wearing these types of devices is uncomfortable for an entire shift. Other possible difficulties may be when wearing glasses underneath or being in humid environments, such as when helping a patient shower.

The solution should provide multimodal input methods for the actions. Multimodal interfaces allow a user to switch between input methods depending on the circumstances of the situation (Oviatt, 2007, pp. 414-418), and there are situations at the hospitals where this can become relevant. For example, when a healthcare worker has occupied hands while performing a task, they cannot make gestures, making voice control a more suitable option. Additionally, a nurse mentioned that they would not want to make a voice command while talking to a patient since that would interrupt the conversation. Then, making a gesture would be a better choice if the situation requires touchless interaction. Moreover, a user can have preferences of which interaction they like the most to use. The solution should also provide alternative input methods for touchless interfaces. Not all situations require touchless interfaces, and sometimes, a touch-based interaction can be more convenient. This requirement also corresponds to Jordan's 1998 principle of Compatibility, saying that the product's method of operation should be similar to the methods of operations used by other products the user has encountered. Touch-based interfaces are more conventional in hospitals, and by providing familiar interfaces in addition to touchless interfaces, users can perceive the solution as more useable.

7.2.4 Alert functionalities

Requirements exclusively regarding alerts are gathered below.

4.1 The solution should allow for accepting alerts with touchless interaction.

4.2 The solution should allow for rejecting alerts with touchless interaction.

4.3 The solution should allow for creating alerts with touchless interaction.

4.4 The solution should provide a fast and easy interaction for issuing an emergency alert.

4.5 The solution should be able to manage multiple alerts simultaneously.

4.6 The solution should provide all the necessary information needed to handle an alert.

4.7 The solution should provide clear information on the status of an alert.

There are three alert actions for which the solution must provide touchless interaction. The first two are accept and reject alerts, which are essential for making the department workflow more efficient. The third action is creating an alert, which can only be created with the call modules on the walls today. This requirement originates from the issue of not always reaching the call module, as the ninth problem area covers. Moreover, healthcare workers can be stressed during emergencies, and the solution should consider their mental state by providing an easy and quick interaction for creating an emergency alert.

The solution must support situations where there are multiple alerts simultaneously, and it must also provide information about the alerts to help the user make informed decisions. This information could vary between departments, and an example of information that could be included is type of alert, room number and bed number. Furthermore, the status of an alert should be provided, for example, if the alert has been escalated. If an alert is escalated, it has not been handled within a specific time limit, causing a new distribution to more healthcare workers.

7.2.5 Call functionalities

In this section, the call requirements are listed.

5.1 The solution should allow for accepting calls with touchless interaction.

5.2 The solution should allow for declining calls with touchless interaction.

5.3 The solution should allow for silencing calls with touchless interaction.

5.4 The solution should allow for initiating calls with touchless interaction.

5.5 The system should inform about missed calls when requested. (W)

The actions accept, decline, silence and initiate calls should be possible with touchless interaction. The interviewed healthcare workers said that there are situations when they receive calls and are unable to respond, for example when performing unclean tasks or having occupied hands. Touchless interaction may help them in these types of situations. A nurse at the gynaecological emergency department said that they chose to silence a call when they are unable to answer it instead of declining it. They meant that there is a risk that the person on the other side of the line believes the call got disconnected if you reject it, whereas if you silence the call, it keeps going, indicating that you are too busy to answer. Therefore, the solution should allow for silencing calls with touchless interaction. The requirement for initiating a call with touchless interactions is based on a doctor's experience presented in the eighth problem area. Some interviewees could not access missed calls, which sometimes complicated their work. Hence, it would be beneficial if the solution could inform the user about missed calls on request.

7.2.6 Usability

This section includes the usability properties the solution must possess.

6.1 The solution should provide information in an accessible way.

6.2 The solution should provide an overview of the current situation. (W)

6.3 The type of event from the solution should be easily distinguishable.

6.4 The event notification should be noticeable.

6.5 The solution should limit the number of actions needed to reach a goal.

6.6 The solution should be perceived as trustworthy.

6.7 The solution should provide clear feedback on one's actions.

6.8 The solution should have the capability to undo actions.

6.9 The solution should consider hygienic aspects to ensure that the healthcare workers feel comfortable sharing it with one another.

6.10 The solution should strive for a quiet environment.

6.11 Any emitted sounds should be easily distinguishable.

6.12 Any emitted sounds should be at a comfortable sound level.

6.13 Any emitted sounds should be prominent.

6.14 Any emitted sounds should be pleasant. (W)

As the third and seventh problem areas present, the healthcare workers have to pick up their phones to access information, which makes the workflow inefficient. Therefore, the solution should follow Jordan's 1998 principle of Visual clarity and provide information in an accessible way. In order to gain an understanding of the situation, the user should be able to access an overview of all current events from the solution. Providing an overview of the situation helps the user to make the right decision, preventing the probability of errors according to the guideline of Error prevention and recovery (Jordan, 1998). Furthermore, there will be various types of events from the solution, such as calls and different alert types, and the solution should once again follow the principle of Visual clarity by clearly communicating to the user which type is occurring.

As previously mentioned, the healthcare workers using the smartphone alert system complained that too much swiping was needed to interact with the system, and this conflicts with Jordan's 1998 principle of Prioritisation of functionality and information. The solution should require as few steps as possible to perform an action to make their workflow efficient. Another way to follow this principle is to provide call and alert notifications that attract the user's attention. Calls and alerts are essential for hospital departments since they provide information needed to provide proper care. Making the notifications noticeable increases the chance of all calls and alerts being managed.

In the medical department, a practical nurse said they did not trust the smartphone alert system. As a result, they mostly looked at the ceiling and room displays to keep track of the alerts. Establishing healthcare workers' trust is an important aspect of getting users actually to use the solution. One way is to provide clear feedback to help the users understand the outcome of their actions, following the principle Feedback for useable design (Jordan, 1998). Additionally, the users should be able to redo actions when mistakes happen or when circumstances change, according to the principle of Error prevention and recovery (Jordan, 1998). For example, a healthcare worker can accept an alert but later be interrupted by something more urgent. Then, the alert needs to be made available to colleagues again.

It was common practice in the visited departments for nurses and practical nurses to share devices among the workforce. If the solution is not hygienic to share with others, the workers will not feel comfortable using it. A requirement regarding hygienic aspects was included to not conflict with the satisfaction aspect of usability and consider the user's emotional response that results from using the solution (International Organization for Standardization, 2018, ISO 9241-210, section 3.10).

Continuous and repetitive alerts can cause alarm fatigue (Jones, 2014), decreasing healthcare workers' ability to distinguish between alerts and increasing the risk of alerts being ignored. Several people working in departments with corridor alert systems expressed that the frequent sounds were annoying. Furthermore, some said that they have learned to ignore some of them, indicating that they have developed alarm fatigue. At the neurological intensive care unit, a healthcare worker said the alert system could be painful for patients with severe headaches. Therefore, striving for a more silent environment is vital for the work environment, the safety and the patient's recovery. When sounds are used, they should be at a comfortable sound level. Nevertheless, they must also be prominent so the user can acknowledge them. The sounds of the alerts varied between different departments, and some were more pleasant than others. It would be valuable if the used sounds could be more harmonious and still catch the user's attention. The visited departments also had different sounds for different types of alerts. The healthcare workers found this helpful, so easily distinguishable and varying sounds should be utilised in the solution.

7.2.7 Voice user interface

Requirements when utilising voice user interfaces are listed below.

7.1 The solution's microphone should be positioned close to the user's mouth.

7.2 The solution should understand different types of dialects.

7.3 The solution should repeat information on request.

During the user studies, it was observed that the hospital environment can be noisy due to equipment sounds and several people being in the same room. As de Camargo et al. (2021) state, voice user interfaces can have trouble interpreting the commands when the surroundings are noisy. To prevent the surrounding sounds from interfering, the microphone of the solution should be placed near the user's mouth. In addition, this placement prevents the risk of activating other devices of the same type that are nearby. The transient nature of the voice user interface output places a heavy cognitive load on the user (Cohen et al., 2004, p. 6). The user should be allowed to ask for the solution to repeat information to reduce the cognitive load, and this requirement follows Jordan's 1998 guideline of Consideration of user resources. Many different dialects exist among healthcare workers, and to be accessible to all, the solution must understand various dialects.

7.2.8 Gesture-based interface

The following list includes requirements when gesture-based control is utilised.

8.1 The solution should not utilise too complex gestures.

8.2 The solution should not utilise too physically challenging gestures.

8.3 The solution should utilise distinct gestures.

8.4 The solution should not utilise an excessive number of gestures.

8.5 The solution should not implement suspenseful gestures.

8.6 The solution should implement one, or more, of the following alternatives: secretive, magical and expressive gestures.

As mentioned in Section 3.1.2, there are several things to consider when designing a gesture-based interface. According to Vatavu (2023), gestures should not be complex, physically challenging, and hard to remember to facilitate gesture-based interaction. Rempel et al. (2014) suggests gestures used in sign language for letters and numbers for gesture-based interfaces because they are distinct. Therefore, distinct is a quality that the selected gestures should possess. In order to avoid overloading the user's memory, following Jordan's 1998 guideline of Consideration of user resources, the solution should not utilise too many different gestures. The degree of social acceptance varies for different gesture-based interactions Montero et al. (2010). Suspenseful gestures, where the gesture is revealed and the effect is concealed, have low social acceptance. The other combinations of visible or hidden gestures and their effects are socially acceptable.

7.3 Myco Mini & Myco Main

This section presents the two prototypes the thesis resulted in. They are designed to support healthcare workers in situations described in the problem areas. The prototypes, *Myco Mini* and *Myco Main*, exemplify two approaches to implementing the requirements into physical products. While the prototypes aim to meet all requirements, certain aspects require further evaluation with users. Specifically, the requirements concerning social aspects and usability. For instance, during Test II, it became apparent that the gesture-based interface needs further evaluation to assess whether it meets requirement 2.6 by having a high level of social acceptability. Another example of a requirement that needs to be tested is 6.6, which entails that the solution should be perceived as trustworthy. Furthermore, since the focus of the project has been on aspects other than the emitted sounds, the requirements regarding this, 6.10-6.13, need to be evaluated in future iterations.

In Figure 7.1 and 7.2 below, the two prototypes are visible. The name *Myco* is taken from Ascom's smartphone line and stands for "My Companion". *Myco Mini* earned its name for its compact size and minimalistic interface, while *Myco Main* signifies a device with only the main features needed for healthcare workers' daily tasks. *Myco Mini* and *Myco Main* have many similarities but several differences as well. Both focus on assisting healthcare workers in various situations by enabling touchless interfaces. The prototypes are described in terms of hardware and interactions.

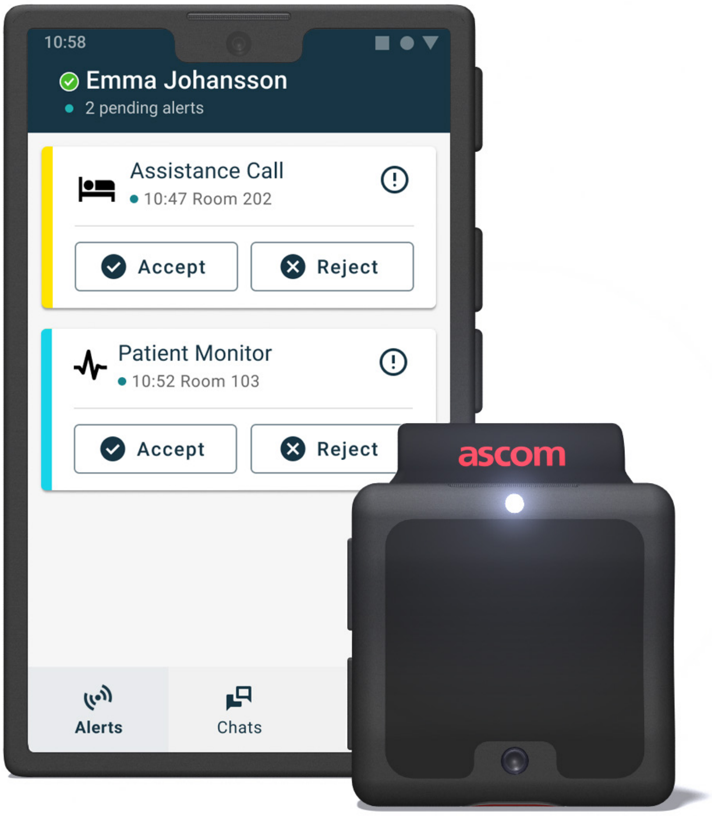

Figure 7.1: Image of *Myco Main* to the left and *Myco Mini* to the right.

Figure 7.2: The 3D-printed prototypes showing the proportions. *Myco Main* is displayed on the left side in the first two photos, and *Myco Mini* is shown on the right.

7.3.1 Hardware

This section describes the physical properties of the prototypes, which aim to fulfil the requirements in the requirement type Hardware and also some Usability requirements. They are designed to match each other's appearances, as well as Ascom's current smartphones.

Myco Mini

Myco Mini is a small, lightweight wearable that assists users in their daily tasks. Except for voice control and gesture control, alternative modalities such as buttons and the option of using the connected smartphone are available to accommodate users with different preferences. The device is worn on the neckline of the shirt or the chest pocket and is connected to a smartphone utilising Ascoms's systems. Depending on the weight of the accompanying smartphone, the wish 1.10 might not be fulfilled, and the solution needs to be tested with users to determine its fulfilment. It consists of two connected parts, the square base and the flexible silicone band, both of which are magnetic. In figure 7.3 *Myco mini* is shown with its band straight. When attaching the device, the band is folded, and the fabric of the shirt is inserted between the square base and the band, allowing the magnets to connect and hold the device in place. The square base is directed outwards on the shirt, enabling interaction with it.

Figure 7.3: Image of *Myco Mini* with the band straight.

The materials used for the device are plastic and silicone. The outer parts of the square base are made of dark grey plastic, while the front and back of the base and the band are made of black silicone. The silicone ensures the device stays securely attached to the fabric and gives the user a reliable grip when interacting with the buttons. The materials allow the device to be disinfected when necessary; hence, Mini meets requirements 1.6 and 6.8.

In the front of the base is a camera that registers gestures made by the user. There is also a small light located on the rounded part between the front and the side closest to the band. The placement of this light allows the user to see it while it is worn and lets observers see it as well. This light signals various events on the device, such as the initiation of an alert and incoming phone calls. Various alerts, each associated with a specific colour, will cause the light to display different colours accordingly. This design choice fulfils requirement 6.3. When speaking to the device, the light will also light up, showing you it is listening to what you are saying. By using visual feedback as a complement to the auditory cues, users can better understand the device's status and actions. There is also a speaker and a microphone close to the light, enabling voice control. These are directed towards the user for clear communication, improved audio quality and to help minimise interference due to background noises (requirement 7.1). The Ascom logo is positioned near the base, at the beginning of the band. This placement ensures that the logo remains visible when it is worn with the band folded and when it is not worn and the band is flat. In Figure 7.4, *Myco Mini* with its band bent is visible.

Figure 7.4: Image of *Myco Mini* with the band bent.

At the front of the square base, there is a multi-function button that enables the user to perform frequently used actions by clicking on the surface. This surface is also made of silicone material to provide a better hold. Located on the side of the base are two volume buttons. This placement allows users to grip the base between their index finger and thumb while adjusting the volume. On the opposite side, there is an IR sensor that registers the location of the device. The side of the base, which is located in the opposite direction towards the band, is an alarm button. In Figure 7.5 the IR sensor and alarm button is visible. This button can be used in emergency situations if the user is being threatened by someone. The button requires to be pressed for a few seconds before being activated to minimise the risk of accidental use.

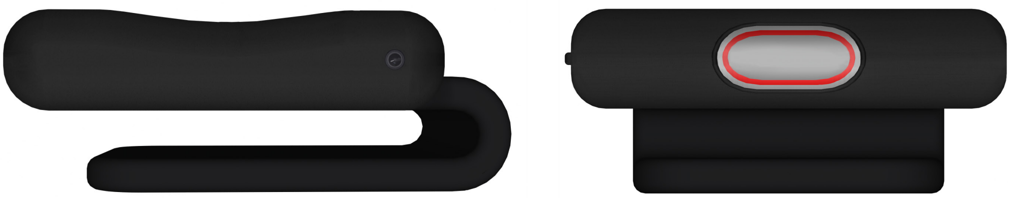

Figure 7.5: Images of *Myco Mini* from the sides showing the IR sensor and alarm button.

Myco Main

Myco Main is a compact smartphone (see Figure 7.6) with only the essential features for healthcare workers, meeting requirement 3.1. Users are supported in various situations by the possibility of using the device as a conventional phone, as well as by voice and gesture control in a completely touchless manner. The intended position of the phone is to have it clipped onto the chest pocket, with the screen directed outwards. However, it can also be positioned in the chest pocket, on the neckline or in the lower pockets of the shirt. The exterior of the phone is made up of dark grey plastic. The phone is durable and can withstand accidental drops (requirement 1.12), and it can also be disinfected (requirements 1.6 and 6.8).

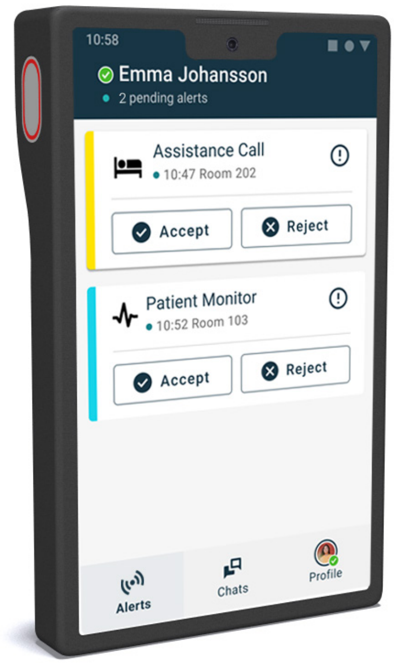

Figure 7.6: Image of *Myco Main*.

Images of *Myco Main* from different angles are shown in Figure 7.7. Two separate displays are integrated into the phone; one is the conventional display covering most of the front, while the other is positioned at the top. The top display enables the user to access visual information in a completely touchless manner while wearing the device as intended, following requirement 6.1. The top display is not touch-sensitive, while the front display is. If the user wants to access more visual information from the phone positioned outside of the chest pocket, they can tilt the phone upwards with their hand. When tilted 90 degrees, the screen flips so the user faces the interface correctly. This way, the user can access all available information quicker than removing the phone from its position and holding it in their hand, according to requirement 6.5. The digital interface of Myco Main is created with Ascom's design system, which has undergone testing to ensure its suitability. Additionally, this integration establishes coherence with their existing smartphones.

Figure 7.7: Images of *Myco Main* from the front, back and sides.

Next to the top display is a microphone that registers voice commands and an IR sensor that can detect the location of *Myco Main*. A speaker and a camera are positioned above the front display, where the purpose of the camera is to register gestures. The speaker's position at the top allows the sound from the phone to travel only a short distance when worn as intended, meeting requirement 7.1. Additionally, the position is suitable for regular phone calls with the phone held to the ear. On one side of the phone, there are two volume buttons and one power button, and on the other side, there is an alarm button that can be used in threatening situations. Similarly to *Myco Mini*, this button must be pressed and held for a few seconds before activating. There is a clip on the back of the phone to attach it to clothes. Furthermore, there is a back camera and a battery cover that can easily be opened if the battery needs to be changed, according to requirement 1.11.

7.3.2 Interaction

In this section, the interaction with *Myco Mini* and *Myco Main* is covered. The purpose of *Myco Mini* and *Myco Main* is to support healthcare workers in their daily tasks by providing touchless interfaces. Therefore, the prototypes meet requirement 3.8. Both devices have similar features, except for the added visual information on *Myco Main*'s screens. *Myco Mini* is intended to be carried with a smartphone, while *Myco Main* functions independently. The input methods are voice control, gesture control, and touch through touchscreen and physical buttons. By offering multiple input modalities, the devices accommodate the diverse needs of healthcare workers and fulfil the wish 3.9.

Voice control enables a completely hands-free interaction, which is valuable during procedures where the worker's hands need to remain sterile or when their hands are full. Thanks to the voice control, the requirements 4.1-4.4 and 5.1-5.5 are fulfilled. When initiating a conversation with the device, the user starts by saying “Hi Myco,” followed by the request. There are no specific, predetermined commands for the various actions. Instead, the user should be able to achieve the same action with different phrases. For example, to answer a call, the user can say both “Hey Myco, answer the call” and “Hey Myco, answer.” After initiation, the devices indicate that they are listening through visual cues. On *Myco Mini*, the LED light lights up and slowly pulsates while speaking to it, and on *Myco Main*, a small animation should be played on the top display. If any necessary information is missing from a request, the devices will ask follow-up questions to ensure the correct action is executed.

Gesture control introduces additional flexibility by allowing the user to interact with the device more quietly. The use of gestures has intentionally been limited to a few frequently used actions, as they need to be learnt and are, therefore, less intuitive than voice control. In total, there are four gestures, and these can be viewed in Figure 7.8. As mentioned in Section 3.1.2, sign language letters and numbers are recommended as gestures because they are easy to recall and distinct. Two gestures follow this recommendation, while the other two are sign language words commonly used in society. The choice of gesture is further motivated when presenting the different features. Since the devices can be worn on different parts of the shirt, it is essential for the gestures to remain comfortable to perform regardless of the device’s positioning. Thus, the camera should have the capability to detect gestures accurately, even when they are performed at various angles. The selection of gestures aims to fulfil the requirements 8.1-8.6. To ensure that the gestures are neither too complex nor physically challenging, they need to be tested with users.

In situations where touchless interaction may not be feasible or wanted, requirement 3.10 is met by providing touchscreens and physical buttons. These backup interactions provide familiarity for healthcare workers, which can be needed in emergencies or when managing large amounts of data.

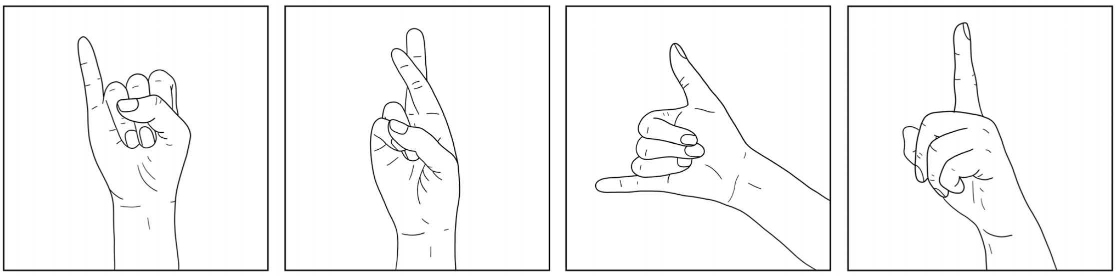

Figure 7.8: Illustrations of the gestures, from left to right, represent actions for receiving information, rejecting alerts and calls, answering calls, and silencing calls.

Allowing all these input methods, healthcare workers can select the most suitable option for each task. Therefore, it improves efficiency and enhances the quality of patient care. The output methods include audio, vibrations, and visual output through *Myco Main* ’s screens and *Myco Mini* ’s lights. The alert information the devices reveal to the surroundings is the same as the information displayed in the corridors today, namely the room number, type of alert and, potentially, bed number. Therefore, requirement 2.5 is followed since no confidential patient information is disclosed. When answering calls in a touchless manner, the call automatically goes to speaker phone. To prevent the person on the other side of the line from saying confidential information, the user can start the conversation by saying they are on speaker phone. Confidential information can be received by switching the call to Mini's accompanying smartphone or by holding Main against the ear. When interacting with the devices with voice or gesture, it responds through speech to confirm the actions, fulfilling requirement 6.7. As an event is triggered, such as an alert or incoming call, the device notifies the worker through auditory, haptic, and visual cues, ensuring the information is received (requirement 6.4).

The features below are available on both devices and can be managed with touchless interaction. These originate from requirements in General functionalities, Alert functionalities, and Call functionalities.

- Managing incoming alerts
- Create alerts
- Managing incoming calls
- Initiating calls
- Turn on the "do not disturb" mode
- Regulate volume

Managing incoming alerts

When an alert is triggered, the user notices this by the alert sound and vibrations from their device. If the user wants, they can receive additional information by asking for it by saying, "Hi Myco, tell me about the alert", or something similar. They can also receive this information by holding their hand in front of the device's camera and gesturing an "i" in American sign language. The gesture is a closed fist but with the little finger pointing up, and this is illustrated in Figure 7.8. *Myco* will then tell the user the most important information about the alert, including the type of alert, room, and bed number from which the alert originated. Consequently, the device provides all necessary information needed to handle an alert, meeting requirement 4.6. If the user is wearing the *Myco Mini*, they can also discern the kind of alert by observing the LED light on the device, which indicates the alert type through its colour. If the user wears the *Myco Main*, they can look down at the top display to receive the same information visually instead. The devices will be able to repeat auditory information upon request, thus meeting requirement 7.3.

When receiving an alert, the user has two choices: accept or reject the alert. If the user chooses to accept the alert, they can use their voice and say "Accept alert". If multiple alerts are pending, the user needs to specify which alert they accept by providing additional information about it. Due to the possibility of multiple alerts, accepting them by using gestures is not feasible. This limitation is made because it is impossible to convey additional information about each alert in gestures without a large number of gestures. It will also not be possible to accept using gestures even when there is only one alert pending since that would break consistency and may cause confusion for the user. If the user wishes to accept by touch instead, they can pick up or tilt *Myco Main* and use it like a regular smartphone, or if they use *Myco Mini*, pick up the connected smartphone. Figure 7.9 illustrates the different interactions of accepting an alert using the *Myco Main*.

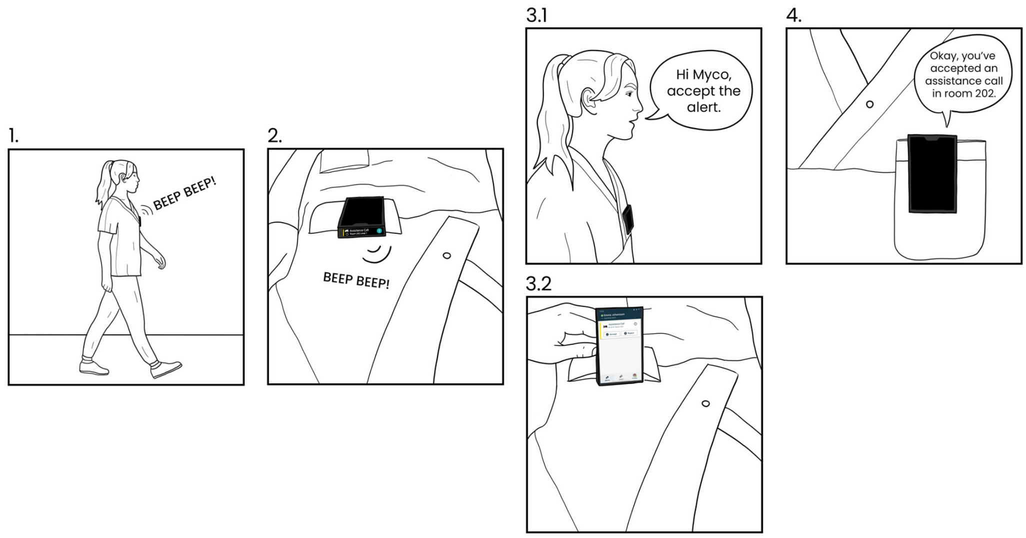

Figure 7.9: Storyboard about accepting an alert using *Myco Main*.

1. **Hears the signal:** A nurse is walking in the hospital corridor when she hears her *Myco Main* signal that an alert has been activated.
2. **Understands the alert:** She looks down at the device hanging on her chest pocket and reads the information on the top display. She understands that the alert is an assistance call in room 202.
3. **Accepts the alert:** (She does either 3.1 followed by 4. or only 3.2)
   - 3.1. She accepts the alert by saying, “Hi Myco, accept the alert” to the device.
   - 3.2. She accepts the alert by tilting the *Myco Main* up with her hand and interacting with the touchscreen.
4. **Confirmation:** The device confirms the voice command by saying, “Okay, you have accepted an assistance call in room 202.”

If they need to reject the alert and let someone else handle it, they can do so in multiple ways. They can use their voice to say “Reject alert” or a similar phrase. If one or multiple alerts are pending and the user wants to reject them all, they can also do so by gesture. This gesture is an “R” in sign language and can be described as crossing the index finger and long finger while holding the rest of the fingers in a closed fist, see Figure 7.8. The two fingers form a cross, a typical symbol for rejection. The alerts can also be rejected by using the touch screen on *Myco Main* or by picking up the connected smartphone to *Myco Mini*. The alternative touchless interactions of rejecting an alert using *Myco Mini* are demonstrated in Figure 7.10. After accepting or rejecting the alert, the user will receive a confirmation of the action to ensure clarity and prevent unintended actions. The confirmation is through speech and can be, for example, “Okay, you have accepted an assistance call in room 202, bed one”, or “Okay, you have rejected all alerts”.

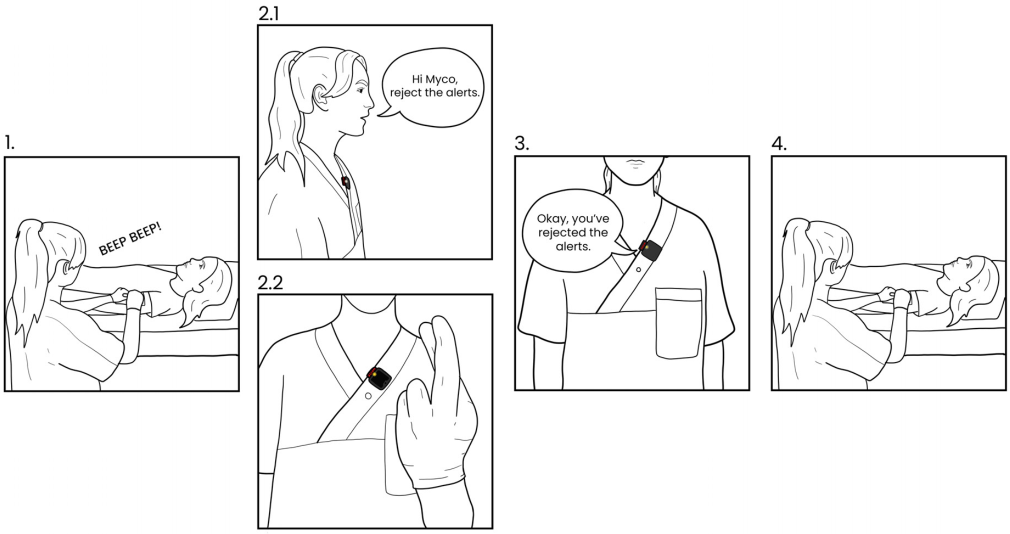

Figure 7.10: Storyboard about rejecting an alert using *Myco Mini*.

1. **Hears the alert:** A practical nurse is helping a patient change their wound dressing when she hears the signal from her *Myco Mini* that an alert has been triggered. Since she is in the middle of her task, she wants to reject the alert and let someone else accept it. She is wearing gloves and wants to remain sterile, so she does not want to pick up her phone.
2. **Rejects the alert:** (either 2.1 or 2.2)
   - 2.1. To reject the alert, she says to *Myco Mini*, “Hi Myco, reject the alert”.
   - 2.2. Since she has one hand free at the moment, she decides to make a gesture to signal to *Myco Mini* that she is rejecting the alert. She puts her hand in front of the device and crosses her index finger and middle finger.
3. **Confirmation:** *Myco Mini* confirms the action by saying “Okay, alerts rejected”.
4. **Continues:** The nurse continues helping the patient.

Create alerts

Three different types of alerts can be created with *Myco Main* and *Myco Mini*, one of which is an assistance alert. This alert is supposed to be triggered when a healthcare worker needs assistance from a colleague. Instead of using the existing assistance buttons on the wall in the patient room, they can, with these devices, create them using their voice from a distance. This allows the healthcare worker to remain in their location, continue with their task or remain sterile if needed. To do so, they can say, “Hi, Myco, call for assistance”. To provide information on which room needs assistance, the hospitals must install specific technology in each room that the IR sensors can detect.

The other type of alert that can be created is an emergency alert. The interaction works similarly to the previous one but creates an alert of higher urgency. The final type of alert is for the healthcare worker's safety. If a situation arises where they feel threatened by another person, such as a patient, they can call for help by pressing the alarm button on the side of the device. The decision was made to have a dedicated button for this action rather than relying on voice control since it may not be suitable to call for help via voice and let the threatening person hear it.

Managing incoming calls
When there is an incoming call, the user hears a signal and feels a vibration. On *Myco Mini*, the LED light also indicates that a call is present by glowing. To get information about who is calling, the user can ask the device or make the gesture for more information (see Figure 7.8) in front of it. On the *Myco Main* top display, the number or the contact calling is also displayed to provide the user with visual information. The incoming call can either be answered, declined or silenced, depending on the user's choice. Suppose the user wishes to answer the call. In that case, they can do so by saying “Answer” or doing the hand gesture commonly associated with a phone call, where the thumb and little finger are extended outward while the rest of the fingers are closed, see Figure 7.8. This is also the sign for "telephone" in American sign language. With *Myco Mini*, the phone call can also be answered by pushing the multi-function button on the front of the device or by picking up the connected smartphone. *Myco Main* can also answer the phone through the touch screen. In Figure 7.11, a storyboard about answering a call using *Myco Mini* is shown as an example of this interaction.

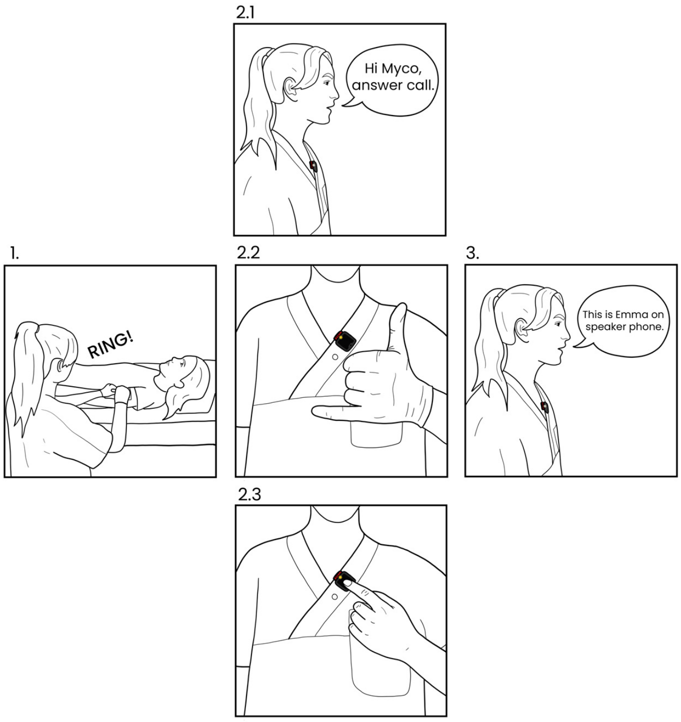

Figure 7.11: Storyboard about answering a call using *Myco Mini*.

1. **Hears signal:** A practical nurse is currently helping a patient to change their wound dressing as she hears the signal of an incoming call from her *Myco Mini*

hanging on her shirt. Since she is almost finished, she decides to answer the call.

2. **Answers call:** (She does either 2.1, 2.2 or 2.3)
   2.1. She answers the call by saying "Hi Myco, answer".
   2.2. Since she has one hand free at the moment she decides to do a gesture to signal to *Myco Mini* that she wants to answer. She holds up her hand with her thumb and little finger extended outward.
   2.3. She finishes up her task and answers after taking off her gloves and disinfecting her hands by pushing in the multi-function button on *Myco Mini*.
3. **Talks:** Since she is with a patient she initiates the call by saying "Practical nurse Emma, you are on speaker phone.

Declining a call is done similarly to accepting it. The user can either say "Decline" or make the "reject gesture" (see Figure 7.8). To decline using touch, the user can hold in the multi function button on *Myco Mini*, dubble click on the power button on *Myco Main* or use the touchscreens on the phones. Below, in Figure 7.12 is a storyboard showing an example of declining a call using *Myco Mini*. A call can also be silenced, which means it continues ringing but with no sound. The alternative interactions for this action are saying "Silence call", pressing the device's power button or holding up the index finger in front of the device, see Figure 7.8. This gesture is commonly used to signal silence or shush someone when held in front of the mouth. Furthermore, it is the sign for "quiet" in American sign language.

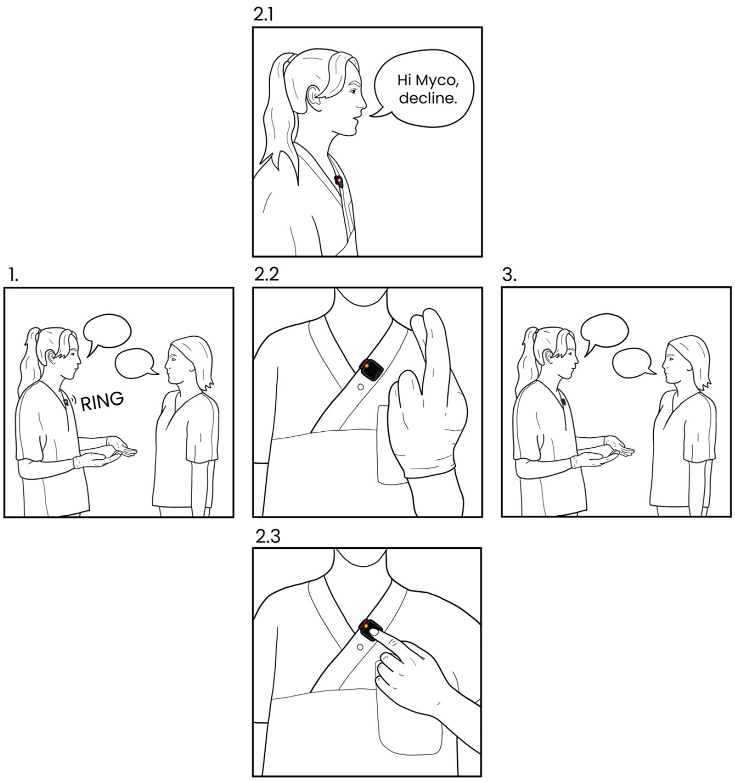

Figure 7.12: Storyboard about declining a call using *Myco Mini*.

1. **Hears signal:** A nurse is in the middle of a conversation with another nurse when the signal of an incoming call starts from her *Myco Mini* hanging on her shirt. She wants to continue the conversation and chooses to decline the call.
2. **Declines the call:** (She does either 2.1, 2.2 or 2.3)
   2.1. She declines the call by saying "Hi Myco, decline call".
   2.2. She declines the call by making a gesture in front of *Myco Mini*. She puts her hand in front of the device and crosses her index finger and middle finger.
   2.3. She declines the call by holding in the multi function button on *Myco Mini*.
3. **Signal stops:** The signal of the call stops and she continues on with her colleague. She plans on calling back when she has more time.

If a call is answered without using the touch screens, it is automatically put on speaker. To ensure that the person on the other side of the line is aware of the phone call being on speaker, it is recommended that the user initiates the call by saying that they are on speaker phone. If a call needs to be kept private, it can be removed from the speaker by picking up *Myco Main* and holding it against the ear. Alternatively, if the user wears the *Myco Mini*, the call can be transferred to the connected smartphone.

Sometimes, the user receives a call simultaneously as there are existing alerts. In these situations, the call is dominant, i.e., the user's action will be applied to the call event. For example, if there are active alerts and an incoming call, the "reject-gesture", see Figure 7.8, will decline the call and not reject all alerts. First after the call is handled, the user can act upon the alerts. This design decision aims to fulfil requirement 3.5 but is not based on studies and needs further evaluation.

Initiating calls
For both *Mini* and *Main*, the user can initiate a call touchless using their voice. They either say the telephone number or the contact's name if the number is stored in the contacts. For example, the user can say, "Hi Myco, call Anna", and after this command, the device will confirm it by saying, "Okay, you are calling Anna".

Turn on the "do not disturb" mode
To ensure that the workers can be undisturbed in situations that require it, they can turn on "do not disturb", DND for short. Therefore, meeting the requirement 3.3. DND can be activated by touch in the graphical interface of the phones or by voice control. For example, the user can say, "Myco, out on DND for five minutes", or "Myco, put on DND", and it will ask how long it should last.

Regulate volume
The volume on the devices can be regulated by voice and the physical buttons on the sides. Since the primary interface is auditory, the decision was not to allow the volume to be set to zero. Allowing this could result in important information being unnoticed.

8
Discussion

In this chapter, a discussion about the thesis is presented. Several aspects and decisions that affected the execution and result are reevaluated and discussed. Furthermore, the topics of ethical considerations, future work, validation, and generalisation are addressed.

8.1 Execution

Due to the complex use context and the users' unique knowledge and experience, user studies were crucial for answering the research question. The departments contacted were emergency, neonatal, intensive care, and infection departments, as their high pace and great need for sterility were assumed to be factors that could complicate the interaction with the devices. In addition, a medical department was contacted because they used Ascom's alert system and smartphones. Of all the contacted departments, we were able to visit three types of emergency departments, one neurological intensive care unit and the medical department. In hindsight, high-pace was not a very important factor for the scope of our project, rather the frequency healthcare workers interacted with mobile devices. For example, many challenges relevant to our project were noted at the visit to the medical department despite it not being the type of department we initially thought would be the most interesting. An apparent reason for this outcome is that this was the only department using Ascom's system, while the others had open alert systems that did not involve the healthcare workers interacting with mobile devices to respond to alerts. With this experience in mind, it would have been better to reach out to a wider range of department types to gather more perspectives.

While formulating the requirements, the initial idea was to categorise them into the requirement types described in the methodology section. When these types did not feel suitable for our project, an approach similar to affinity diagramming was used. Similar requirements were grouped, and after some iterations, the groups were given names. The new types may not be perfect; for example, the content of the type Usability is very diverse and might have benefited from having undertypes, such as "Sounds". Further iterations could be done to improve the categorisation, which would increase the readability of the requirements.

During the first evaluation, it was surprising that the participants preferred Mini-Wearble over Bone conduction headphone. The Bone conduction headphone had the same functionality as the MiniWearable, and the headphone made it possible to access confidential information when surrounded by people. Either the MiniWearble was a better solution, or the result was influenced by how the ideas were represented. The participants tried voice control using the product TOKK, similar to the MiniWearble, and they also tried a pair of bone-conduction headphones but with no voice control functionality. Due to the similarities between TOKK and MiniWearable, the voice control functionality might have been more straightforward to translate to MiniWearable than to Bone conduction headphone, making MiniWearble more graspable. If this evaluation were to be redone, more coherent prototypes would be used to make the comparison between ideas more fair.

Since the project focused on touchless interfaces, the time spent refining the final prototypes' hardware and physical appearance was limited. Much inspiration was taken from Ascom's previous products, both in terms of physical appearance and also the graphical interfaces on *Myco Main*. This decision was made to ensure visual coherence with the existing products and to dedicate more time to the touchless interfaces instead. *Myco Main* had several similarities with the previous Ascom smartphone, Myco 2, with the main one being the top display. Since interviews and evaluations took place at a medical department that previously used Myco 2, it is unsurprising that the prototype resulted in a similar device. It became clear that the healthcare workers in this department missed the top display, which influenced their opinions and responses about the prototypes. While other visited departments did not express a need for a top display, likely because they had not previously used one, it can be implied that it would also benefit them. This conclusion is drawn from their tendency to check the displays in the corridors when hearing an alert, proving that visual information is important.

8.2 Benefits & drawbacks of touchless interfaces

The final prototypes incorporate both voice user interfaces and gesture-based interfaces. During the development of the prototypes, it was discussed whether gestures should be excluded or not due to the challenges that became apparent as time went on. One of these was that to be able to perform hand gestures, the hands need to be unoccupied, which may not always be the case. It also became clear during testing that knowing where and how far away to hold the hand so the camera could recognise the gestures was challenging. Furthermore, the clothes could be a limiting factor. If the device is carried attached to the pockets, the camera can point in unwanted directions due to them being quite loose, which could complicate the use of gestures. Using gestures is also less commonly used today and demands more learning than voice control. One benefit of gestures is the possibility of the interaction being completely silent. For example, if a healthcare worker is in the middle of a conversation, it may not be suitable to disrupt to make a voice command. In those types of situations, using gestures could be very beneficial. However, the device needs to provide proper feedback to show the user that the interaction was interpreted correctly. For this, auditory feedback serves as a viable alternative, but this makes the interaction no longer silent. This limitation becomes especially noticeable on *Myco Mini*, which has limited visual output and consequently requires auditory feedback.

When discussing the benefits and drawbacks of gestures with the mentors at Ascom, they suggested incorporating them into our prototypes. Providing gestures, in addition to voice control, would support a wider range of users, allowing them to choose their preferred interface type. The selected gestures were static, where one hand was held in a specific position in front of the device. We discussed using moving gestures and believed that this could be a better solution for making the gesture less obvious to observers. Due to technical limitations and the risk of other unintentional movements being recognised as gestures, they were not selected.

Much time during the development of the prototypes was dedicated to discussing which features should be available to use with touchless interfaces. Since this project focused on exploring touchless interfaces, we wanted to incorporate them into our prototypes. Although, it was most important to ensure that the interactions that would take place would be clear and understood by the users. Since the prototype would be used in life-or-death situations, the impact of any misunderstandings or errors in interaction could be critical. When a healthcare worker chooses to accept an alert, it is crucial that they understand which alert they have accepted and that they receive proper feedback that the action was registered. Otherwise, if a user accepts an alert by accident, it would lead to other workers not receiving the alert and possibly jeopardising the safety of a patient. Since multiple alerts can be active simultaneously, it can be challenging for the user to manage these in a completely touchless manner. It may be difficult or time-consuming to ensure that the correct alert is being interacted with, especially with no visual output. With this in mind, it was discussed whether users should be allowed to accept alerts in a touchless manner. Ultimately, the decision was made that it should be allowed, but the user needs to be able to give specifications about the alert that limits the potential of errors. For example, if multiple alerts are pending, the user needs to specify the alert they accept by saying the room number or other distinct data. Given our aim to minimise the number of gestures to lower the cognitive load, providing this data using gestures would be challenging. Therefore, gestures were excluded from the acceptance process, requiring users to provide the necessary information verbally or use the touchscreens to accept.

8.3 Validation & generalisation

This project addresses a wicked problem, and one characteristic of wicked problems is that there is no stopping rule (Rittel & Webber, 1973). This means there is a lack of clear signals of when the solution is final, and instead, the attempt to solve the problem is stopped due to external factors, which in our case is that the time ran out. Our project succeeded in identifying challenges and needs, but there is a high probability that additional user studies would result in an even better solution. It cannot, with certainty, be said that the requirements would support a useful solution for departments other than those visited. Additionally, to increase the validity, the user studies could include additional visits to the same department types since the organisation can vary considerably between departments of the same type.

Both evaluations with users were conducted at the medical department. This decision was based on the assumption that they would understand the usage faster since the prototypes implemented the same alert system as they were used to. The validity of the evaluation results is limited to similar departments, and further evaluations are needed to assess the usefulness of the solution in other departments. The low number of participants is another aspect that affects the validity of the evaluation results. The evaluations were conducted simultaneously as the participants worked, meaning only healthcare workers the department could spare without compromising patient care were available.

Many of the gathered insights originated from stories the healthcare workers told rather than from observations. As mentioned in Section 4.3.1, observations sometimes cover an event more accurately. However, much timing would be needed to observe these challenges, particularly in the emergency departments where the work tasks of a day are very unpredictable. For example, to observe the insight from the emergency department that resulted in P8, we would first need to time an emergency situation. Then, the doctor would need to perform a task that requires both hands simultaneously as they need to call a consultant due to lack of specific knowledge.

The project focused relatively little on the patients' experience. Interacting with patients during user studies would be ethically challenging since they are in a vulnerable position. Instead, the healthcare workers were asked about their assumptions of how patients would experience the touchless interactions. This data does not have high validity since it is based on healthcare workers' previous experience with patients. The primary source needs to be approached to increase the validity. Preferably in the real hospital setting and while demonstrating the interactions, since the human's ability to imagine a situation can be limited.

The user studies did not exclusively focus on how Ascom products were used, except for the visit to the medical department, but rather on healthcare workers' interaction with communication devices in general. Therefore, most requirements apply to other companies that sell communication systems and devices for hospitals. However, some of the requirements regarding alert functionalities are written according to the actions, accept and reject, that Ascom uses in their system. Parts of the requirements could possibly be used to develop hospital equipment utilising touchless interfaces that are not communication-related. In that case, requirements about social aspects and touchless interfaces could be helpful, while requirements regarding communication functionalities would not be. Ascom also provides communication solutions to other industries, and segments of the requirements may apply to these. Nevertheless, the contexts of the other industries are very different from the context the requirements support. Therefore, significant changes would be needed.

8.4 Ethical considerations

Ethical considerations have been part of this project and have influenced our approach in several ways. Early on, the decision was made not to include the patient perspective in the research as previously discussed. The main reason for this was the vulnerable situation that patients can be in and the ethical dilemmas that come with that. To tackle this issue, user studies of former patients could have been conducted. However, this approach may not have accurately portrayed the actual situation, since it could be challenging to simulate the vulnerability. Additionally, the patients' memories regarding the healthcare workers' communication devices may be limited.

To ensure ethical compliance during the user studies, the interviewees were provided with information about the study beforehand to ensure that they were fully informed about its purpose. They were also made aware of what the collected data would be used for and assured that they could withdraw from the study at any time. Additionally, the names of all interviewees and hospitals have been anonymised. To ensure anonymity, no recordings of interviews or photos of the hospitals were taken.

Another ethical consideration was deciding not to influence the healthcare workers about what action to choose when responding to alerts. The worker can choose to either accept or reject an alert, and it is their choice to make this decision based on the situation along with their experience and knowledge. The interface will not nudge the worker to accept alerts since that will not always be the best option. For example, the voice user interface does not specifically ask the user to accept an alert after providing information about it. With this topic in mind, another potential ethical issue can be discussed. Could an interface that simplifies the actions of rejecting alerts and declining calls lead to healthcare workers choosing to do these actions more frequently? Consequently, leading to prolonged wait times for patients before receiving assistance? In the current situation, the persistent sounds emitted by mobile devices affect the work environment negatively. However, these sounds may also prompt healthcare workers to respond directly in order to silence them. Nonetheless, by simplifying the action of rejection, the alert can be redirected to another colleague who is available, resulting in the patient receiving quicker help. Maintaining a quiet and undisturbed environment is also essential for healthcare workers to perform their tasks effectively. Therefore, we believe that by integrating touchless interfaces, patient care can be optimised, ultimately enhancing the overall experience for both healthcare workers and patients.

8.5 Future work

The results from this thesis should be seen as the first iteration of exploring touchless interfaces in communication devices for healthcare workers. Even though the results are promising, they represent only a starting point in addressing the complex needs and challenges faced in healthcare environments. Continued research will be necessary to expand upon these initial insights, ultimately leading to solutions that support healthcare workers. Further exploration of gestures is recommended, specifically considering the type of gestures and the technology used to interpret them. As previously discussed, challenges have emerged during the development of the gesture-based interface, which should be investigated further.

The decision to incorporate voice user interfaces was obvious early on since it supports many usage situations. However, one aspect that remains unexplored is how the voice user interface is affected by having multiple devices in the same area. Drawing from our prior experiences with similar interfaces, we have encountered instances where multiple devices register a single voice command despite it being directed at only one device. This issue could potentially arise in hospitals, where there would be multiple users of these devices. Therefore, limiting the range of the device's voice detection may be needed. However, this solution may require the users to wear the devices closer to their mouth for accurate interpretation, which may not align with their preferred positioning of the device. Another aspect that would be interesting to explore is how well the voice user interface can interpret different accents. It is important that people with different accents can use the device to ensure usability across a wide range of users.

During the last evaluation with healthcare workers, a discussion took place regarding how an alert should be presented. The two different options discussed were earcons and spoken words. In the final prototypes, upon alert activation, a signal is initially emitted, after which the user must request spoken information about the alert if they desire to know more. An alternative approach would be to have the spoken information come automatically when the alert is triggered. The choice to only use earcons was made so that the device avoids disturbing the user by talking to them in unwanted situations. We were interested in knowing if this would be an issue, thereby discussing it during the evaluation. In most cases, the participants did not believe it would be an issue and consequently leaned towards having the spoken alerts automatically. However, they expressed uncertainty about this decision, making it essential to investigate further in future iterations.

Additionally, it would be interesting to look into the personality of the voice user interface. For instance, should the device be able to make suggestions on what alert to accept first and to remind the worker to do specific tasks, or should it remain in the background and only speak when spoken to? As previously discussed, investigating the patient's perspective on the use of touchless interfaces would also be interesting for future work. The reason for this is to ensure the usefulness of the interface in the correct context since a good patient experience is important for proper care. Before a new device can be released to the healthcare domain, extensive clinical testing needs to be performed to ensure safety and proper functionality. Therefore, this step is crucial for the future work of these touchless interfaces.

9
Conclusion

This thesis was in collaboration with the company Ascom and explored how touchless interfaces could facilitate healthcare workers' workflow by integrating them into their communication devices. The thesis aimed to answer the following research question:

What should be considered when designing touchless interfaces to support healthcare workers when communicating on a mobile device?

An iterative design thinking process was followed to address the research question, and it included the stages: empathise, define, ideate, prototype and test. Due to the complex and unfamiliar context of use, user studies were crucial to understanding the challenges and needs. Therefore, interviews and observations were conducted at five visits to hospital departments. These user studies resulted in 12 problem areas, summarising the identified situations that could possibly be improved by integrating touchless interfaces. Three overarching themes could be identified in the problem areas: following hygiene routines, being physically constrained, and workflow deviations. Thereafter, 64 requirements for ten problem areas were formulated based on the results from the user studies and the literature review (see Section 7.2). The requirements were divided into the following types:

- Hardware
- Social aspects
- General functionalities
- Alert functionalities
- Call functionalities
- Usability
- Voice user interface
- Gesture-based interface

The purpose of the requirements was to support designers when integrating touchless interfaces in hospital communication devices. The recommended touchless interfaces for hospital communication devices are voice and gesture-based. Ideas were brainstormed and prototyped to exemplify how these requirements could be implemented. The prototypes were also used during evaluations with users to gain further insights about users' attitudes and needs. The last prototype iteration resulted in two communication devices named *Myco Main* and *Myco Mini*. *Main* is intended to be used independently, while *Mini* should be carried with a smartphone. In the last evaluation, the participants were optimistic about the voice user interface as a support in their work. Although, there were concerns regarding the usefulness of the gesture-based interface (see Section 6.8).

Additional user studies should be conducted to ensure that the requirements support more types of hospital departments. Moreover, the healthcare workers' attitude towards gesture-based interfaces needs to be further explored, along with the appropriateness of static versus motion gestures. This study also needs to be supplemented by the patient's perspective on the use of touchless interfaces. In summary, this thesis can be seen as a successful starting point in understanding how to integrate touchless interfaces in hospital communication devices.

Bibliography

Amazon. (n.d.-a). *Alexa Communications*. https://www.amazon.com/alexa-drop-in-calling-intercom/b?ie=UTF8&node=21393410011&ref=pe_alxhub_aucc_en_us_IC_HP_6_HUB_COM

Amazon. (n.d.-b). *Alexa features*. https://www.amazon.com/b?ie=UTF8&node=21576558011

Amazon. (n.d.-c). *Alexa News*. https://www.amazon.com/alexa-news-flash-briefing/b?ie=UTF8&node=21362891011&ref=pe_alxhub_aucc_en_us_IC_HP_7_HUB_NEWS

Amazon. (n.d.-d). *Alexa Smart Home*. https://www.amazon.com/alexa-smart-home/b?ie=UTF8&node=21442899011&ref=pe_alxhub_aucc_en_us_IC_HP_1_HUB_SMA

Apple. (n.d.). *Apple Vision Pro*. https://www.apple.com/apple-vision-pro/

Ascom. (n.d.-a). *About us*. https://www.ascom.com/about-us/

Ascom. (n.d.-b). *Ascom Myco™ 4 smartphone*. https://www.ascom.com/products-and-services/mobile-devices/smartphones/myco-4/

Ascom. (n.d.-c). *Ascom software*. https://www.ascom.com/products-and-services/software/

Ascom. (n.d.-d). *Ascom Unite*. https://www.ascom.com/products-and-services/software/unite-communications-software/

Ascom. (n.d.-e). *Enterprise Communication Software, Tools & Solutions | Ascom*. https://www.ascom.com/solutions/enterprise/

Ascom. (n.d.-f). *Mobile devices*. https://www.ascom.com/products-and-services/mobile-devices/

Ascom. (n.d.-g). *Mobilenheter för vården*. [Photography]. https://www.ascom.com/globalassets/assets/global/gmc/healthcare-2021/phone_collection-copy.png?width=640&format=webp

Bernard, H. R. (2011). *Research methods in anthropology : Qualitative and quantitative approaches* (5th ed.). AltaMira Press.

BMW. (2019). *Get the most out of gesture control – BMW How-To*. [Video]. YouTube. https://www.youtube.com/watch?v=_mGwJh4da5w

Brahm, C., & Kleiner, B. H. (1996). Advantages and disadvantages of group decision-making approaches. *Team performance management*, *2*(1), 30–35. https://doi.org/10.1108/13527599610105538/FULL/PDF

Buchanan, R. (1992). Wicked Problems in Design Thinking. *Design issues*, *8*(2), 5–21.

Carroll, J. M. (1997). Scenario-Based Design. In M. G. Helander, T. K. Landauer, & P. V. Prabhu (Eds.), *Handbook of Human-Computer Interaction* (2nd ed., pp. 383–406). North-Holland. https://doi.org/10.1016/B978-044481862-1.50083-2

Cervone, H. F. (2009). Applied digital library project management: Using Pugh matrix analysis in complex decision-making situations. *Oclc systems & services: international digital library perspectives*, *25*(4), 228–232. https://doi.org/10.1108/10650750911001815

Churchman, C. W. (1967). Guest Editorial: Wicked Problems. *Management science*, *14*(4), B141–B142. https://doi.org/10.1287/mnsc.14.4.B141

Cohen, M. H., Giangola, J. P., & Balogh, J. (2004). *Voice User Interface Design*. Addison-Wesley Professional.

Cronin, S., & Doherty, G. (2018). Touchless computer interfaces in hospitals: A review. *Health informatics journal*, *25*(4), 1325–1342. https://doi.org/10.1177/1460458217748342

Dam, R. F., & Teo, Y. S. (2024). *Scamper: How to Use the Best Ideation Methods*. Interaction Design Foundation.

Davidhizar, R. (1992). Interpersonal Communication: A Review of Eye Contact. *Infection control and hospital epidemiology*, *13*(4), 222–225. https://doi.org/10.2307/30147101

de la Barré, R., Chojecki, P., Leiner, U., Mühlbach, L., & Ruschin, D. (2009). Touchless Interaction-Novel Chances and Challenges. In J. A. Jacko (Ed.), *Human-Computer Interaction. Novel Interaction Methods and Techniques* (pp. 161–169). Springer. https://doi.org/10.1007/978-3-642-02577-8_18

de Bono, E. (2017). *Six Thinking Hats: The multi-million bestselling guide to running better meetings and making faster decisions*. Penguin Life.

de Camargo, V. P., Balancieri, R., Teixeira, H. M. P., & Guerino, G. C. (2021). Touchless Modalities of Human-Computer Interaction in Hospitals: A Systematic Literature Review. *Proceedings of the xx brazilian symposium on human factors in computing systems*, 1–11. https://doi.org/10.1145/3472301.3484328

Easwara Moorthy, A., & Vu, K.-P. L. (2014). Voice Activated Personal Assistant: Acceptability of Use in the Public Space. In S. Yamamoto (Ed.), *Human Interface and the Management of Information. Information and Knowledge in Applications and Services. HIMI 2014. Lecture Notes in Computer Science* (pp. 324–334). Springer. https://doi.org/10.1007/978-3-319-07863-2_32

Espinoza-Hernández, S., Yang, E., Ozturk, E., Platt, R., & Mehta, K. (2023). When Healthcare Meets Conversational AI: A Narrative Review of Amazon Alexa Devices in Healthcare. *2023 ieee global humanitarian technology conference (ghtc)*, 322–326. https://doi.org/10.1109/GHTC56179.2023.10354743

Fiorinelli, M., Di Mario, S., Surace, A., Mattei, M., Russo, C., Villa, G., Dionisi, S., Giannetta, N., Di Simone, E., & Di Muzio, M. (2021). Smartphone distraction during nursing care: Systematic literature review. *Applied nursing research*, *58*. https://doi.org/10.1016/j.apnr.2021.151405

Foong, Y. C., Green, M., Zargari, A., Siddique, R., Tan, V., Brain, T., & Ogden, K. (2015). Mobile Phones as a Potential Vehicle of Infection in a Hospital Setting. *Journal of occupational and environmental hygiene*, *12*(10), D232–D235. https://doi.org/10.1080/15459624.2015.1060330

Frayling, C. (1993). Research in Art and Design. *Royal college of art research papers*, *1*(1), 1–5.

Fridley, J. L., Jorgensen, J. E., & Lamancusa, J. S. (1997). Benchmarking: A process basis for teaching design. *Proceedings frontiers in education 1997 27th annual conference. teaching and learning in an era of change*, *2*, 960–967. https://doi.org/10.1109/FIE.1997.636016

Google Help. (n.d.). *Use Camera Switches*. https://support.google.com/accessibility/android/answer/11150722?hl=en&ref_topic=6151780&sjid=6922029584958427729-EU

Hanington, B., & Martin, B. (2019). *Universal Methods of Design, Expanded and Revised*. Quarto Publishing Group.

Hasso Plattner Institute of Design. (n.d.). *An Introduction to Design Thinking PROCESS GUIDE*. https://web.stanford.edu/~mshanks/MichaelShanks/files/509554.pdf

Hayward, V., Astley, O. R., Cruz-Hernandez, M., Grant, D., & Robles-De-La-Torre, G. (2004). Haptic interfaces and devices. *Sensor review*, *24*(1), 16–29. https://doi.org/10.1108/02602280410515770/FULL/PDF

Hoggan, E. (2013). Haptic Interfaces. In S. Price, C. Jewitt, & B. Brown (Eds.), *The SAGE Handbook of Digital Technology Research* (pp. 342–358). SAGE Publications Ltd. https://doi.org/10.4135/9781446282229

Hsu, H.-H., Chang, C.-Y., & Hsu, C.-H. (2017). *Big Data Analytics for Sensor-Network Collected Intelligence*. Academic Press.

Humane. (n.d.). *Ai Pin*. https://hu.ma.ne/aipin

Interaction Design Foundation. (2016, March). *Design Thinking (DT)*. https://www.interaction-design.org/literature/topics/design-thinking

International Organization for Standardization. (2018). *Ergonomics of human-system interaction — Part 11: Usability: Definitions and concepts (ISO 9241-11:2018)*. https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en

Iqbal, M. Z., & Campbell, A. G. (2021). From luxury to necessity: Progress of touchless interaction technology. *Technology in society*, *67*. https://doi.org/10.1016/j.techsoc.2021.101796

Jaguar. (2018, June). *Jaguar I-PACE 2019 | Gesture Tailgate*. [Video]. YouTube. https://www.youtube.com/watch?v=mSq7GinPFro

Jones, K. (2014). Alarm fatigue a top patient safety hazard. *Canadian medical association journal*, *186*(3), 178–178. https://doi.org/10.1503/cmaj.109-4696

Jordan, P. W. (1998). *An introduction to usability*. Taylor & Francis.

MacLean, K. (2000). Designing with haptic feedback. *Proceedings 2000 icra. millennium conference. ieee international conference on robotics and automation. symposia proceedings (cat. no.00ch37065)*, 783–788. https://doi.org/10.1109/ROBOT.2000.844146

Majaranta, P., & Bulling, A. (2014). Eye tracking and eye-based human–computer interaction. In H. Fairclough & K. Gilleade (Eds.), *Advances in Physiological Computing* (pp. 39–65). Springer. https://doi.org/10.1007/978-1-4471-6392-3_3

Mercedes-Benz Group. (2022, April). *MBUX reaches a new level.* https://group.mercedes-benz.com/innovation/digitalisation/connectivity/mbux-interior-assist.html

Meta. (n.d.). *This is Meta Quest Pro.* https://www.meta.com/se/en/quest/quest-pro/

Microsoft. (n.d.-a). *HoloLens 2.* https://www.microsoft.com/en-us/hololens/hardware#document-experiences

Microsoft. (n.d.-b). *Microsoft HoloLens 2.* https://www.microsoft.com/en-us/hololens

Milgram, P., & Kishino, F. (1994). A Taxonomy of Mixed Reality Visual Displays. *Ieice transactions on information and systems*, *77*(12), 1321–1329. https://www.researchgate.net/publication/231514051_A_Taxonomy_of_Mixed_Reality_Visual_Displays

Montero, C. S., Alexander, J., Marshall, M. T., & Subramanian, S. (2010). Would you do that?: understanding social acceptance of gestural interfaces. *Proceedings of the 12th international conference on human computer interaction with mobile devices and services*, 275–278. https://doi.org/10.1145/1851600.1851647

Moran, K. (2019). *Usability Testing 101.* Nielsen Norman Group. https://www.nngroup.com/articles/usability-testing-101/

Moran, K., & Gordon, K. (2023). *How to Conduct a Heuristic Evaluation.* Nielsen Norman Group. https://www.nngroup.com/articles/how-to-conduct-a-heuristic-evaluation/

Nielsen, J. (1994). *The Theory Behind Heuristic Evaluations.* Nielsen Norman Group. https://www.nngroup.com/articles/how-to-conduct-a-heuristic-evaluation/theory-heuristic-evaluations/

Nielsen, J. (2012). *Usability 101: Introduction to Usability.* https://www.nngroup.com/articles/usability-101-introduction-to-usability/

Nielsen, J., & Molich, R. (1990). Heuristic evaluation of user interfaces. In J. C. Chex & J. Whiteside (Eds.), *CHI '90: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 249–256).

Osvalder, A. L., & Ulfvengren, P. (2015). Människa-tekniksystem. In M. Bohgard, Lovén E., L. Mårtensson, & L. Rose (Eds.), *Arbete och teknik på människans villkor* (3:1). Prevent.

Oviatt, S. (2007). Multimodal Interfaces. In *The Human-Computer Interaction Handbook* (2nd ed., pp. 413–432). CRC Press.

Pearl, C. (2016). *Designing Voice User Interfaces: Principles of Conversational Experiences.* O'Reilly Media, Inc.

Pillet, S., Berthelot, P., Gagneux-Brunon, A., Mory, O., Gay, C., Viallon, A., Lucht, F., Pozzetto, B., & Botelho-Nevers, E. (2016). Contamination of healthcare workers' mobile phones by epidemic viruses. *Clinical microbiology and infection*, *22*(5), 1–456. https://doi.org/10.1016/j.cmi.2015.12.008

Punde, P. A., Jadhav, M. E., & Manza, R. R. (2017). A study of Eye Tracking Technology and its applications. *2017 1st international conference on intelligent systems and information management (icisim)*, 86–90. https://doi.org/10.1109/ICISIM.2017.8122153

Reeves, S., Benford, S., O'Malley, C., & Fraser, M. (2005). Designing the spectator experience. *Proceedings of the sigchi conference on human factors in computing systems*, 741–750. https://doi.org/10.1145/1054972.1055074

Rempel, D., Camilleri, M. J., & Lee, D. L. (2014). The design of hand gestures for human–computer interaction: Lessons from sign language interpreters. *International journal of human-computer studies*, *72*(10-11), 728–735. https://doi.org/10.1016/J.IJHCS.2014.05.003

Rise, K., & Alsos, O. A. (2020). The Potential of Gesture-Based Interaction. In M. Kurosu (Ed.), *Human-Computer Interaction. Multimodal and Natural Interaction* (pp. 125–136). Springer Cham. https://doi.org/10.1007/978-3-030-49062-1_8

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences*, *4*(2), 155–169. https://doi.org/10.1007/BF01405730

Schneider, O., MacLean, K., Swindells, C., & Booth, K. (2017). Haptic experience design: What hapticians do and where they need help. *International journal of human-computer studies*, *107*, 5–21. https://doi.org/10.1016/J.IJHCS.2017.04.004

Sharp, H., Preece, J., & Rogers, Y. (2019). *Interaction Design: Beyond Human-Computer Interaction* (5th ed.). John Wiley & Sons.

Sibert, L. E., & Jacob, R. J. (2000). Evaluation of eye gaze interaction. *Proceedings of the sigchi conference on human factors in computing systems*, 281–288. https://doi.org/10.1145/332040.332445

Stanton, N. A., Salmon, P. M., Rafferty, L. A., Walker, G. H., Baber, C., & Jenkin, D. P. (2017). *Human Factors Methods: a Practical Guide for Engineering and Design* (2nd ed.). Taylor; Francis.

Stryker. (2023). *Vocera Smartbadge*. https://www.stryker.com/us/en/acute-care/products/vocera-smartbadge.html

The de Bono Group. (n.d.). *Six Thinking Hats*. https://www.debonogroup.com/services/core-programs/six-thinking-hats/

Ultraleap. (n.d.-a). *Experience is everything. Go play.* https://www.ultraleap.com/enterprise/xr/vr-arcades/

Ultraleap. (n.d.-b). *Make in-store stand out*. https://www.ultraleap.com/enterprise/touchless-experiences/immersive-retail/

Ultraleap. (n.d.-c). *Reach into the future of immersive learning*. https://www.ultraleap.com/enterprise/xr/vr-training/

Ultraleap. (n.d.-d). *Say hello to the second generation of our iconic hand tracking camera*. https://www.ultraleap.com/

Ultraleap. (n.d.-e). *Touchless takes visitors further*. https://www.ultraleap.com/enterprise/touchless-experiences/museums-themeparks/

Unger, R., & Chandler, C. (2012). *A Project Guide to UX Design - For User Experience Designers in the Field Or in the Making* (2nd ed.). New Riders.

Vårdgivarguiden. (2024). *Handhygien*. https://vardgivarguiden.se/kunskapsstod/vardhygien/hygienrad/basala-hygienrutiner/handhygien/

Vatavu, R.-D. (2023). Gesture-Based Interaction. In J. Vanderdonckt, P. Palanque, & M. Winckler (Eds.), *Handbook of Human Computer Interaction* (pp. 1–47). Springer Cham. https://doi.org/10.1007/978-3-319-27648-9_20-1

Wachs, J. P., Stern, H. I., Edan, Y., Gillam, M., Handler, J., Feied, C., & Smith, M. (2018). A gesture-based tool for sterile browsing of radiology images. *Journal of the american medical informatics association*, *15*(3), 321–323. https://doi.org/10.1197{\%}2Fjamia.M241

Wikberg Nilsson, Å., Ericson, Å., & Törlind, P. (2017). *Design : process och metod* (1:4). Studentlitteratur.

Wilson, C. (2013). *Brainstorming and Beyond: A User-Centered Design Method*. Morgan Kaufmann. https://doi.org/10.1016/C2012-0-03533-8

Yonck, R. (2010). The age of the interface. *The futurist*, *44*(3). https://www.proquest.com/magazines/age-interface/docview/218577167/se-2

Zimmerman, J., & Forlizzi, J. (2014). Research Through Design in HCI. In J. Olson & W. Kellogg (Eds.), *Ways of Knowing in HCI* (pp. 167–189). Springer.

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Appendix 1

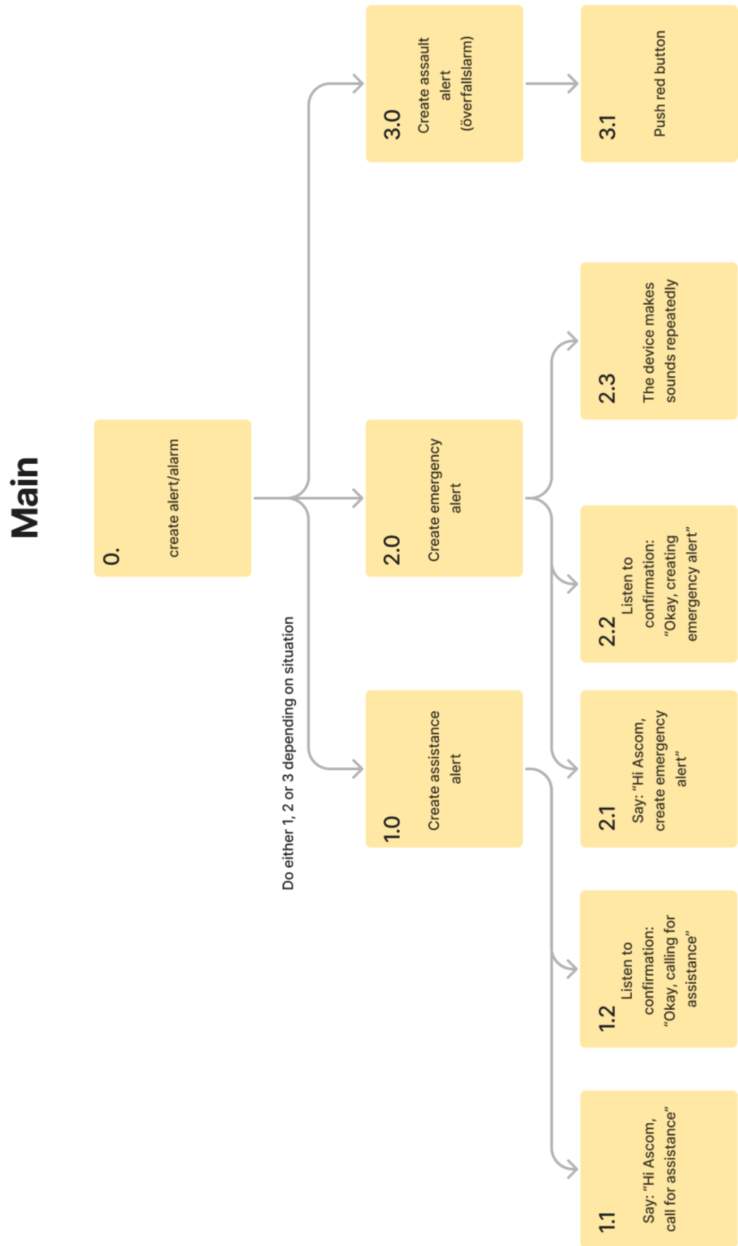

Figure A.1: Interaction flow for creating alerts in *Myco Main*.

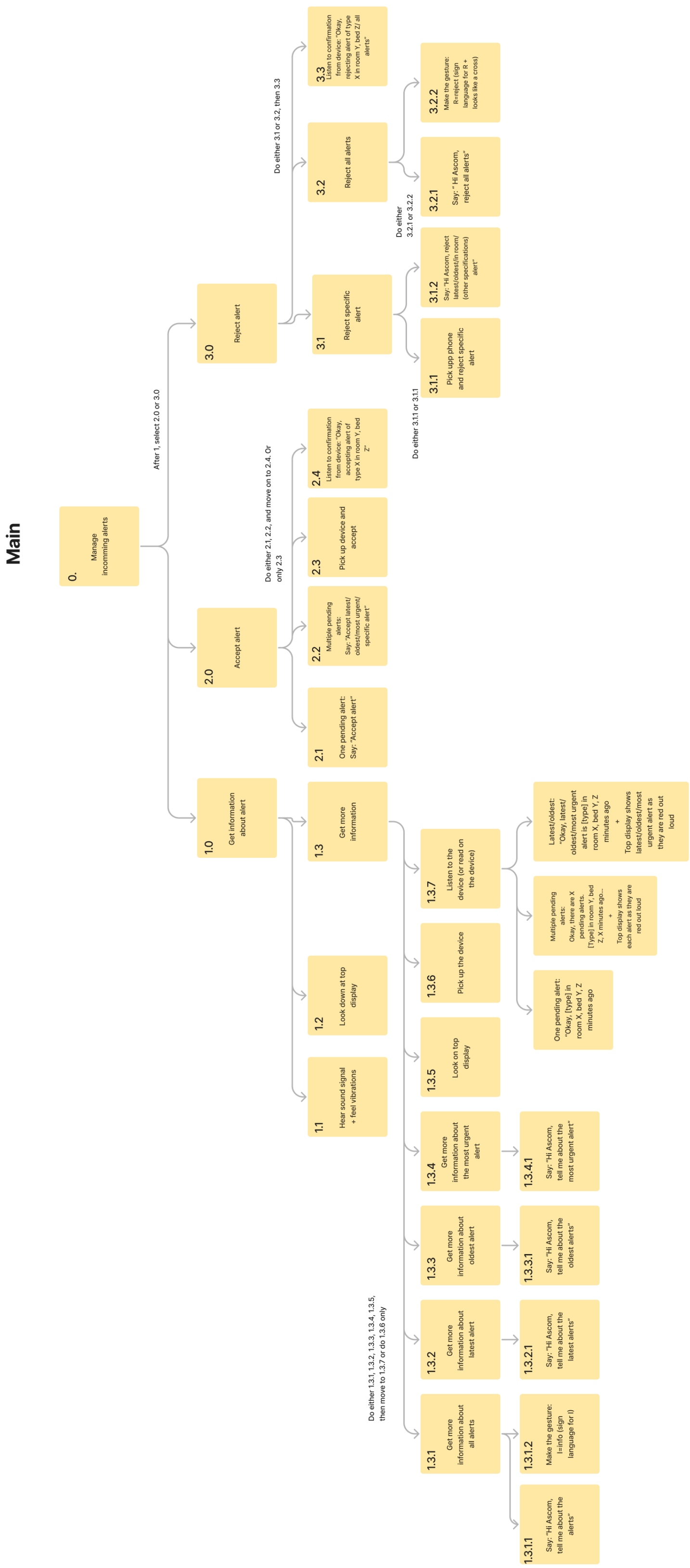

Figure A.2: Interaction flow for managing incoming alerts in *Myco Main*.

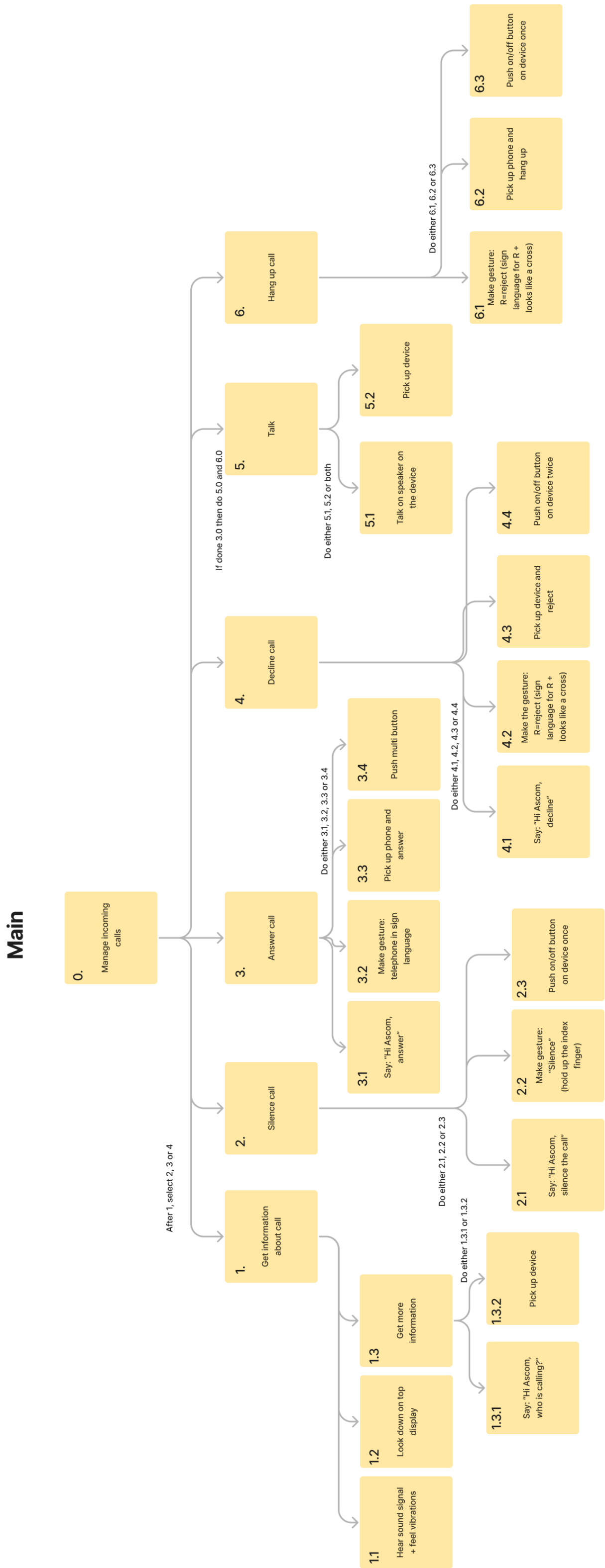

Figure A.3: Interaction flow for managing incoming calls in *Myco Main*.

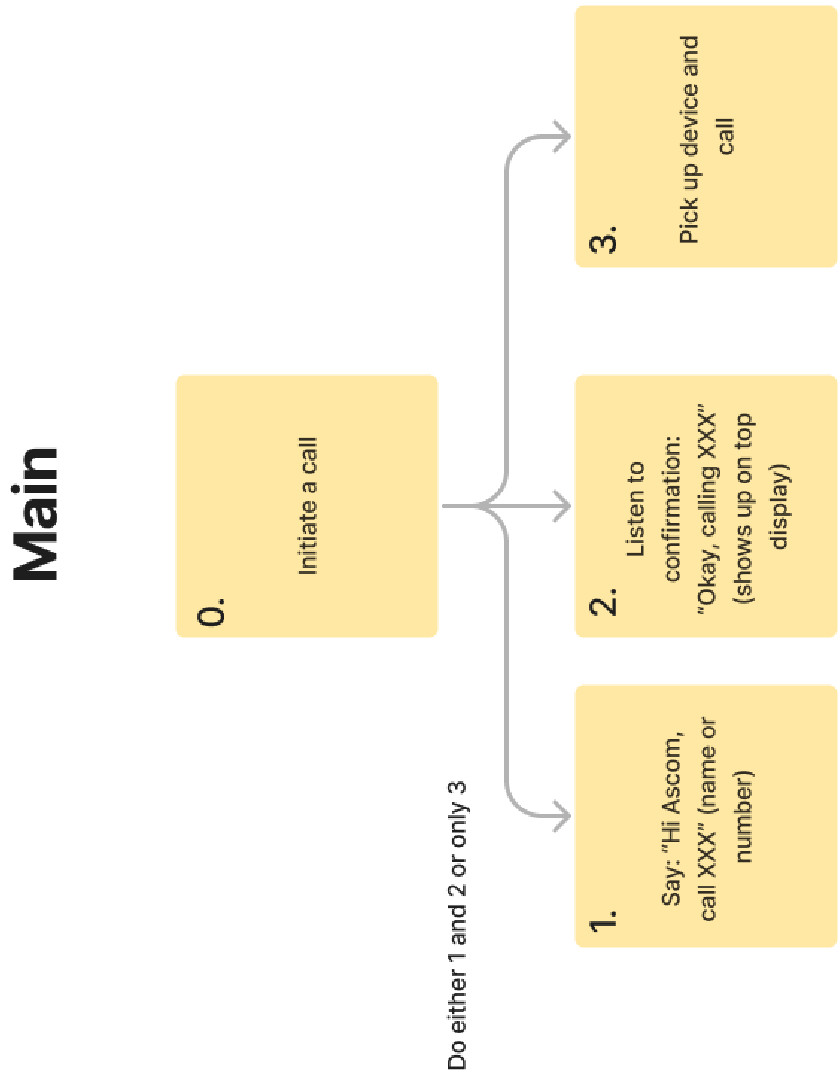

Figure A.4: Interaction flow for initiating calls in *Myco Main*.

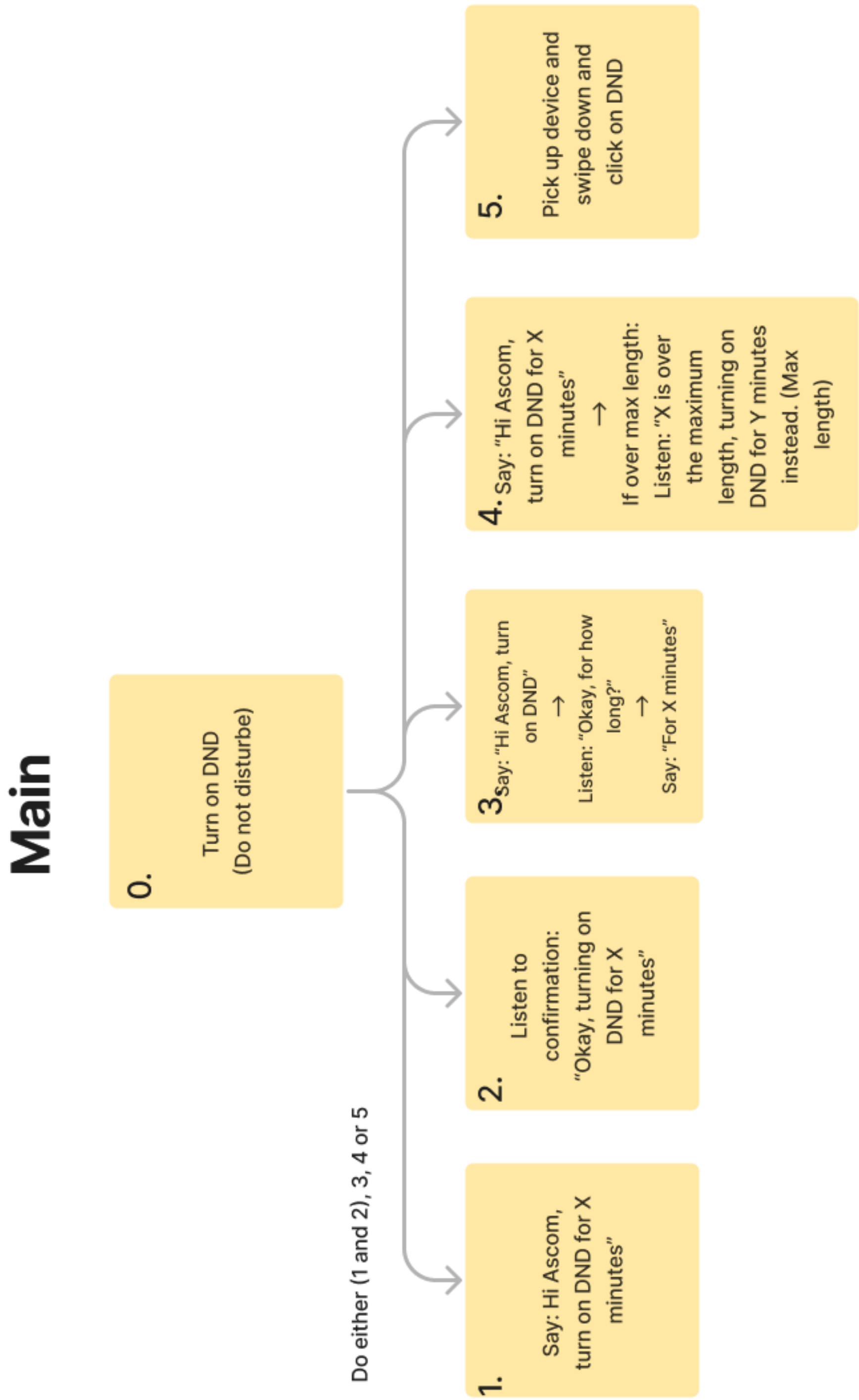

Figure A.5: Interaction flow for turning on DND in *Myco Main*.

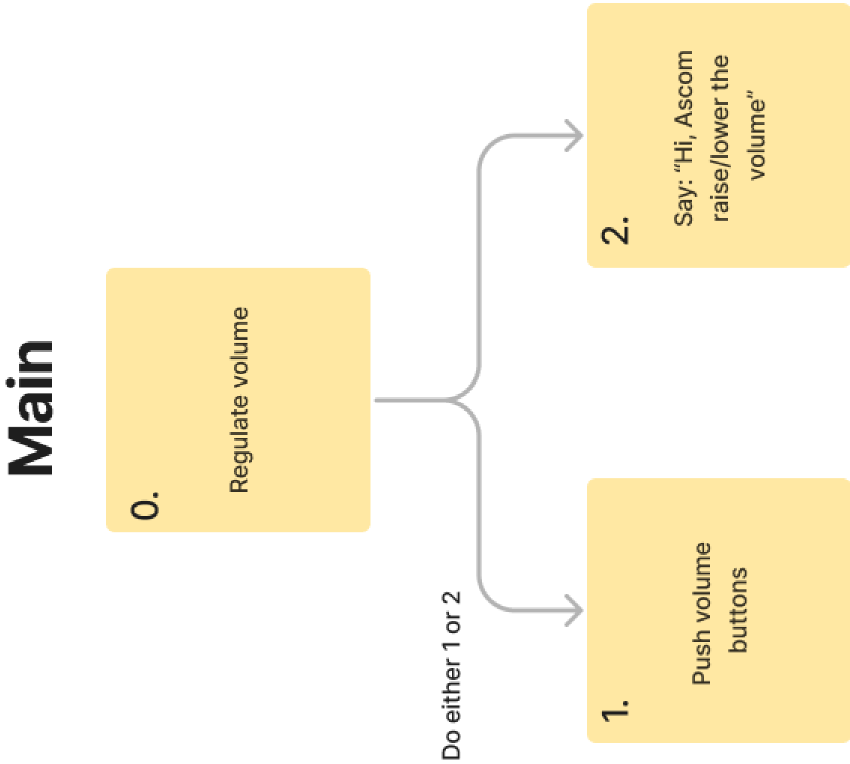

Figure A.6: Interaction flow for regulating volume in *Myco Main*.

Figure A.7: Interaction flow for creating alerts in *Myco Mini*.

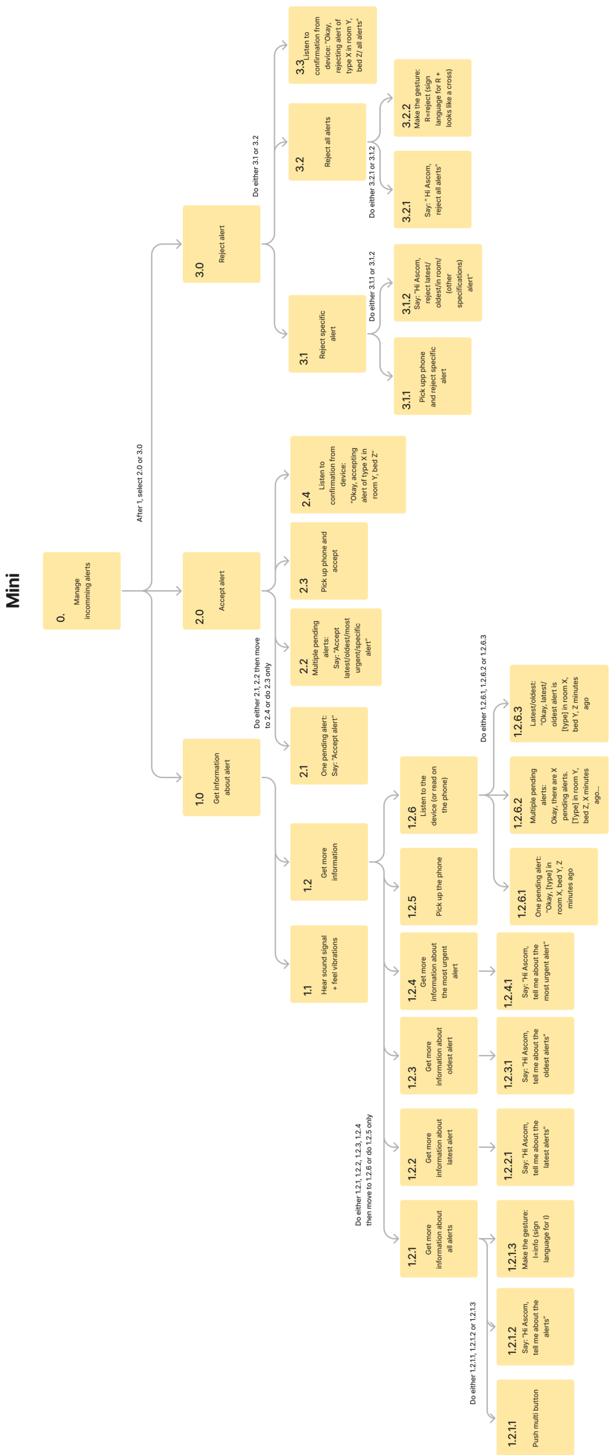

Figure A.8: Interaction flow for managing incoming alerts in *Myco Mini*.

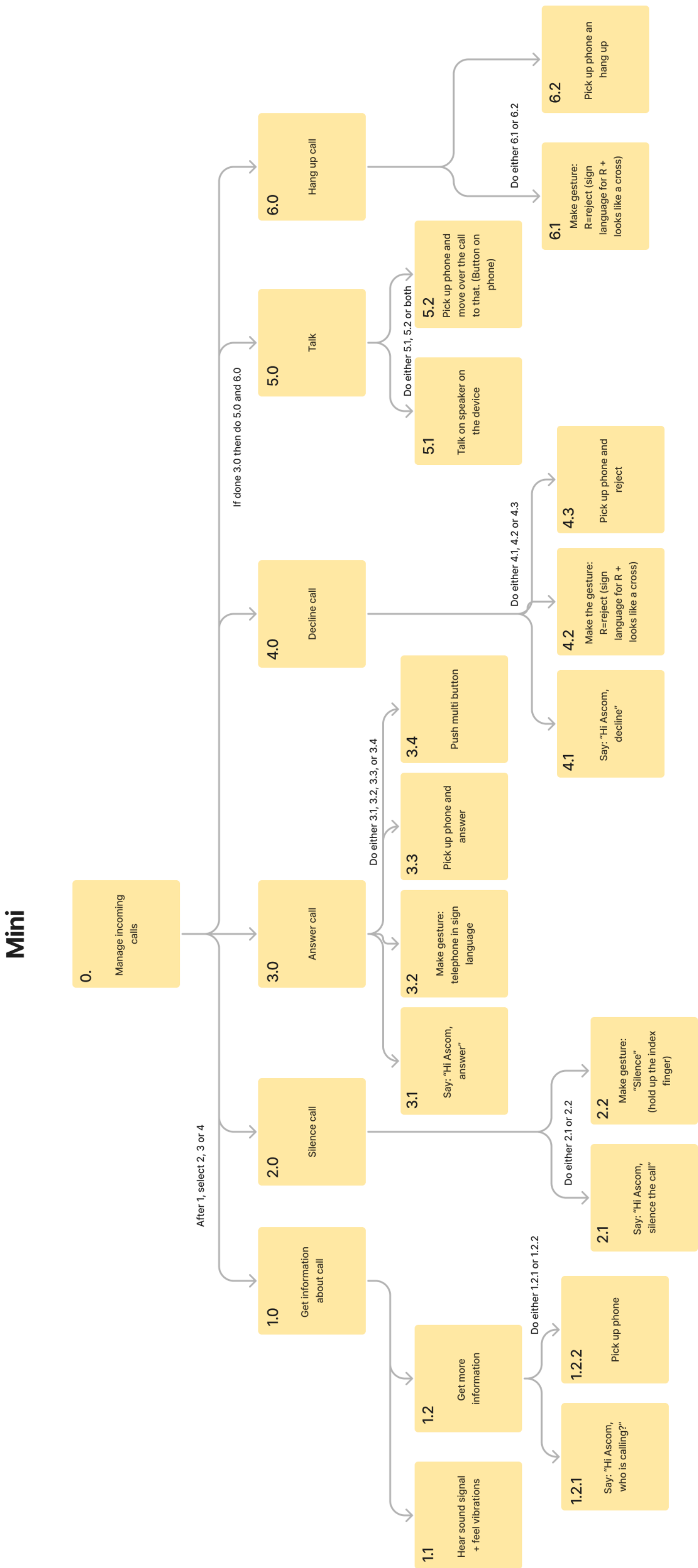

Figure A.9: Interaction flow for managing incoming calls in *Myco Mini*.

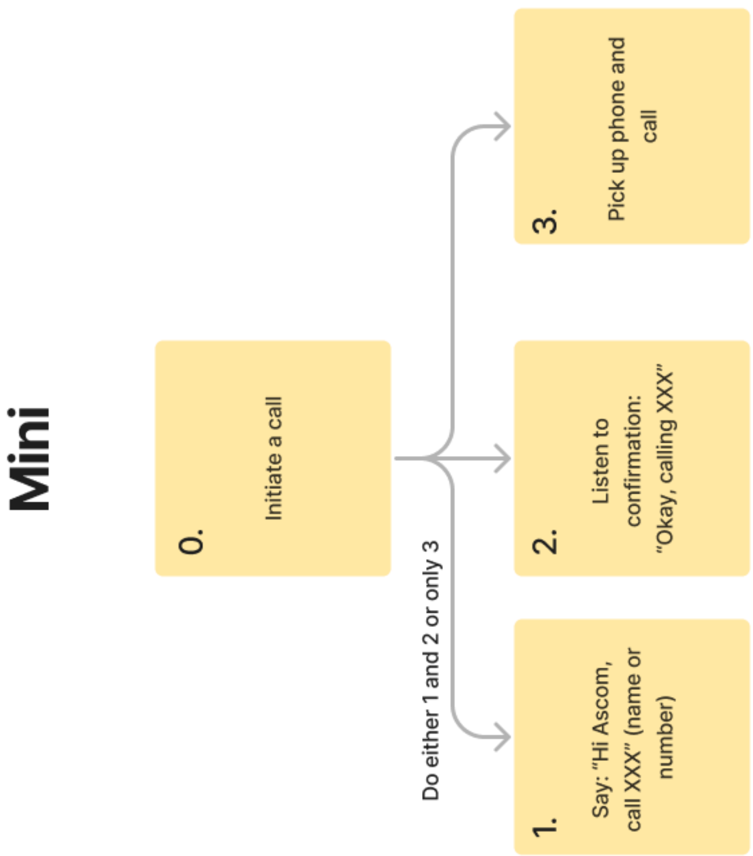

Figure A.10: Interaction flow for initiating calls in *Myco Mini*.

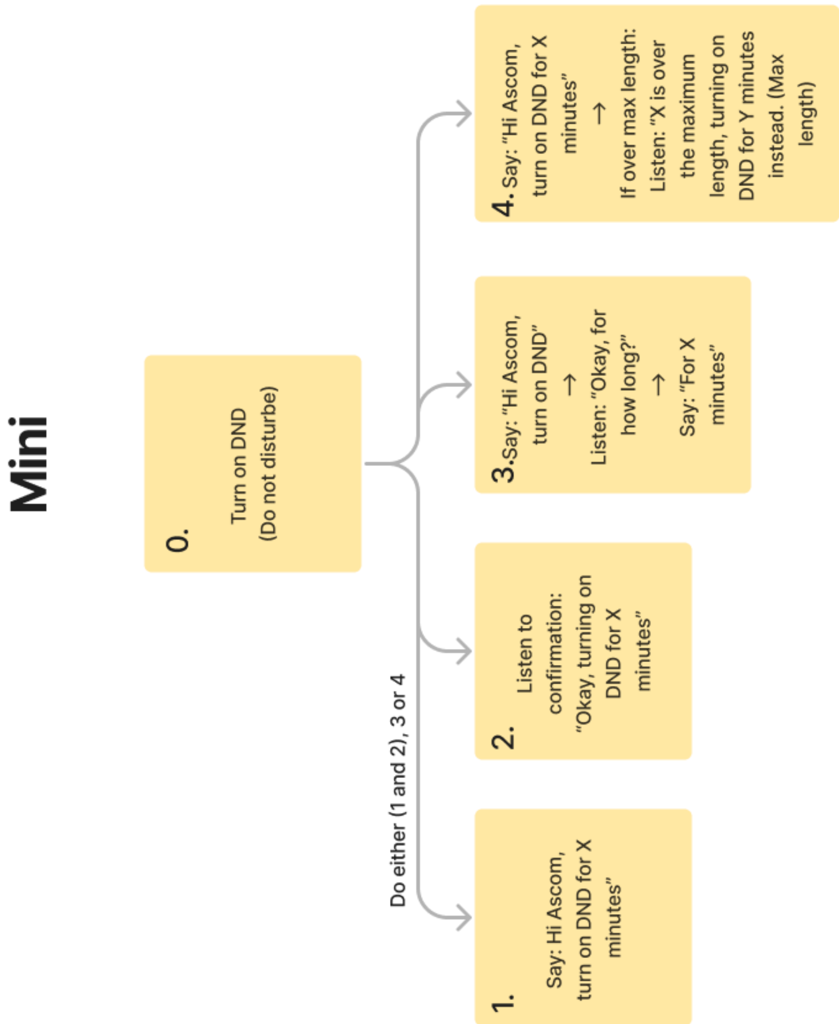

Figure A.11: Interaction flow for turning on DND in *Myco Mini*.

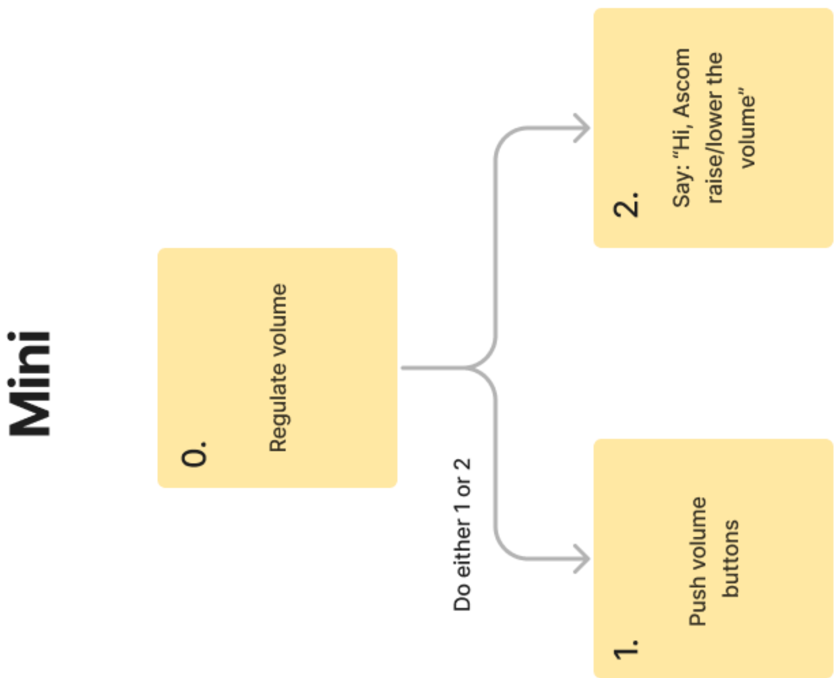

Figure A.12: Interaction flow for regulating volume in *Myco Mini*.