FULFILLING PSYCHOLOGICAL NEEDS OF CRITICALLY ILL PATIENTS THROUGH SOUNDSCAPE AUGMENTATION

MASTER THESIS BY LINDY KYRA KOK

TU Delft Critical Alarms Lab

Design for Interaction

TU Delft supervisors:
Dr. E. Özcan Vieira & G.L.M. Louwers MSc

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"HEALTH IS A PRECIOUS GOOD.
BEING HEALTHY IS A MIRACLE,
YOU COULD SAY."

(ex-ICU patient, 2024)

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Fulfilling psychological needs of critically ill patients through soundscape augmentation

Author
Lindy Kyra Kok
4804082

TU Delft Supervisory Team
Department of Human-Centered Design

Dr. E. Özcan Vieira (Chair)
G.L.M. Louwers MSc (Mentor)

TU Delft Critical Alarms Lab

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I am proud to present my thesis 'fulfilling psychological needs of critically ill patients through soundscape augmentation'. Enjoy!

Lindy

EXECUTIVE SUMMARY

Although the current Intensive Care environment focuses on providing the best care, the current sounds in that environment do not contribute to an optimal patient experience, leading to high stress levels. Literature study showed that soundscape augmentation can reduce patients' stress in healthcare settings if implemented correctly. This project focuses on designing and validating such a system for critically ill patients in the Adult Intensive Care. Throughout the project, key stakeholders are considered; patients, healthcare professionals and loved ones.

A soundscape is defined as the acoustic environment as perceived or experienced and/or understood by a person or people, in context (ISO 12913, 2014). The current acoustic environment has been outlined through a context study, along with its impact on key stakeholders. Together, this provided a clear understanding of the existing ICU soundscape. It can be stated that the current ICU soundscape hinders healing because it affects patients' psychological well-being.

Existing interviews from the Critical Alarms Lab, which aims at shaping the future of soundscapes in these environments, are used to explore patient experiences in ICUs. Four unfulfilled psychological human needs were identified as the barriers to a positive ICU experience: lack of autonomy, comfort, recognition and stimulation. Following literature, these unfulfilled psychological human needs can be fulfilled by providing the right sonic ambience at the right moment. Together with the context study outcomes, a comprehensive patient journey map was created to gain insights into when those psychological needs are either fulfilled or unfulfilled. Interventions in ICU soundscapes need a tailored approach because psychological needs are constantly changing over time and do not arise and disappear at the same time for everyone. A personalized approach was needed to improve the ICU experience.

Four key interaction moments were defined: Patients before admission, loved ones at the start of the admission, healthcare professionals during admission and patients during admission. Several prototypes were created to conduct usability tests with fellow students and healthcare professionals. Insights were gained on which prototype provided the highest engagement and which technique was most intuitive and useful for integrating the system into the healthcare workflow.

A new brand identity was created, resulting in the final design: Amadé - A Soundscape Augmentation System that provides personalized soundscapes, tailored to patients' needs. By aligning soundscapes with patient preferences and clinical needs, Amadé reduces stress and improves patient comfort. User interfaces were created, focusing on the right tone of voice for each interaction moment. An evaluation test was conducted with ex-ICU patients in multiple online sessions. There was a positive response to the usability of the interfaces, but distrust of the system's effectiveness emerged. The feedback and insights gathered from these tests resulted in recommendations for future research and a project reflection.

Keywords: ICU, Patient, HCP, Healthcare, Soundscape, System design, User experience

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READING GUIDE

If you ...

LIST OF ABBREVIATIONS

ICU
Intensive Care Unit

EMC
Erasmus Medical Center
In Dutch: Erasmus Medisch Centrum

FG
Franciscus Gasthuis

HCP
Healthcare Professional

IDE
Industrial Design Engineering

PICS
Post Intensive Care Syndrome

PICS-F
Post Intensive Care Syndrome - Family

CAL
Critical Alarms Lab

HCD
Human-Centered Design

The illustrations are created by the author unless otherwise indicated.

INTRODUCTION

This chapter introduces the need for a soundscape augmentation system in the Adult ICU. It provides the theoretical framework used throughout this project and the main research question and the project's objectives are formulated. In addition, the project's approach and the methods used are introduced.

1.

1.1 GENERAL INTRODUCTION

Imagine listening to the sound of the sea: the rhythmic crash of waves against the shore and the soft rustle of the wind through the coastal grass. These sounds are not just background noise; they are essential cues that help us orient ourselves in the environment. As humans, we heavily rely on auditory information for navigation, communication and responding to stimuli in our surroundings.

The acoustic environment in Intensive Care Units (ICUs) is an important feature of patient care. Wu et al. (2019) found that the acoustic environment plays a leading role in the overall environmental evaluation, which can be explained through the term "soundscape". A soundscape includes all types of sounds in an environment, with emphasis on how they are experienced in a context (Brown, 2012; Kang et al., 2016; Grinfeder et al., 2022). The soundscape in ICUs has long been recognized as noisy and stressful, with negative effects on both patients and healthcare professionals (HCPs) (Schmidt et al., 2020); The constant noise of alarms, medical equipment and conversations can contribute to increased stress levels of patients, confusion, sleep disturbance and annoyance, which hinders the healing process. However, studies have shown the importance of the auditory stimuli within the soundscape, particularly for HCPs because it contains valuable information regarding the patient's condition (Oleksy & Schlesinger, 2018; Fatima et al., 2016). HCPs are dependent on equipment and patient sounds and need these auditory stimuli to provide patient care.

Soundscape augmentation can serve as a solution to optimize the current soundscape in the ICU. Louwers et al. (2024b) state that the strategies available for soundscape augmentation consist of either removing sounds, changing sounds, adding sounds, or a combination of the three. They elaborate that although augmentations to ICU soundscapes have primarily involved just the removal of sound through alternative patient room layouts, sound-absorbing materials, noise-cancelling headphones, foam earplugs, and behaviour protocols (Vreman et al., 2023), it is important to recognize that only removing unwanted sounds is not always appropriate, as it can create anxiety, due to the absence of events (Stockfelt, 1991). This can result in the opposite effect on patient stress; increased stress levels. The fact that HCPs are dependent on the sounds in the environment as well as the fact that omitting sounds causes anxiety for patients, made this project focus on adding sounds to create a new experience. We consider that the right auditory environment can provide essential cues that help HCPs provide care and help patients make sense of their surroundings, reduce their anxiety and stress levels and feel connected to the world outside.

1.1.1 THEORETICAL FRAMEWORK

To develop a comprehensive understanding of the impact of the auditory environment on ICU patients, this project relies on three key studies, providing the theoretical framework:

- Relationship between sound and need fulfilment (Louwers et al., 2022): This theory suggests that designing categorically different soundscapes dependent on users' needs will have beneficial effects. This is particularly relevant in the context of ICUs, where needs vary between individuals.

- Designing sound compositions for the fundamental needs of ICU patients (Louwers, Pont, Gommers, et al., 2024a): This theory defined four design parameters; eventfulness, sonic ambience qualities, narrative structure and sound distribution of sound compositions. Understanding the parameters provides insights into the psychological effects of the soundscape on patients.

- Augmenting Soundscapes of ICUs: a Collaborative Approach (Louwers, Pont, Van Der Heide, et al., 2024b): This theory emphasizes five characteristics of soundscape augmentations in ICUs; personalized, humanized, integrated, user-friendly and familiar. These characteristics provide the starting point for the design phase.

1.2 PROJECT SCOPE

1.1.2 AIM AND RESEARCH QUESTION

The aim of this project is to design and validate a soundscape augmentation system that reduces the stress experienced by patients in the Adult ICU. To achieve this aim, the project focuses on the following objectives:

- To explore the ICU patient experiences, focusing on the unfulfilled psychological needs.
- To design a soundscape augmentation system tailored to the ICU environment.
- To gather patient feedback on the intervention.

Based on the aim and objectives, the following research question (RQ) is formulated which guides this design project:

MAIN RQ:

HOW MIGHT WE CREATE A SYSTEM IN THE ADULT ICU THAT FULFILS THE UNFULFILLED PSYCHOLOGICAL NEEDS OF CRITICALLY ILL PATIENTS BY AUGMENTING THE SOUNDSCAPE DURING THEIR ADMISSION?

This research is significant because it addresses a critical aspect of patient care in ICUs. By potentially reducing stress through soundscape augmentation, the design could lead to improved patient outcomes and shorter ICU admissions. Additionally, it may provide guidelines for optimizing ICU environments.

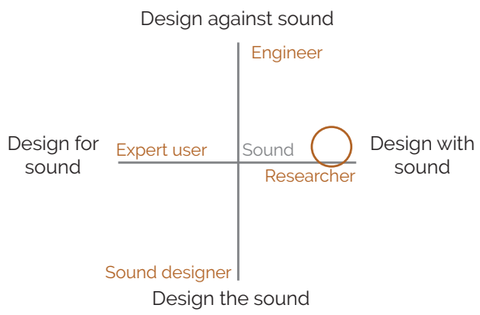


Figure 1: Scope of the project based on framework of Monache et al. (2022)

The stakeholders of the graduation project are supervisors of the Delft University of Technology, who are members of the Critical Alarms Lab (CAL) at the Faculty of Industrial Design Engineering (IDE). The CAL focuses on shaping the future of soundscapes in socio-technological environments (Critical Alarms Lab, 2022). They aim to improve the work conditions of ICU clinicians and the recovery process of patients within the domain of healthcare. CAL, Philips Patient Monitoring and Erasmus MC are collaborating on this project.

This project elaborates further on existing research of the CAL through sound-driven design. Figure 1 shows the aim of this project, comparing it to other ways of dealing with sounds. It is worth noting that this project is not about designing sound files, but about designing sound experiences, based on the knowledge obtained during the project. To scope the initial project assignment, the following decisions have been made:

Erasmus Medical Center (EMC)
This project focuses on the single-occupancy ICU boxes in EMC.

Target Group
This project focuses on the Adult ICU in EMC.

Design Limitations
No requirements regarding the type of intervention (e.g. product, service or product-service combination) have been specified.

The project is situated in the domain of healthcare. Healthcare is a complex system and it is not always possible to predict changes or the impact of interventions on these systems, due to their complex nature (Ratnapalan & Lang, 2019). Therefore, it is important to use an iterative process to effectively adjust to the needs of the stakeholders in the domain. The following section elaborates on the project approach and its methods.

1.3 PROJECT APPROACH

1.3.1 THE APPROACH

The double-diamond approach was used during this project. It consists of four phases: 1-Discover, 2-Define, 3-Develop, and 4-Deliver (Kochanowska et al., 2021). Figure 2 visualizes this approach. It provides a structured framework for stimulating creativity and encouraging innovative thinking in which user research plays an important role.

RESEARCH PHASE
The discovery phase aims to create a deeper understanding of the initially identified problem by looking for different perspectives and gaining experience in the specific context. The ICUs in Erasmus Medical Center and Franciscus Gasthuis are visited frequently and the patient experience in ICUs has been studied comprehensively.

The define phase allows the designer to define the actual problem based on the information gained. The insights of the research phase are combined, resulting in a design brief. The problem statement as well as the design goal and interaction visions are presented, which serve as a starting point for the design phase.

DESIGN PHASE
The development phase is the creative phase in which as many solutions as possible are investigated. Multiple ideas are generated and several concept are created to evaluate based on their usability.

The delivery phase enables designers to let go of ideas that do not fully address the defined problem and to further develop ideas that do. Multiple tests with the stakeholders were conducted to ensure the effectiveness of the design.

The design solution is based on the insights of the research and design phases, ensuring a solution that is based on human-centered design (HCD). This is a practice where designers focus on four key aspects: (1) people and their context, (2) understanding and solving root problems, (3) understanding that everything is a complex system with interconnected parts, (4) implementation of small interventions (Interaction Design Foundation, 2024).

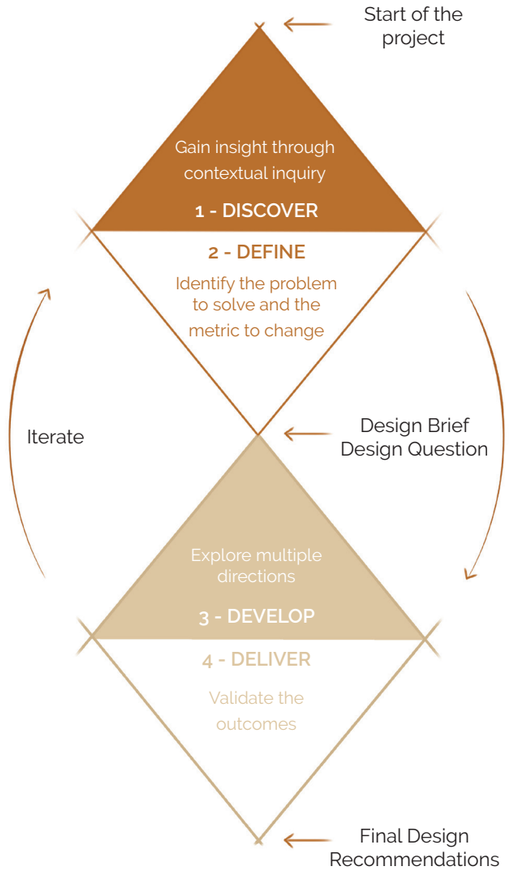


Figure 2: Representation of the Double Diamond Approach used in this project

1.3.2 THE METHODS

Mixed-method methodologies were used to tackle the complexity of the project and to make sure the decisions were substantiated to be able to answer the main research question. Table 1 provides the activities performed during the project and Figure 3 represents the methodologies used in the activities throughout the project, related to the Double-Diamond approach visualized in section 1.3.1.

Research Phase

The research phase consisted of primary research methods, including a systematic literature review, a qualitative thematic analysis of patient experiences and a survey study focusing on estimating sound preferences. Secondary research methods included unstructured observations in ICUs and IC cafes to understand the patient journey in ICUs. To synthesize the research outcomes, the 5W1H method (who, why, what, when, where, how) is used.

Design Phase

Following the design goal, formulated in the design brief, multiple ideas were generated through brainstorm sessions with fellow IDE students. The PMI method was used to evaluate the ideas, resulting in a design direction. A concept was created based on the Information diagram of the envisioned system. The usability of the concept was evaluated through usability tests, leading towards the final design. The final design was evaluated through interviews with ex-ICU patients. A future vision of the design implementation is presented.

Organized Activities	Date
Visit ICU Erasmus MC	Feb/April
Visit IC Café	March
Visit ICU Franciscus Gasthuis	April
Creative Session with Fellow Students	April
Usability Tests with Fellow Students	May
Usability Tests with HCP	June
Expert Session Philips Designer	July
Expert Session UI Designer	July
Validation with ex-ICU patients	July
Expert Session Video producer	August

Table 1: Organized activities performed in the project

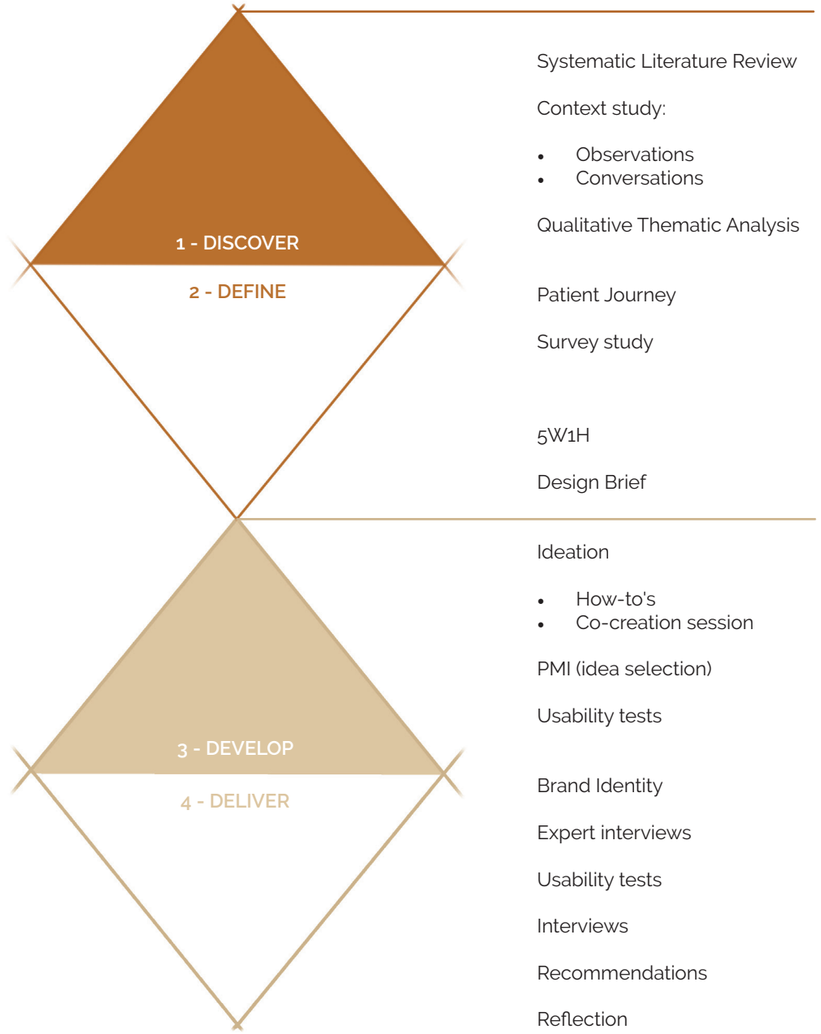


Figure 3: Representation of the methods used during this project

INTENSIVE CARE

This chapter introduces the ICU context in detail through observations and literature study. It presents the different stakeholders of the context, focusing on the ICU in the Netherlands. This chapter is required to get an impression of the context we are designing for.

2.

2.1 INTENSIVE CARE IN THE NETHERLANDS

In the Netherlands, intensive care plays a crucial role in providing advanced medical care to patients with life-threatening conditions or serious injuries. The intensive care unit (ICU) is a specialized hospital unit dedicated to the care of critically ill patients requiring life support and those at extremely high risk of organ failure and death (Ervin et al., 2018).

2.1.1 IC ADMISSIONS

Effective intensive care requires prevention, early warnings and response systems, and a multidisciplinary approach before, during and after the ICU stay. This is reinforced by the fact that while some patients are admitted to the ICU as part of planned procedures, such as heart or brain surgery, the majority of patients arrive unexpectedly due to a range of critical conditions, including cardiac arrest or life-threatening accidents (IC Connect, 2024). In the Netherlands, ICU admissions are divided into three categories: elective-surgical, medical (non-surgical), and emergency-surgical (Stichting NICE, n.d.). These categories indicate different routes of patient care based on the urgency and type of medical intervention required:

ELECTIVE-SURGICAL ADMISSIONS

This type of admission involves patients scheduled for surgery who are known in advance to require postoperative ICU care.

Examples:
- *Orthopaedic surgery: complex spinal surgery.*
- *Cardiac surgery: bypass operations or valve replacements.*
- *Neurosurgery: brain tumour operations.*
- *Major abdominal surgery: pancreatoduodenectomy.*

MEDICAL (NON-SURGICAL) ADMISSIONS

This type of admission involves patients who have not undergone surgery but require intensive care due to acute medical conditions.

Examples:
- *Respiratory diseases: severe pneumonia or acute respiratory distress.*
- *Cardiac conditions: heart attack or heart failure.*
- *Neurological disorders: stroke or status epilepticus.*
- *Infectious diseases: sepsis or severe infections causing multiple organ failure.*

EMERGENCY-SURGICAL ADMISSIONS

This type of admission involves patients who require unexpected surgery and subsequently require ICU care due to the urgency and complexity of their condition.

Examples:
- *Trauma: serious car accidents or gunshots.*
- *Acute abdominal conditions: perforated bowel or pancreatitis requiring surgery.*
- *Vascular surgery: ruptured aneurysm of the aorta.*
- *Emergency cesarean sections: when the health of the mother or baby is at risk.*

Roos-Blom et al. (2024) conducted a registry-based observational study in which they investigated the development in quality of ICU care over time, using the Dutch National Intensive Care Evaluation (NICE) registry. They created an overview of the ICU admissions from 2009 to 2021 (Figure 4), which shows that the majority of ICU patients arrive unexpectedly (58,6%) compared to patients admitted due to planned surgery (41,4%). This aligns with the claim of Ervin et al. (2018), stating that ICU admissions require a multidisciplinary approach. As the percentages mentioned are not so far apart, this project focuses on both planned and emergency admissions.

Next to that, the study shows that the majority of patients is male (60,7%). However, it is crucial to take the specific needs and responses to treatment of both male and female patients into account. This project will, therefore, consider the requirements of all patients.

41,4%
elective surgery

46,4%
medical admission

12,2%
emergency surgery

60,7%
male patients

39,3%
female patients

Figure 4: Characteristics of ICU patients in the Netherlands

2.2 ICU STAKEHOLDERS

The ICU is a complex environment where various stakeholders play essential roles. Understanding the different stakeholders that are involved in the ICU is crucial for optimizing ICU care for both planned and emergency admissions.

2.2.1 KEY STAKEHOLDERS

The healthcare professionals (HCPs), ICU patients and the loved ones of the patients are referred to as 'key stakeholders'. They share the same goal: Optimal ICU care. However, each stakeholder has unique contributions to this goal, as explained in Figure 5.

HEALTHCARE PROFESSIONALS
The healthcare professionals in the ICU include a diverse team dedicated to providing high-quality care to critically ill patients. They monitor and assess patient conditions continuously while being in contact with the patient's loved ones to create and implement individualized care plans. They have ongoing professional development to stay updated on the latest ICU practices and innovations.

ICU PATIENT
The ICU patient is the heart of the critical care system. As explained in the previous section, ICU patients are admitted to the ICU for a variety of reasons, including surgical recovery, trauma or acute complications. They typically experience a range of psychological and physical challenges due to the severity of their conditions.

LOVED ONES
Closely related to the ICU patient are the loved ones, including family members and close friends. Their involvement and support are essential for the emotional wellbeing of the patient. They often act as advocates, ensuring that the needs of the patients are communicated to the healthcare team. They are involved in making critical healthcare decisions, especially when the patients are unable to do that themselves.

Figure 5: Key stakeholders of the ICU context

2.2.2 ICU TEAM

A specialized team works hard to ensure that patients receive the highest level of specialized care possible. The team consists of intensivists, ICU nurses, physicians and many other professionals, collaborating closely to deliver optimal treatment (Figure 6). The following parts refer to the Figure with corresponding numbers.

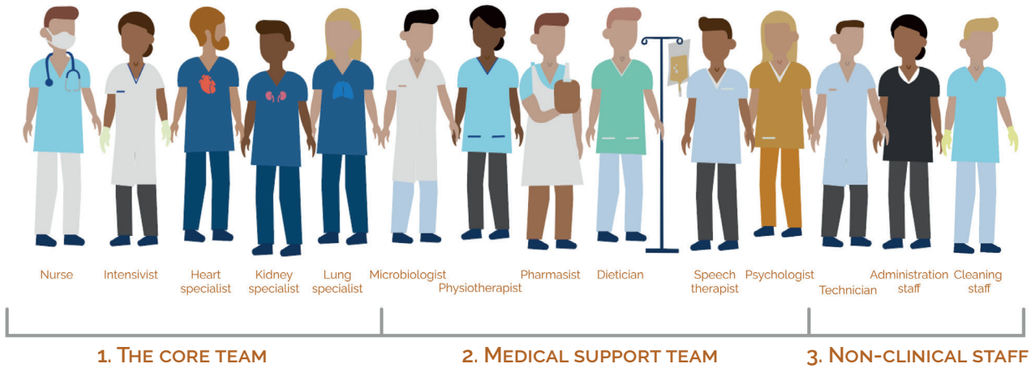


Figure 6: Overview of the ICU team

1. THE CORE TEAM

- **Physicians** are medical doctors who completed extensive training and education in the diagnosis and treatment of illnesses and injuries. They are licensed to prescribe medications, perform surgeries, and provide a wide range of medical care to patients.

- **The intensivist** is a physician who is in charge of the treatment of ICU patients and serves as the primary caregiver in the ICU. Supported by other specialists like cardiologists, neurologists and internists, they diagnose and treat the patient. They have the power to make decisions about the medical treatment of a patient.

- **Lung, heart and kidney specialists** are physicians who support and investigate the treatment of patients. They advise the intensivists and nurses.

- **ICU nurses** are providing personalized attention and support throughout the day and night. They are responsible for the care of one to three patients. They execute the treatment, care and advise physicians. They are involved in discussions regarding treatment, but they cannot make decisions themselves.

Both intensivists and ICU nurses have specialized in intensive care medicine for many years.

2. MEDICAL SUPPORT TEAM
The core team is supported by other clinical staff members such as microbiologists and dietitians who are specialized in their field. Their knowledge is used to support the core ICU team in their treatment of the patient.

3. NON-CLINICAL STAFF
Non-clinical staff members do not provide medical treatment. They do not have direct contact with the patient but are valuable in the environment due to their expertise.

In this thesis, with HCPs, we refer to ICU nurses and intensivists.

2.2.3 ECOSYSTEM

An ecosystem of the ICU stakeholders is created to show the value exchange between all stakeholders of the ICU environment in the Netherlands (Figure 7). It is used to understand the position of the stakeholder, which will be taken into account when designing the intervention.

The following design decisions have been made based on the ecosystem:

- The experience will be designed from the patient's point of view because these users will be influenced most by the design.
- The main digital interface will be designed from the HCPs' point of view because these users will interact with these interfaces the most.
- Although the loved ones are not the primary focus of the experience, their wishes should be taken into account. They are beneficial to make the product valuable.

Legend Value Exchange in Ecosystem

- Money
- Personal Data
- Regulation
- Medical Support
- Emotional Support

- Core Team
- Medical Support Team
- Non-clinical Staff
- Government

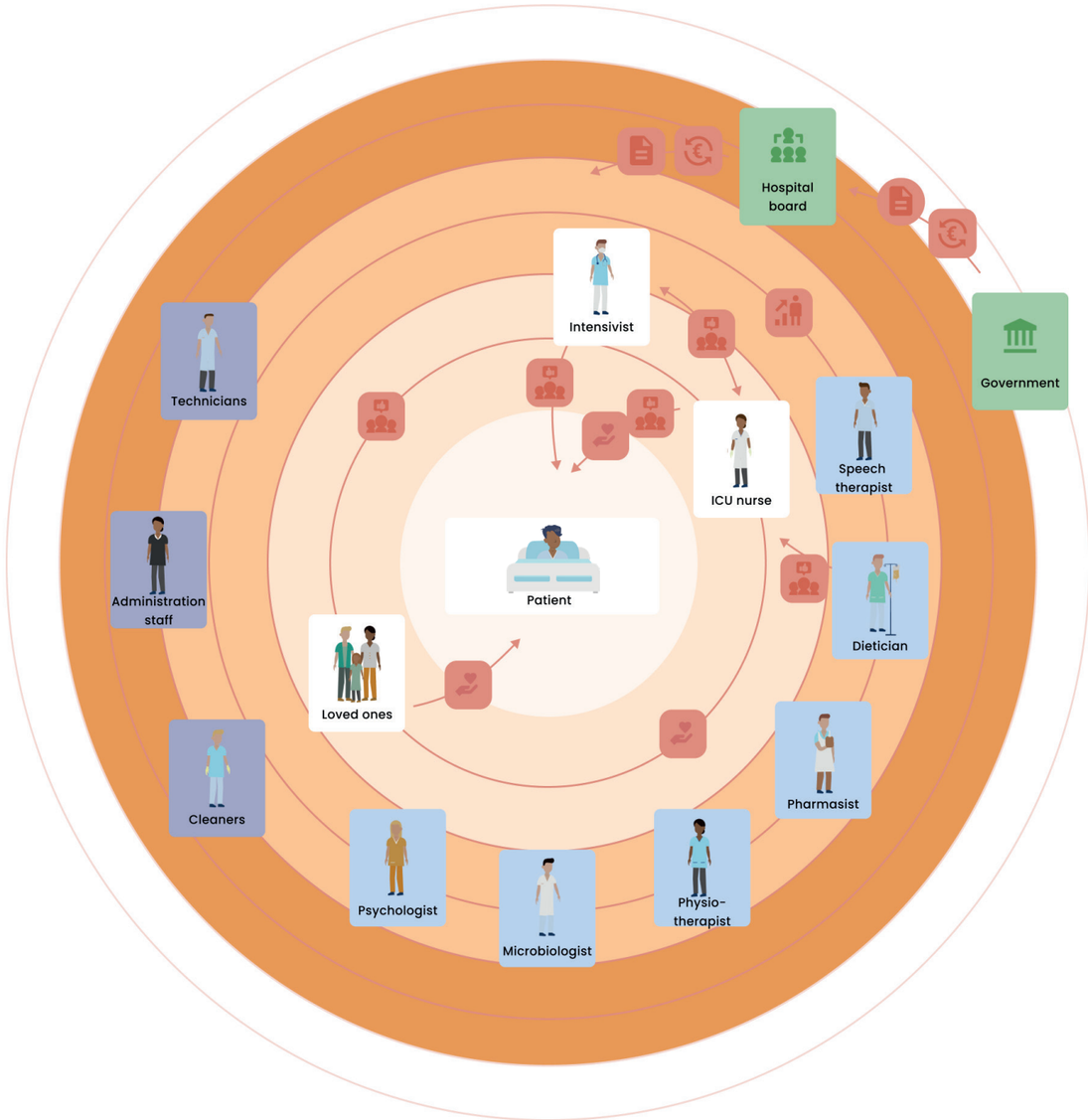


Figure 7: Ecosystem of ICU stakeholders and their value exchange

2.3 ICU ENVIRONMENT

This project specifically focuses on the Adult ICU at EMC in Rotterdam (the Netherlands). The decision to concentrate on this particular ICU is based on several factors:

- **Representative population**

The ICU at Erasmus MC takes care of a diverse group of patients with a wide range of medical conditions. This variation ensures that the findings of this study have broader relevance.

- **Innovative technology**

Erasmus MC is known for implementing innovative treatment methods and advanced technologies in the ICU. The findings of this study provide insights into how such innovations can contribute to improved patient care.

- **Expertise and multidisciplinary team**

The ICU at Erasmus MC has a team of trained and experienced healthcare professionals. This team can evaluate multidisciplinary approaches, offering us valuable insights for our design.

2.3.1 THE ERASMUS MC

The EMC is a large university medical center in the Netherlands. Within the landscape of healthcare, EMC's ICU in Rotterdam is known for its advanced medical care and technology (Erasmus MC, 2024). The general architectural concept was the result of the new hospital processes designed within the EMC, which integrate the care required within patient-centered topics (EGM Architecten, n.d.). Everything at the EMC revolves around creating a healing environment that reduces stress levels during hospital visits, accelerates patient recovery and provides a pleasant work environment for staff (Erasmus MC, 2024). However, despite the efforts to reduce stress levels, the reality is that stress remains a significant concern for patients.

The EMC Intensive Care is equipped with multiple wings (A, B, C, D) referred to as 'units'. The patient rooms are called 'boxes' (Figure 8). The green rooms are the actual patient rooms, used to hospitalize the patient. These rooms are mirrored opposite of each other and between each two rooms there is an area where nurses can keep an eye on patients through windows (yellow). The orange rooms are 'disinfected' rooms, making space for patients who can either transmit dangerous viruses or need to be protected from possible infections. The blue rooms are storage rooms with sterile supplies and non-sterile or general supplies. Next to the boxes, there are facilities like offices, lunch rooms and waiting rooms for families (pink and purple). The floor plan (Figure 8) helps to visualize the people flow through the ward.

The general Adult IC has an optional independent Cardiac ICU (Intensive Cardiac Care Unit, ICCU). The ICCU admits patients with acute heart failure, vascular problems or planned heart surgery. Typical for this ICCU is the high rate of 'bed changes' during the day. Most of the patients are there for less than 24 hours but on the most Adult ICUs, patients are hospitalized for a long(er) period of time (Schokkin, 2019). Figures 9 and 10 provide an impression of the entrance and ICU corridor in Erasmus MC.

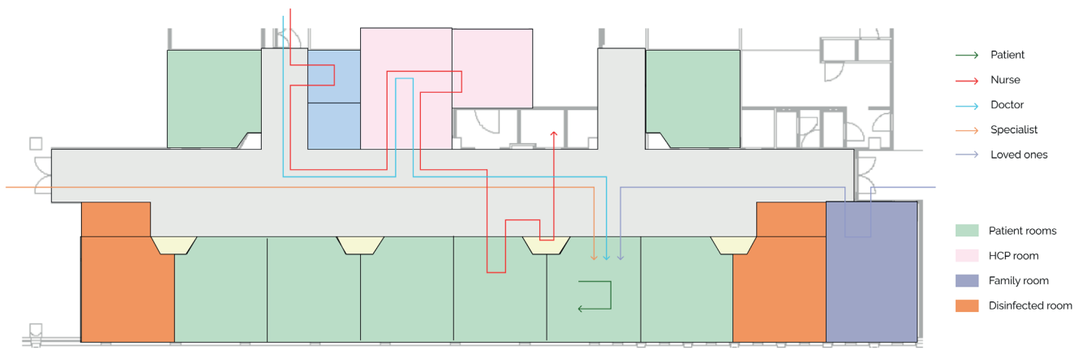


Figure 8: Floor plan of an ICU wing in EMC

Figure 9: The entrance of the Erasmus MC (picture from: EGM Architecten, n.d.)

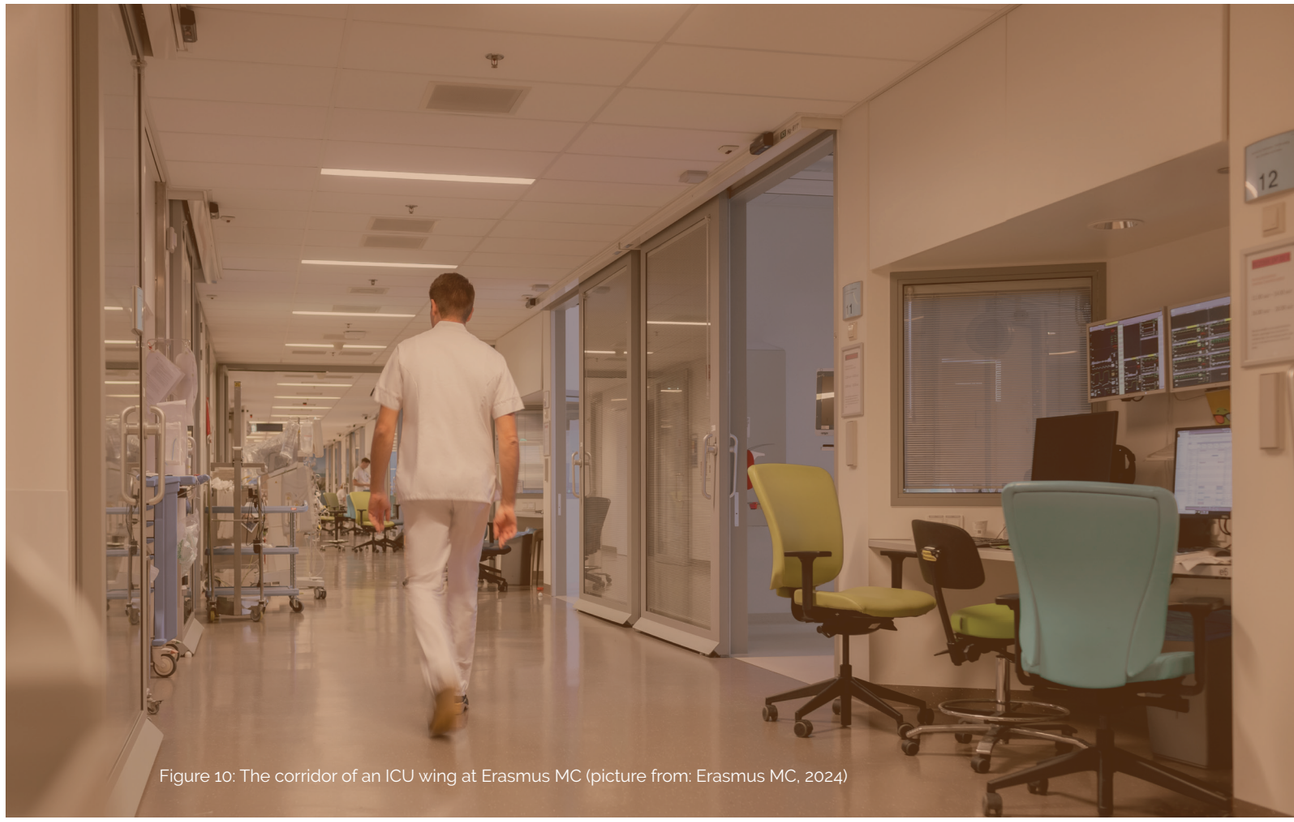


Figure 10: The corridor of an ICU wing at Erasmus MC (picture from: Erasmus MC, 2024)

2.3.2 ROOM LAYOUT AND EQUIPMENT

The ICU rooms in EMC are equipped with medical equipment suitable for intensive care treatment and products for personal care (IC Connect, 2024). Figure 11 visualizes this ICU room.

The most prominent part of the room is the intensive care bed (7). It has electricity points and digital networks to be able to provide special care. The mattress can be adjusted to different positions. Next to the bed is the syringe pump (1). This is used to give the patient the right amount of medicine. The pump beeps when it is almost empty and/or if the medicine is not reaching the patient properly. For example, if an infusion is not attached properly. Another prominent device is the dialysis device, which removes toxins from the patient's blood (4). This device takes over the role of the kidneys when a patient's kidney stops working and raises alarms when it is not working properly. To remove toxins from the blood, a central line is needed. This is a tube that is placed near the heart and is attached to the skin so it will not come off.

The ventilator is a device that helps the patient breathe in and out by blowing extra oxygen or air into the lungs (2). This device raises an alarm if there is a sudden change in measurements. The machine is connected through a tube in the mouth. The HCP can see all the patient's measurements on the central monitor in the room (6), which is connected to the patient monitoring device (5). This device combines measurements, such as blood pressure, respiration rate, heart rate, etc. Alarms can go off if a value deviates from the standard. Each room is equipped with emergency cardiopulmonary resuscitation (CPR) equipment, including defibrillators, to provide immediate intervention care in life-threatening situations.

Figure 12 gives an impression of the interior of the ICU from the HCP point of view and Figure 13 from the patient's point of view. The numbers in both figures correspond to the numbers in Figure 11. Although there is an attempt to provide emotional care in ICU rooms, it remains limited; The primary focus is on treating the patient. While there is a small patient information board maintained by loved ones to inform HCPs of the patient's preferences and offer some level of support, this effort is minimal and secondary to the clinical priorities.

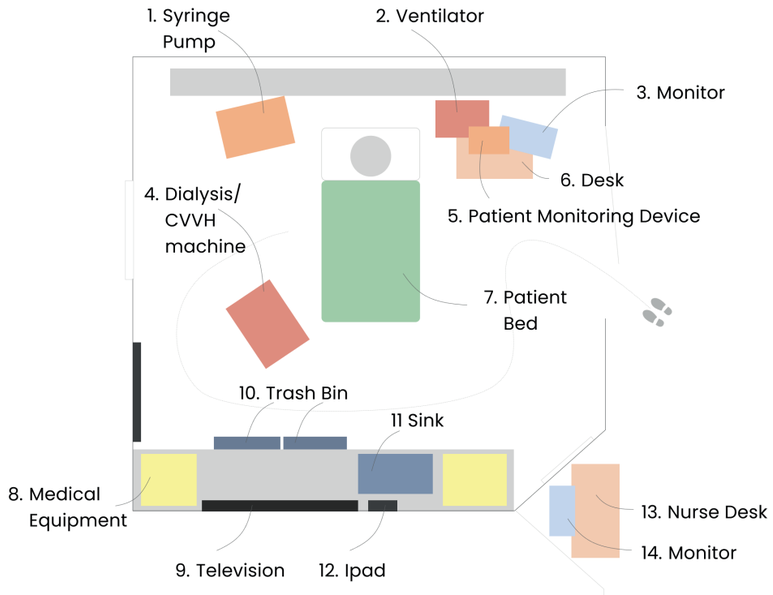


Figure 11: Top view of ICU box

Figure 12: The ICU box environment from the HCP point of view

Figure 13: The ICU box environment from the patient point of view

ICU SOUNDSCAPE

This chapter introduces several necessary terms to understand the context study that follows. The current acoustic environment in the ICU is visualised, followed by its impact on the key stakeholders. Together, it is considered as the ICU soundscape. The connection between sound and need fulfilment is explained, leading us to the empirical research in the next chapter.

3.

3.1 SOUNDSCAPE

'A SOUNDSCAPE CONSISTS OF EVENTS HEARD, NOT OBJECTS SEEN.'

Remember the introduction: imagine listening to the sound of the sea. What do you hear? The rhythmic crash of waves against the shore and the soft rustle of the wind through the coastal grass. These elements form a soundscape, an auditory environment that shapes our perception of the world around us.

3.1.1 THE TERM SOUNDSCAPE

The term 'soundscape' came to light in a study of music in the 1970s through the work of a Canadian composer R.M. Schafer (Schafer, 1977). He defined the term 'soundscape' as "an environment of sound (or sonic environment) with emphasis on the way it is perceived and understood by the individual, or by a society". More recently, the International Organization for Standardization (ISO) published a new International Standard on soundscape, which defines the term as:

"A SOUNDSCAPE IS THE ACOUSTIC ENVIRONMENT AS PERCEIVED OR EXPERIENCED AND / OR UNDERSTOOD BY A PERSON OR PEOPLE, IN CONTEXT."
(ISO 12913, 2014)

We should not confuse the terms 'acoustic environment' and 'soundscape'. They might seem interchangeable but they refer to different concepts in the domain of auditory experience:

Acoustic environment

This term refers to a physical phenomenon: it includes all the sounds that exist in a particular location at a given time. In essence, the acoustic environment is objective; it can be measured and analyzed using scientific instruments.

Soundscape

This term refers to a perceptual construct: it includes the subjective experience and interpretation of those sounds by a listener. It considers how sounds interact with one another and how they are experienced by people within that environment.

First, we need to understand different key elements of a soundscape to make sure we understand the concept:

- **Psychological impact**

As the definition suggests, soundscapes have a psychological impact on humans, influencing our emotions and overall wellbeing. Natural soundscapes are often associated with a calming effect on people similar to that of natural landscapes (Cerwén et al., 2016; Franco et al., 2017). It can be understood in terms of their ability to reduce stress, as highlighted in studies showing that exposure to nature sounds lowers heart rates, decreases anxiety levels and promotes a sense of tranquillity (Alvarsson et al., 2010; Diette et al., 2003). A VR study has shown that listening to natural sounds was more helpful for stress recovery than simply watching them (Annerstedt et al., 2013). This is an interesting outcome because we can state that our outcome thus needs to integrate sound into the hospital environment, instead of only visual cues.

- **When sound becomes noise**

When sound exceeds a certain threshold of volume, frequency, or duration, it can become noise; Our perception of the sound transforms from a pleasant or neutral auditory experience into an intrusive one. According to the World Health Organization (2010), noise pollution can have significant negative effects on health, including increased stress levels, impaired sleep and reduced cognitive function. Unlike ambient sounds that contribute to a pleasant soundscape, noise disrupts daily life by causing annoyance and interrupting communication and rest (Goines & Hagler, 2007). This transition from sound to noise often reflects an imbalance in the auditory environment, where the characteristics of the noise overwhelm the listeners' ability to enjoy the sound. Effective sound management can thus reduce noise in specific environments, taking into account specific listeners and actions in the environment.

By understanding the concept of soundscapes, we gain a deeper understanding of how sound influences people and the role it plays in our lives. This can contribute to the understanding of how and why we want to augment the soundscape in the ICU.

3.1.2 SOUNDSCAPE AUGMENTATION

The importance of the distinction between 'auditory environment' and 'soundscape' is that it implies that the augmentation of soundscapes can occur aurally, through the addition of sounds, or through non-aural methods that guide or influence the visitor's psychological perception of the auditory environment (Villicaña-Shaw et al., 2021). Non-aural methods might involve visual cues, environmental design or other sensory inputs to influence the perception of the auditory environment. Implementing these strategies can be challenging in the hospital environment due to the need for interdisciplinary expertise, longer timeframes for noticeable impact and extensive, costly adjustments to the environment. Therefore, this project focuses on adding sounds to the current soundscape, resulting in 'augmented soundscapes', because the aural augmentation of soundscapes can have immediate effects on how individuals perceive and interact with their surroundings. By introducing specific sounds, tailored to fundamental human needs, we can potentially improve psychological wellbeing.

Louwers et al. (2024b) conducted research by assessing the perceived quality of a soundscape by evaluating a soundscape on independent dimensions of pleasantness (i.e. annoying to pleasant) and eventfulness (i.e. uneventful to eventful), using a two-dimensional framework of Mitchell et al. (2022). They found four concerns / underlying needs of ICU soundscapes: Alienated, Unvaried, Unfamiliar and Disruptive. They used these soundscape concerns to define five distinct characteristics for designing effective augmentations to ICU soundscapes:

User-Friendly

It is important that the interactions with systems would have to incorporate equally accessible auditory, tactile or visual cues. In addition, the user-friendliness of soundscape augmentations should extend to not only patients but also other users of the system.

Humanized

To effectively implement augmentations to the ICU soundscape, systems would need to be people-centered and therefore, avoid dehumanizing the environment. The patients (and other possible users) should be central to the design process.

Integrated

The nature of the ICU as a place of critical care has to be taken into account in the design process. Any functionality of soundscape augmentation has to be integrated relative to that context. Adaptability of the system implies integration with patient data systems.

Personalized

Augmentation of soundscapes within ICUs should rely on individual preferences/needs because every patient is unique. It should provide a personal listening experience. In addition, personalization should be achieved without putting additional strain on HCPs.

Familiar

By providing a familiar interaction with recognizable auditory cues for information, patients could be grounded in reality by being anchored to their known environment, providing orientation. Especially during vulnerable stages of admissions, familiar sounds can be valuable.

3.1.3 MUSIC IN CRITICAL HEALTHCARE

The use of music in hospitals has been studied in detail and is well documented in literature. Music therapy has positively influenced patients in critical healthcare settings by reducing anxiety, relieving pain and improving overall wellbeing (Bradt & Dileo, 2014; Chou & Özcan Vieira, 2020; Dalli et al., 2022). In addition, music can provide a sense of familiarity and comfort, a psychological safety factor, in what would otherwise be a stressful environment (Black et al., 2017).

Despite these benefits, this project does not focus on music therapy but rather on sound compositions as proposed by Louwers et al. (2024a): Unlike traditional music, sound compositions can be specifically tailored to the acoustic environment and psychological needs of critically ill patients. These sound compositions offer a more flexible and context-specific approach to soundscape augmentation. This approach aligns with the findings of Langeveld et al. (2013) who emphasized the importance of designing products tailored to the individual needs of people.

By focusing on sound compositions instead of music, we aim to address some of the limitations associated with music in the ICU. While music can be beneficial, it also has the potential to be overwhelming, especially if it does not align with patients' personal preferences or the clinical atmosphere (Bradt et al., 2013). Next to that, sound compositions can be designed to be easily integrated into the auditory environment, enhancing positive stimuli while minimizing potentially disruptive noises. Therefore, this project uses the advantages of soundscape augmentation through selected sound compositions, providing an adaptable solution to improve patient well-being in critical healthcare settings.

3.1.4 ACOUSTIC BIOTOPE

The focus on the aural aspects of soundscape augmentation using sound compositions aligns with the concept of acoustic biotopes. The acoustic biotope encompasses all of the sounds in a specific environment that influences patient and staff behaviour and interactions (Özcan et al., 2022). Figure 14 shows a basic representation of the acoustic biotope in the ICU. The ultimate goal of an acoustic biotope is to facilitate sound-induced actions and interactions among the ICU team. Understanding the ICU's acoustic biotope is crucial for analyzing how the sounds impact patient well-being, resulting in the current ICU soundscape. The next section will therefore focus on the context study to be able to visualize the current ICU soundscape.

Figure 14: Basic representation of the acoustic biotope in the ICU

3.2 CONTEXT STUDY

To be able to understand the ICU soundscape in-depth, the ICU in EMC and FG and an IC cafe in Rijnmond were visited multiple times. Observations were carried out in the ICUs while focusing on the responses of patients, HCPs and loved ones to the soundscape. They are referred to as 'key stakeholders of the context' as explained in section 2.2.

3.2.1 METHOD

Unstructured observations were conducted, meaning that the method of observation and/or the behaviours of interest was not defined prior to the study (Mulhall, 2003). It allowed the researcher to be open to everything because the field was entered without predetermined actions. The aim of the observations was to understand the behaviour of the different stakeholders in the context.

Observing as HCP
When shadowing the nurses and doctors for two complete days, the researcher was involved in all their activities.

Observing as patient
When doing a pilot test for the supervisor, the role of a patient was taken on to experience how they experience the different sounds in the environment.

Observing as loved one
When visiting an IC cafe, former ICU patients and their loved ones were being observed. Informal interviews were carried out to learn more regarding their sound perception.

Non-participant observer
When walking around in the ICUs, the researcher, as a non-participant observer, observed where the sounds came from, who was responding to what sounds, and what could be improved.

3.2.2 RESULTS

OBSERVING AS HCP
Visiting the ICU as a HCP provided a lot of knowledge about the complex environment of ICUs where it is crucial to be alert all the time. Many more specialists visited sporadically than expected and there is a lot of cooperation between the nurses. They remained very calm under critical conditions. Interestingly, the nurses started talking about the alarms without being asked about them. This could indicate that the alarms are a significant concern or a topic of interest among HCPs. Some interesting quotes show the differentiation of perception regarding alarms:

"THESE ALARMS ARE DRIVING ME CRAZY!"
"I LIKE ALARMS, THEY KEEP YOU ACTIVE."
"THE ALARMS ARE A NECESSITY HERE."

OBSERVING AS PATIENT
The positioning of the bed allows the patient to feel special; they are the centre of the room, contributing to the feeling that all the attention is directed to them. This can be experienced as positive when the patient desires constant care. At the same time, it can cause the patient to become very vigilant (Almerud et al., 2007). Despite not being surrounded by people directly, they feel like they are constantly being watched. This state of vigilance can make the patient feel stressed.

The researcher experienced it herself while being exposed to soundscape augmentation: Due to changes in soundscape (being exposed to different sound fragments), the vigilance (and thus the stress) was reduced, leading to a more relaxed perception of the environment.

OBSERVING AS LOVED ONE
Visitors to the IC cafe meet former IC patients and their loved ones. They share experiences and advice each other. It is organized by IC Connect, a patient organization for (former) ICU patients, loved ones and bereaved (IC Connect, 2024). The IC cafe was visited in Rijnmond to learn from the interactions between loved ones and former IC patients because a life-threatening illness affects not only the patient but also their loved ones.

Sometimes loved ones endure more stress and emotional strain from admission than the patient him/herself. Due to the constant stress about the patient's recovery, the hectic ICU environment, travel to the hospital, sleepless nights and the accompanying emotions of fear and uncertainty, a lot of pressure is put on them. Some get tremendously affected by this afterwards, which can result in Post Intensive Care Syndrome-Family (PICS-F), causing loved ones to develop psychological problems, such as depression, anxiety and Post Traumatic Stress Disorder (PTSD). Most of the loved ones mentioned symptoms of PICS-F, indicating that it has a huge impact on their daily lives.

"I REMEMBER WELL THE TIME A MAN SANG OUR FAVOURITE SONG TO MY THEN-COMATOSE WIFE. A TEAR APPEARED ON HER CHEEK AS IF SHE KNEW WHAT WAS HAPPENING."

3.3 ICU SOUNDSCAPE

The soundscape in the ICU in the Netherlands is characterized by sounds that reflect the complex nature of the environment. Section 3.3.1 focuses on the acoustic environment in the ICU. Section 3.3.2 dives into the impact of this acoustic environment on the key stakeholders. The combination of both sections entails the ICU soundscape.

3.3.1 ACOUSTIC ENVIRONMENT

Following the context study from section 3.2, the current acoustic environment in the ICU is visualised in Figure 15. The complex acoustic environment with different listeners and different listening intentions, makes up the acoustic biotope in the ICU (as discussed in section 3.1.4). The following sound sources are present in the ICU soundscape, contributing to the acoustic biotope:

1. MEDICAL EQUIPMENT

The ICU is filled with various medical equipment. Infusion pumps, cardiac monitors, ventilators and dialyze machines are generating continuous beeps, alarms and mechanical noises. These sounds are essential for monitoring patient status and ensuring that equipment is functioning properly.

2. PAGING AND INTERCOM

Paging and intercom systems are used for communication between HCPs to alert them about important information. The most important are the notifications HCPs get about differences in patient conditions, but also announcements regarding patient updates, emergencies or requests for assistance are broadcasted by these systems.

3. PATIENT SOUNDS

Patients produce sounds themselves such as voice sounds, crying and yawning. These sounds come from expressing needs and emotions or from pain, discomfort or delirium, and they provide insights into their condition.

4. PATIENT CARE ACTIVITIES

HCPs engage in various patient care activities that produce sounds. These include conversations among HCPs, patient assessments and procedures such as suctioning, wound care, intubation or chest tube placement. Footsteps, doors opening and closing and medical carts wheeling around are also contributing to the ambient noise.

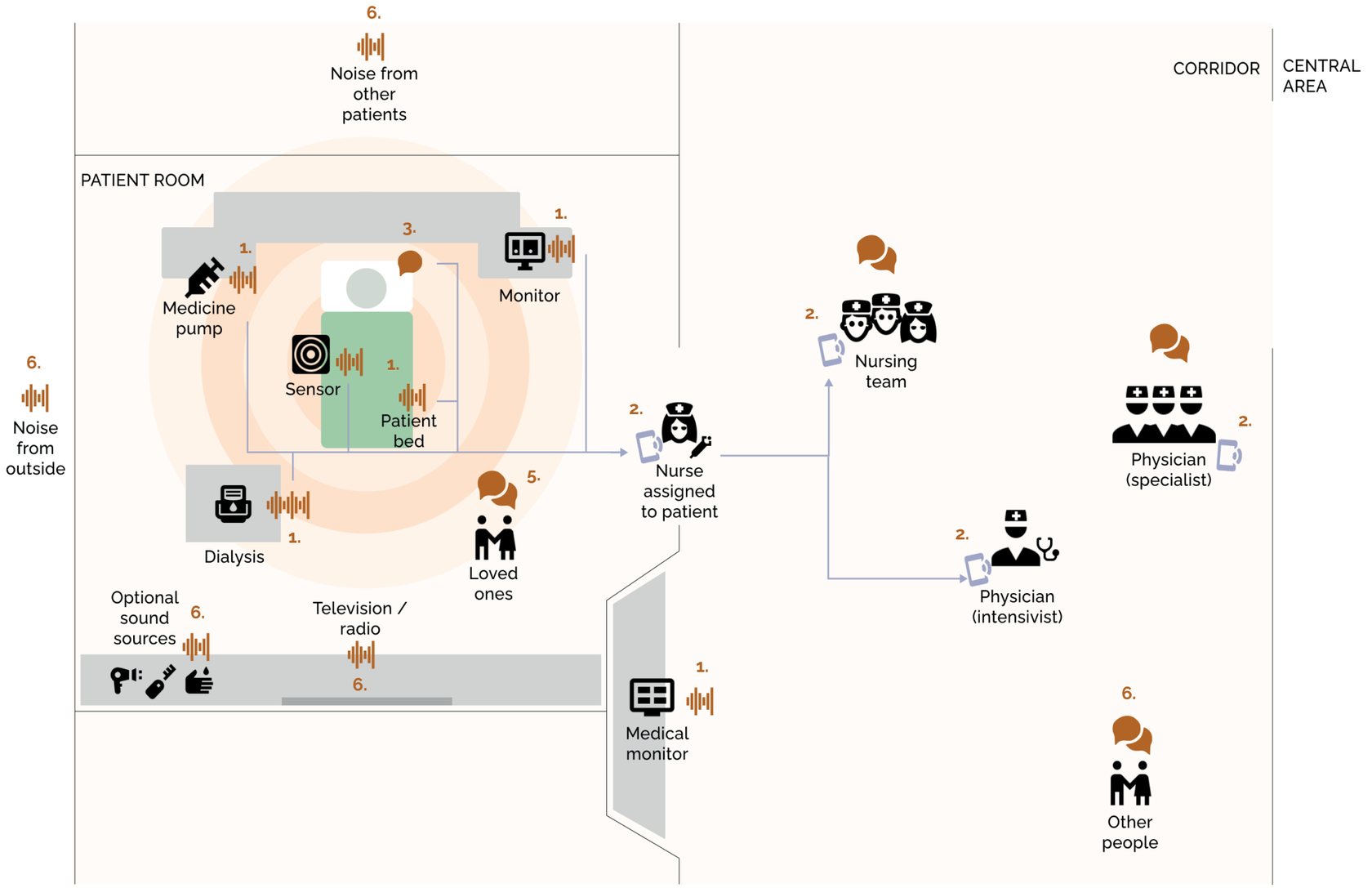


Figure 15: Visualisation of the acoustic environment in the ICU

Sounds sent by source to pagers carried by HCPs

5. LOVED ONES

The presence of visitors influences the soundscape through their engagement in conversations with the patient or the HCPs, providing mental support. While these interactions can comfort the patient, they contribute to the overall noise level.

6. ENVIRONMENTAL NOISE

Environmental factors influence the soundscape. For example outside traffic noise, other patients and construction activities but also heating, ventilation and air conditioning are producing sounds and therefore contributing to the noise level.

3.3.2 IMPACT ON THE STAKEHOLDERS

The elements highlighted in Section 3.3.1 form the acoustic environment in the ICU. The various sound sources within this environment can influence the perceptions and behaviour of the key stakeholders. This section examines the impact of these sounds within the ICU soundscape on key stakeholders, highlighting how they affect experiences and outcomes in the ICU (Figure 16).

The Patient

Early on in the establishment of ICUs, there were initial concerns raised about how the ICU environment within these units might affect the cognitive and psychiatric well-being of patients (Cabello et al., 2008), (Elliott et al., 2013), (Freedman et al., 2001) because these units are characterized by high sound levels, which may contribute to delirium. ICU delirium is defined as 'an acute and fluctuating disturbance of consciousness and cognition', which is associated to the ICU soundscape (Sangari et al., 2021). It impacts a significant portion of ICU patients, ranging from 20 to 80% of ICU patients (Girard et al., 2008). This psychological issue limits the mental abilities of patients and results in reduced awareness of the environment. It is an independent risk factor for adverse outcomes in the ICU including increased mortality rates, post-ICU cognitive dysfunction ICU and hospital length of stay (Girard et al., 2008), contributing to PICS. Many nonmodifiable risk factors influence the development of ICU delirium, such as age, severity of illness and baseline cognitive status. Therefore, it becomes even more interesting to focus on modifiable risk factors such as sound in the environment.

The context study revealed that delirium was indeed a trigger nowadays to become stressed. Some ex-ICU patients expressed that they went mad listening to music all the time. Others found it pleasant, but only when their favourite music was played. And others preferred complete silence. These findings lead to an approach that takes into account patients' personal preferences.

The acoustic environment can also affect sleep quality, which directly impacts the occurrence of delirium (Kang et al., 2023). Waye et al. (2013) stated that ICU noise impairs sleep, which is in line with Xie et al. (2009), stating that the soundscape in ICUs can be disruptive to the sleep of patients. Although improving sleep is not the focus of this study, it is suggested that better soundscape management throughout the day can result in better sleep performance of patients throughout the night.

Besides the psychological impact, the ICU soundscape also has physical impact. Patients may experience stress due to the soundscape; unknown, unexpected and loud sounds can lead to increased stress levels, which can then increase heart rate and blood pressure (Nilsson et al., 2005). This negative impact affects the patient's ability to recover because these activations can cause changes in the immune system (Passchier-Vermeer & Passchier, 2000).

"I FELT LIKE I WAS ALWAYS IN A STATE OF ALERTNESS BECAUSE OF THE NOISE AROUND ME."

Figure 16: Visualisation of the key stakeholders and quotes frrom context study

The HCP

In ICUs, alarms are omnipresent (Simpson & Lyndon, 2019). These alarms are necessary to alert HCPs through sounds when a parameter deviates from the normal range or when failure of equipment occurs. This continuous monitoring of patients' vital parameters is indispensable but their continuous exposure may be overwhelming (Sowan et al., 2016). The average number of alarms that are generated per patient, to which a caregiver in critical care reacts when on duty, is from 150 to 400 or more (Keller, 2012). This can cause the nursing staff to be exposed to alarm fatigue. Alarm management in ICUs is very complex for designers because it involves many different product suppliers. Studies show that changing default alarm settings and standard in-service education on monitor use are insufficient to improve alarm systems safety and reduce alarm fatigue (Sowan et al., 2016). Other studies show that there are some potential solutions to alarm fatigue, such as organizational and educational interventions (Ruskin & HueskeKraus, 2015) but these solutions are not based on reducing the alarms itself. This complex situation creates a need for adding sounds with positive effects on alarm fatigues, not changing the complex alarm system itself.

The Loved ones

The current ICU soundscape also affects loved ones being present in the ICU while visiting the patient. Due to the constant overload of mechanical noises, such as beeping monitors and devices, loved ones may experience the ICU environment as stressful. The soundscape creates an overstimulating surrounding, which can make loved ones worry about the state of the patient.

The lack of comforting and familiar sounds can make the environment feel intimidating, which further isolates the loved ones from the patient and the care process. Addressing the benefits of the intervention in the ICU by incorporating soothing sounds could improve the well-being of both patients and their loved ones, providing a more supportive and less stressful experience during a critical time.

"WE TRY TO MINIMIZE UNNECESSARY NOISE, BUT WE CANNOT DO MUCH ABOUT IT."

"THE NOISE WAS OVERWHELMING. IT MADE ME WORRY ABOUT HOW MY MOTHER WAS COPING WITH IT."

3.4 SOUND AND NEED FULFILMENT

When designing soundscapes for ICUs, it is crucial to understand the human psychology and behaviour that may be affected by this soundscape, as explained in section 3.3. This involves recognizing the fundamental human needs that influence how people engage with the soundscape.

3.4.1 HUMAN NEEDS

Maslow (1943) described his theory that contains five hierarchical levels of basic human needs; the bottom of the hierarchy (for example food and water) must be satisfied first before an individual can attend to the needs that are higher up in the hierarchy (Figure 17).

By looking at the ICU through the lens of Maslow, it is clear that the HCPs' primary focus is on the bottom two layers of the hierarchy. If we assume that the bottom two layers (the basic needs) are being fulfilled by HCPs, we can say that the future intervention should concentrate on fulfilling the psychological needs (layers 3 and 4). An improved soundscape could then support fulfilment for the upper layers of the hierarchy, contributing to satisfaction of the patient (top layer).

Desmet and Fokkinga (2020) introduced a typology of thirteen fundamental needs for human-centered design, inspired by the theory of Maslow. This typology is a structured classification system of psychological human needs and sub-needs. It provides a structured framework for developing design strategies that align with human needs. Despite sub-needs clarifying how needs manifest in specific contexts, individuals may have different sub-needs, making the list incomplete. Huang and Desmet (2023) tackled this by introducing the concept of 'need facets', a term that was introduced by motivation researchers (Reeve et al., 2003; Ng et al., 2011). These need facets are the different aspects or components of a single need that share a common foundation but each with unique features (Vansteenkise et al., 2020). These facets within the fundamental needs enhance the understanding of each need while maintaining their simplicity, creating a framework for designers to address user needs more precisely and effectively in their work.

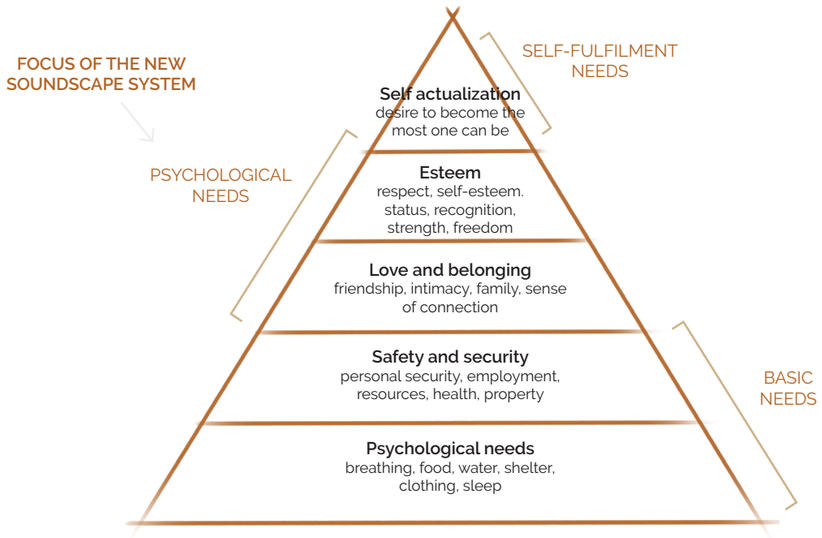


Figure 17: Pyramid of Maslow: Hierarchy of human needs

3.4.2 UNFULFILLED NEEDS

In Europe, the daily presence of environmental noise poses a burden on human health and well-being (European Environment Agency, 2020). These negative experiences with our environment imply that certain needs remain unfulfilled. Louwers et al. (2024b) found in a qualitative investigation that patients in single-patient ICU rooms experienced the soundscape as alienating, unvaried, unfamiliar and disruptive. This aligns with a mixed-method study by Kim et al. (2024), which identified nine factors contributing to negative ICU patient experiences: hopelessness, being dependent, traumatic experiences, lack of distraction, loneliness and disconnectedness, loss of dignity, pain and discomfort, illness and exhaustion and lack of sleep and disturbing environment. Next, they revealed eight factors contributing to positive ICU patient experience: human interaction, hopeful perspective, distraction from illness, sense of safety, sense of control, feeling like oneself, feeling restored and relief from pain and discomfort. These factors entail underlying fundamental human needs, which can be considered as the barriers to a positive ICU experience.

These experiences highlight the specific areas where patients' needs can be unfulfilled, which can potentially be fulfilled with the right sounds at the right moment. This requires research into the unfulfilled psychological needs of patients and when those occur.

EMPIRICAL RESEARCH

This chapter explores the empirical research conducted to identify and understand the psychological unfulfilled needs of critically ill patients, when those occur and to test whether it is possible to estimate the sound preferences of others. By conducting research in those fields, we provide a foundation for the design brief.

4.

4.1 SUB-RESEARCH QUESTIONS

The aim of this project, as explained in Section 1.1.2, is to understand how patients experience the ICU and to create an innovative solution to the problem statement, using soundscape augmentation. The observations in the context study and the literature review were focused on understanding the ICU soundscape and its current impact on patients and HCPs. These insights result in three sub-research questions, based on the project's goal. They aim to provide insights that will be used throughout the design phase.

4.1.1 SUB-RQ1: UNFULFILLED PSYCHOLOGICAL NEEDS

The first sub-research question is related to the unfulfilled psychological needs of critically ill patients. These unfulfilled psychological needs form the barriers to a positive ICU experience, as explained in Section 3.4. What is preventing them from having a positive ICU experience? What are the main barriers that can be identified and focused on during the design process? How do HCPs perceive the experience of patients?

The first sub-research question is as follows:
WHAT ARE THE UNFULFILLED PSYCHOLOGICAL NEEDS OF CRITICALLY ILL PATIENTS IN THE ICU ENVIRONMENT?

This sub-research question is addressed in Section 4.2.

4.1.2 SUB-RQ2: PATIENT JOURNEY

The second sub-research question is related to the unfulfilled psychological needs of critically ill patients, discovered through sub-research question 1. When do these barriers to a positive ICU experience occur? Which events have a high impact on the patient journey?

The second sub-research question is as follows:
WHEN DO THE UNFULFILLED PSYCHOLOGICAL NEEDS OF CRITICALLY ILL PATIENTS OCCUR DURING ADMISSION?

This sub-research question is addressed in Section 4.3.

4.1.3 SUB-RQ3: PERSONALIZED SOUNDSCAPE SYSTEM

The third sub-research question focuses on an important characteristic of the augmented soundscape, as described by Louwers et al. (2024): personalization. How can we personalize the system? What is the best way to provide the soundscape system with the personalized input? Which stakeholders are involved in the personalization process?

The third sub-research question is as follows:
HOW CAN WE PERSONALIZE THE SYSTEM SO THAT IT IS TAILORED TO THE UNFULFILLED PSYCHOLOGICAL NEEDS OF CRITICALLY ILL PATIENTS?

This sub-research question is addressed in Section 4.4.

4.2 PATIENT EXPERIENCES

This section focuses on patient experiences, according to sub-RQ1. It elaborates on how to use those experiences in future interventions. Understanding patient experiences in ICUs is crucial for designing meaningful improvements from a human-centered design approach. This study aims to explore and compare the perspectives of patients and HCPs regarding patient experiences in ICUs through a qualitative thematic analysis using pre-existing graduation theses and research from the CAL. The research question guiding this study is:

SUB-RQ1:
WHAT ARE THE UNFULFILLED PSYCHOLOGICAL NEEDS OF CRITICALLY ILL PATIENTS IN THE ICU ENVIRONMENT?

4.2.1 METHOD

A qualitative thematic analysis was conducted to learn from the experiences of patients and HCPs in ICUs, following the approach outlined by Braun & Clarke (2006). This method consists of identifying, analyzing and reporting patterns in data (Figure 18). A total of 136 quotations from patients and 177 quotations from HCPs were analyzed (Appendix A.1). These quotations were sourced from extensive interviews conducted by previous graduation students (Van Houwelingen, 2022; Cucinella, 2020 and Schokkin, 2019) and a PhD student (Kim et al., 2024). They are all connected to the CAL, providing a lot of insights into ICU experiences. Each quotation was coded to identify key themes that reflect the patient experience. The coding process involved identifying significant statements and dividing them into positive and negative experiences. The analyzing process involved the clustering of common patterns or meanings (Appendix A.2). These clusters were further refined through iterations and resulted in five themes, respectively. These themes represent the core aspects of patient experiences in ICUs from the patient perspective as well as the HCP perspective. The themes are related to the unfulfilled human needs, which represent the barriers to a positive ICU experience. These barriers are connected to the sonic ambience types that can be used in the design phase of the project. This methodological approach ensured that the themes were reflective of the diverse experiences expressed by both patients and HCPs.

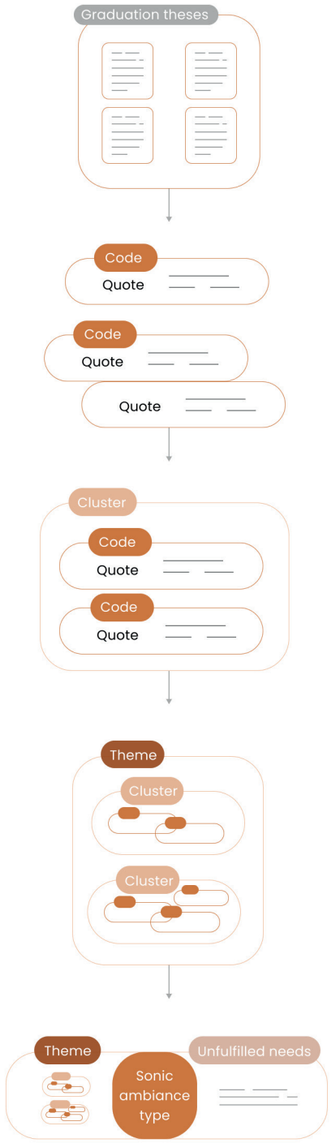


Figure 18: Representation of steps taken within the qualitative thematic analsis

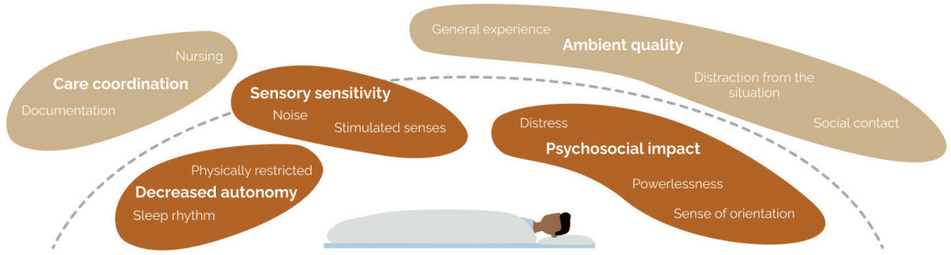


Figure 19: Themes as a result of the thematic analysis of the patient perspective

4.2.2 RESULTS

Figure 19 shows the themes that emerged from the patient perspective analysis, distributed around the patient. The proximity of each theme to the patient indicates whether it primarily relates to internal experiences or external factors. The themes coloured in dark orange are those with higher concentrations of negative quotations. The themes are as explained as follows:

CARE COORDINATION

This theme is defined as the way the care system is coordinated in the Netherlands.

Clusters:
o Nursing
o Documentation

SENSORY SENSITIVITY

This theme is defined as being affected by internal as well as external stimuli. This can cause patients to be easily overwhelmed.

Clusters:
o Stimulated senses
o Noise

AMBIENT QUALITY

This theme is defined as the characteristics of the environment that have an impact on the patient.

Clusters:
o General experience
o Distraction from the situation
o Social contact

DECREASED AUTONOMY

This theme is defined as the support of the environment or the person itself to their self-reliance.

Clusters:
o Sleep rhythm
o Physically restricted

PSYCHOSOCIAL IMPACT

This theme is defined as the effect caused by a lack of deficit needs, i.e. safety, health, breathing and sleep. These are the lower levels that must be satisfied according to Maslow (1943).

Clusters:
o Distress
o Powerlessness
o Sense of orientation

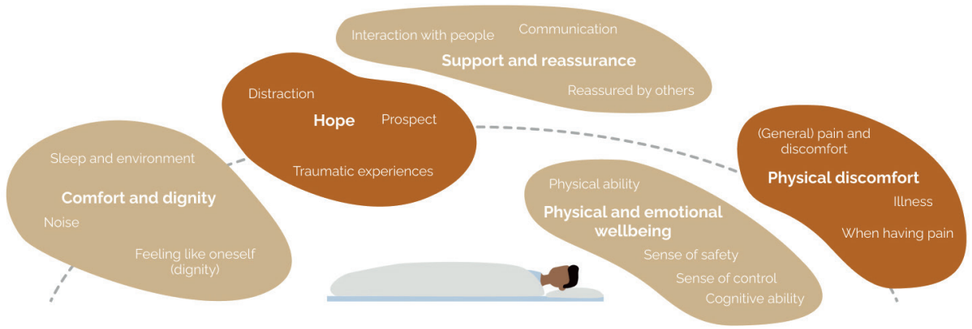


Figure 20: Themes as a result of the thematic analysis of the HCP perspective

Figure 20 shows the themes that emerged from the HCP perspective analysis, distributed around the patient. The proximity of each theme to the patient indicates whether it primarily relates to internal experiences or external factors, according to HCPs. The themes coloured in dark orange are those with higher concentrations of negative quotations. The themes are explained as follows:

Comfort and dignity

This theme is defined as the patient's perception of their ability to maintain their identity, control and dignity while receiving care.

Clusters:
o Sleep and environment
o Noise
o Feeling like oneself (dignity)

Hope

This theme is defined as the patient's perception of their prospects and their sense of hope and resilience during their stay.

Clusters:
o Prospect
o Traumatic experiences
o Distraction

Support and reassurance

This theme is defined as the support and reassurance provided to patients by HCPs through effective communication.

Clusters:
o Reassured by others
o Interaction with people
o Communication

Physical and emotional wellbeing

This theme is defined as the physical discomfort and emotional distress experienced by patients.

Clusters:
o Physical ability
o Sense of safety
o Sense of control
o Cognitive ability

Physical discomfort

This theme is defined as the challenges associated with being sick and the impact of illness on the overall stay.

Clusters:
o (General) pain and discomfort
o When having pain
o Illness

4.2.3 DISCUSSION

Barriers to a positive ICU experience

The themes that resulted from the qualitative thematic analysis were analysed in detail, focusing particularly on those with the highest concentrations of negative quotations (from both the patient and HCP perspectives regarding patient experiences in ICUs). From the patient's perspective, the themes identified were 'Decreased autonomy', 'Sensory sensitivity' and 'Psychosocial impact'. From the HCP perspective, the themes identified were 'Hope' and 'Physical discomfort'.

These findings are examined concerning the fundamental human needs, using the detailed typology of Fundamental Human Needs for Human-Centered Design (Huang et al., 2023). This overview can be found in Table 2, showing the themes identified with the most negative quotes relative to the other themes, connected to the related fundamental human needs and need facets as interpreted by the researcher. Some boxes are intentionally left blank to improve readability.

As a result of the relations between the themes of the analysis and the fundamental human needs, the following fundamental human needs are considered as being unfulfilled in the ICU, resulting in the following four barriers to a positive ICU experience:

- **Lack of Autonomy**
- **Lack of Comfort**
- **Lack of Recognition**
- **Lack of Stimulation**

"MEDICAL ALARMS MEAN FOR ME STRESS, STRESS, STRESS, STRESS, VERY STRESSFUL MOMENTS AND NOT BEING ABLE TO SLEEP."
Ex-ICU patient

Theme	Decreased Autonomy	Sensory Sensitivity	Psychosocial Impact	Hope	Physical Discomfort
Fundamental Human Need (Need Facet)	Autonomy (volition / individuality)		Autonomy (volition / individuality)	Autonomy (volition / individuality)	
		Stimulation (mental)	Stimulation (mental)	Stimulation (mental / physical)	
		Comfort (tranquility / bodily)			Comfort (tranquility / bodily)
	Recognition (respect)		Recognition (respect)		

Table 2: Overview of the themes existing of relatively most negative quotes, related to the fundamental human needs

Sonic Ambience Types

The four defined barriers to a positive ICU experience (Lack of Autonomy, Comfort, Recognition and Stimulation) are related to a study performed by Louwers et al. (2022), which connects fundamental human needs to sonic ambience types and sonic ambience qualities. This relationship is used in this study, aligning the barriers to specific sonic ambience types (Table 3). These sonic ambience types can be used to create specific auditory enviroments that can enhance the listener's experience. This enabled us to connect the lack of certain fundamental human needs to certain sonic ambience types, being used to inform the design intervention of the project.

Barrier	Lack of Autonomy	Lack of Comfort	Lack of Recognition	Lack of Stimulation
Sonic Ambience Type	Pleasurable	Comfortable	Motivating	Stimulating
Sonic Ambience Qualities	Harmonious Momentous Engaging	Familiar Safe Relaxed	Energetic Focused Positive	Vibrant Inspirational

Table 3: Overview of the barriers connected to sonic ambience types with related sonic ambience qualities

Contradiction

While both patients and HCPs recognize the importance of emotional and physical support, there are differences in their perspectives found in this study. Patient's emphasis on their self-reliance, referring to their ability to take care of themselves and manage their own needs, is not as negatively perceived by HCPs: they emphasize more on the prospects of the patients, referring to the potential for the recovery of patients. It is thus interesting to notice that although both concerns are related to the best possible outcome for the patient, both have different interests first-hand. Enhancing both main concerns could lead to better ICU care, improving the experience of patients as well as HCPs.

Interpretation of the researcher

It is important to notice that the interpretations of the findings in this study are influenced by the perspective of the researcher. This subjective element can both enrich and limit the study. On the positive side, designers can use their expertise to translate complex data into research findings. Their interpretations can reveal connections that a more objective approach might miss. Next to that, qualitative research often needs interpretive skills which designers are trained for. Deeper meanings and insights can be discovered that might not be immediately obvious from the data itself.

Limitations

The study has several limitations: First, the results of the interpretations can be influenced by bias of the researcher because of past experiences or preconceptions. To mitigate this risk, we were as transparent as possible in the documentation of how interpretations were derived. Second, the sample size of quotations may not fully capture the diversity of experiences across different ICU settings. Additionally, the study focused on verbal quotations, which might lead to overlooking non-verbal cues that also contribute to patient experience. Third, the resources used are not only focusing on the patient experience in EMC but also in other hospital environments. As a result, the findings may not fully reflect the specific needs of patients in a particular hospital, potentially leading to variations in outcomes between different hospitals.

4.2.4 CONCLUSION

The study revealed insights into the negative experiences of patients and HCPs by identifying themes with the highest concentrations of negative quotations. By linking these themes to fundamental human needs, critical barriers to a positive patient experience were identified: lack of autonomy, comfort, recognition and stimulation. These barriers are connected to sonic ambience types with related sonic ambience qualities, providing us with relative information for the design phase.

Our research suggests that by tailoring the sonic ambience types to fulfil the unfulfilled psychological human needs, the experience of patients in ICUs might be positively influenced. Furthermore, the study expresses the need for patient-centered approaches in ICU settings. By understanding the patient perspectives, designers can develop interventions that can improve the overall stay of patients in ICUs. This can potentially reduce stress and improve the recovery of patients. The study raises the question of when these unfulfilled psychological needs occur. This is the focus of the next section.

ANSWER TO SUB-RQ1

What are the unfulfilled psychological needs of critically ill patients in the ICU environment?

Critically ill patients experience a lack of comfort, autonomy, recognition and stimulation. These unfulfilled psychological needs are considered as barriers to a positive ICU experience.

4.3 PATIENT JOURNEY

To understand when and why the unfulfilled psychological human needs, described in Section 4.2, occur, a patient journey map has been created. This section focuses on the user persona and the patient journey of critically ill patients in ICUs, according to sub-RQ2. It elaborates on when unfulfilled psychological needs occur so that the intervention can be designed from a user perspective. The research question guiding this study is:

SUB-RQ2:

WHEN DO THE UNFULFILLED PSYCHOLOGICAL NEEDS OF CRITICALLY ILL PATIENTS OCCUR DURING ADMISSION?

4.3.1 USER PERSONAS

A user persona is a composite character that encapsulates data gathered and synthesized from user research (Fraser, 2012). The insights from the context study (Chapter 3) and the qualitative thematic analysis (Section 4.2) are combined and translated into user personas. Figure 21 shows a developed persona that represents the relevant type of ICU patients that will interact with the product. Figure 22 shows another persona that represents the relevant type of HCPs that will interact with the product. These user personas will be used to create a journey map to answer sub-RQ2.

PATIENT PERSONA

The patient persona, represented by 'Peter Verbeek' provides insights into the experiences of an ICU patient. Positioned centrally in the room, he feels as the focal point of attention and he is overwhelmed by the constant monitoring. The ICU soundscape, filled with constant noise, contributes to his anxiety and stress.

HCP PERSONA

The HCP persona, represented by 'James Blom and Sarah van Dijk' provides insights into the experiences of HCPs regarding patient experiences in ICUs. It reflects a highly skilled ICU nurse and intensivist with years of experience. They heavily rely on the alarms in the ICU, using their acute awareness skills. They remain calm under high pressure and their interactions with other HCPs shows a high level of social skills.

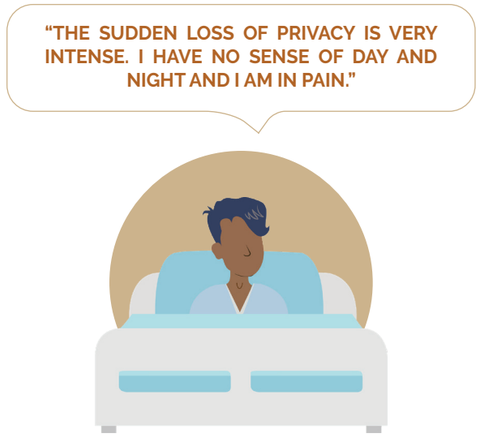


Figure 21: Patient Persona

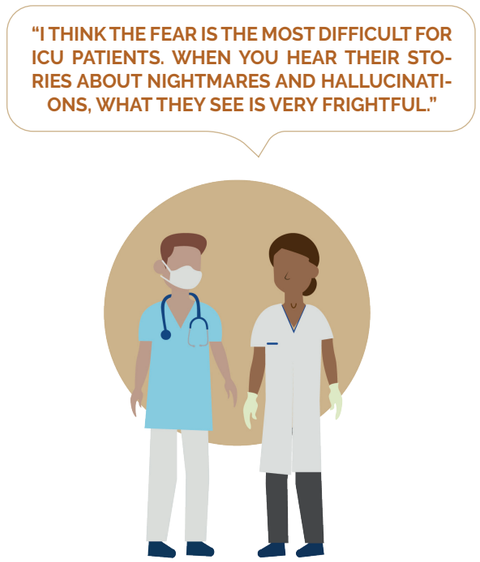


Figure 22: HCP Persona

Peter Verbeek

Age: 64 years old
Occupation: Construction worker (formerly)
Residence: Utrecht, the Netherlands

Peter is a resilient and optimistic man. He has always been known for his sense of humor and his ability to be friends with everyone he meets. He is married to Maria and they have two adult children.

Personality

Peter had a long career as a construction worker, but the physical demands of the job began to affect his health. He struggled with back pain and a high blood pressure.

Reason of hospitalization

He was admitted to the intensive care unit several days ago after having chest pains. He was diagnosed with a heart attack and had emergency surgery. He is currently recovering in the ICU. Although he is awake, he is very weak and unable to speak due to the tube.

Emotional state

Negative	Positive
Frustrated	Satisfied
Bored	Engaged
Worried	Content

Relationship wih technology

Devices owned and used:

Needs & Frustrations

- Lack of autonomy
- Lack of comfort
- Lack of recognition
- Lack of stimulation

Peter is satisfied with the care of the professionals but he is frustrated about his own disabilities throughout his stay. His environment is not stimulating and he is worried about his recovery process.

James Blom: ICU nurse (34 years old)
Sarah van Dijk: Intensivist (42 years old)

As an ICU nurse and Intensivist, James and Sarah play a crucial role in the care of critically ill patients. They support each other through challenging cases for over ten years.

Personality

Both are dedicated, empathetic and highly skilled. They approach their work with professionalism and a sense of empathy for the patients and loved ones. Their calming presence help to reassure both patients and families.

Needs

Both want to maintain a pleasant workflow while providing the best possible care for their patients.

Emotional state

Negative	Positive
Frustrated	Satisfied
Bored	Engaged
Worried	Content

Relationship wih technology

Internet	
Mobile / tablet	
Social media	

Needs & Frustrations

They express that patients must find it hard to deal with their prospect due to intensive care admission. Additionally, they indicate that they think patients are very affected by their pain and it is difficult to manage their symptoms. James and Sarah want to feel less frustrated about the possible downsides of intensive care admission.

4.3.2 METHOD

Understanding the patient journey is crucial to designing something that improves the patient experience because it enables a designer to think about the problems from the user's perspective (Sassen, 2023). The insights from the qualitative thematic analysis (Section 4.2) combined with the context study (Chapter 3) lead to an event-based patient journey.

With events, we refer to all events that take place regarding interactions with the ICU patient. The journey map focuses on the psychological human needs related to the soundscape in the ICU that are either fulfilled or unfulfilled by an event. It is inspired by the previously established patient journey map from Van Houwelingen (2022), which is part of the CAL. Our journey map is used to determine the users' frustrations (unfulfilled psychological human needs) and motivations (fulfilled psychological human needs).

4.3.3 RESULTS

Figure 23 (next page) shows the patient journey map. We learned from the context study (Chapter 3) that ICU nurses operate within a structured schedule; A day, evening or night shift. These shifts are crucial in guiding patient care and ensuring a smooth transition during handovers between HCPs. As a result. these shift changes are used as a guideline for creating the patient journey map.

4.3.4 DISCUSSION

The patient journey map shows the psychological fulfilled and unfulfilled needs over time. These needs are not static; they evolve continuously. Observations indicate that unfulfilled psychological human needs fluctuate based on various events within the ICU environment. These events occur throughout the day, but no two days are the same. This highlights the need for a flexible approach to patient care. Therefore, the patient journey is created for reference throughout the project, not as a strict guideline.

It is important to notice that the patient journey is a generic representation that captures the continuous changes in patient needs over time. Given the fact that psychological human needs can vary in intensity (Huang & Desmet, 2023), this project assumes that multiple needs may be simultaneously present or absent at any given time. As it can vary greatly from person to person when and why certain needs are not fulfilled, it is important to create an intervention that addresses the specific needs of a particular patient. It requires an approach that focuses on providing feedback on the intervention by patients, based on their perspective on their own needs. Only then specific needs will be fulfilled based on the input received from the patient. This raises the question of how we can personalize the system so that it is tailored to those specific needs.

This study focused only on examining patient needs throughout day and evening shifts, not night shifts. Because there is no specific research conducted through the night, any conclusions drawn about the needs throughout the night are speculative and based on the researcher's interpretations. This limitation highlights the need for further research to understand the patient experiences throughout the night shifts.

4.3.5 CONCLUSION

The patient journey map shows the division of psychological fulfilled and unfulfilled needs with an event-based approach, based on the created user personas. It can be concluded that the timing of unfulfilled needs depends on the events occurring in the environment (context-specific) and how a specific person reacts to that event. It can be stated that interventions in the soundscape of ICUs need a tailored approach because psychological human needs are constantly changing over time and they do not arise and disappear at the same time for everyone. By focusing on a personalized approach to overcoming the barriers to a positive ICU experience, the ICU experience can be improved.

ANSWER TO SUB-RQ2

When do the unfulfilled psychological needs of critically ill patients occur during admission?

The unfulfilled psychological needs of critically ill patients occur during admission in response to specific events in the ICU environment. These needs arise based on how the patient reacts to these events, which means that the timing varies for each individual.

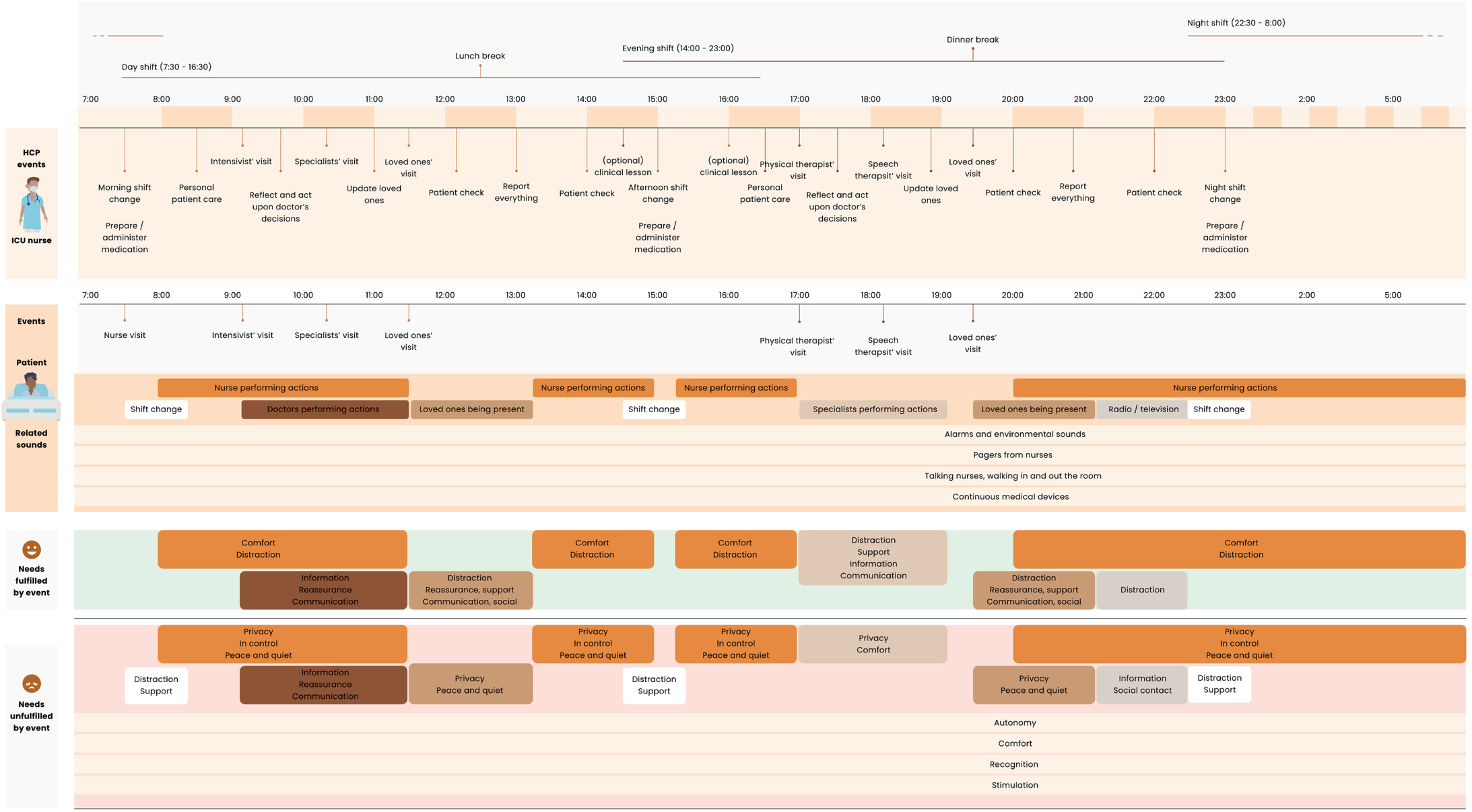


Figure 23: Event-based patient journey map

4.4 SOUND PREFERENCES

This section focuses on sound preferences, according to sub-RQ3. It elaborates on how we can use sound preferences to personalise future interventions. The aim of this study is to understand individual sound preferences and how well others can estimate these preferences. The research question guiding this study is:

Sub-RQ3:

How can we personalize the system so that it is tailored to the unfulfilled psychological needs of critically ill patients?

4.4.1 METHOD

The system envisioned uses various sound files categorized into nature sounds, human sounds and technological sounds (Louwers et al., 2022). The conceptual framework of the system is based on assumptions of the researcher, related to the personalization steps. These assumptions are translated into sub-research questions within this study (Table 4).

Assumption	Related sub-RQ	Aim
Completing the questionnaire results in a representative outcome for the user.	1. Does completing the questionnaire lead to a representative outcome?	To know whether the input can be used to get the right output.
Completing the questionnaire results in a corresponding outcome when you are closely related to someone.	2. Does completing the questionnaire about someone you are closely related to lead to a representative outcome?	To know whether the input can be used to get the right output.
The questionnaire is intuitive/easy to complete.	3. Is the questionnaire intuitive/easy to complete?	To know whether the questions are understandable and easy to answer.

Table 4: Overview of assumptions and related sub-research questions

Participants

A total of 40 participants were involved in this study. Two separate surveys were distributed, receiving 40 and 34 responses, respectively. The participants were recruited through personal networks and communication platforms, primarily WhatsApp. They were asked to indicate their sound preferences in the first survey and estimate the preferences of someone they are closely related to in the second survey. Table 5 shows an overview of the relationships between the participants who participated in survey 2.

Type of Relationship	Amount
Married couple	9
Unmarried couple	14
Parent-Child	9
Sister-Brother	2

Table 5: Types of relationships between participants of survey 2

Survey Design

Survey 1 - Individual sound preferences

The first survey was divided into three sections:

- Sound perception (self-assessment)

Participants were asked to share their sound preferences in 12 questions, which focused on the four sonic ambience types (described in Section 4.2): comforting, pleasurable, motivating and stimulating soundscapes. For each question, the participants could choose from three categories: A) nature sounds, B) human sounds and C) technological sounds.

- Overall preference

Participants indicated their preferred sound categories for two specific situations: when they want to relax (comforting and pleasurable soundscapes) and when they want to become active (motivating and stimulating soundscapes) (Table 6). This part is used for reference whether their previous answers correlated with their actual perception of being relaxed or becoming active.

- Questionnaire feedback

Participants provided feedback on the survey itself, including how challenging the questions were and how they felt during the completion of the survey. A Likert scale (1-5) was used to gain quantitative data regarding participants' mental state and sense of success.

Survey 2 - Estimating sound preferences

The second survey included two sections:

- Estimating other's preferences

Participants estimated the sound preferences of someone they are closely related to, replicating the questions asked in the first part of the previous survey.

- Questionnaire feedback

Participants provided feedback on the survey itself, including how challenging the questions were and how they felt during the completion of the survey. A Likert scale (1-5) was used to gain quantitative data regarding participants' mental state and sense of success.

Survey Question	Sonic Ambience Type	Circumstance
Q1, Q2, Q3	Comfort	To relax
Q4, Q5, Q6	Pleasurable	
Q7, Q8, Q9	Motivating	To activate
Q10, Q11, Q12	Stimulating	

Table 6: Overview of relationships between question, ambience type and expected circumstance

Data Analysis

After collecting responses, the data was analyzed to examine the overlapping responses and discrepancies between the two surveys. Specifically, the analysis focused on:

- Related sub-RQ1

Evaluating if the outcome from the sound perception section correlates with the stated overall preference outcomes. For this, the sonic ambience types comfortable and pleasurable were considered as 'relaxing' while motivating and stimulating were considered as 'activating', referred to as 'circumstance'.

- Related sub-RQ2

Comparing participants' self-assessments with the estimations from someone they are closely related to, to determine if perceptions align.

- Related sub-RQ3

Analyzing the feedback to assess the clarity of the questionnaire, providing insights into the possible improvements for future interventions.

4.4.2 RESULTS

This section presents the results from both surveys conducted to evaluate soundscape preferences and the ability to estimate those for others. An overview of the results can be found in Appendix B.

Table 7 shows the percentages of participants who had a correct match between their indicated sound preferences and the corresponding circumstances. For example, 77,5 % of participants provided consistent responses regarding the circumstance of 'relaxing' when asked about specific sonic ambience types.

Survey Topic	Survey	To Relax	To Activate
Individual Sound Preferences	1	77,5 %	60,0 %
Estimating Sound Preferences	2	62,8 %	55,4 %

Table 7: Overview of correct matches related to circumstance

Table 8 presents the percentages of participants' responses regarding their mental effort (how mentally demanding it felt), sense of success (how successful they felt) and their mental state (how stressed or relaxed they felt) while filling in both questionnaires. Responses were given on a Likert scale (1-5), where ratings of 1 and 2 are categorized as 'negative', 3 as 'neutral', and 4 and 5 as 'positive'.

Survey Question	Survey	Negative	Neutral	Positive
Mental Effort	1 2	7,5 % 13,9 %	22,5 % 22,2 %	70,0 % 63,9 %
Sense of Success	1 2	2,5 % 0 %	24,8 % 44,4 %	72,7 % 55,6 %
Mental State	1 2	7,5 % 2,8 %	10,0 % 30,5 %	82,5 % 66,7 %

Table 8: Overview of answers to the feedback questions

In response to the open-ended question asking for additional comments, participants most frequently noted that not all questions had suitable answers for them.

4.4.3 DISCUSSION

This study explored the way individual sound preferences can be indicated and the ability to estimate the sound preferences of people you know well. It extends previous research by highlighting the importance of understanding individual sound preferences in soundscape perception.

Looking at the results of the first survey, it can be stated that completing the questionnaire in its form right now results in representative outcomes for the circumstance 'relaxing' (77,5 %) as well as 'activating' (60 %). These findings suggest that a personalized soundscape system should consider individual sound preferences to improve patient experience and not create a baseline that should cover the preferences of individuals.

Looking at the results of the second survey, it can be stated that completing the questionnaire about someone you are closely related to led to a representative outcome in over half of the cases (62,8% & 55,4%). While these findings indicate that there is a reasonable chance of predicting the correct preferences for someone familiar, they do not necessarily imply that the accuracy is sufficient for all contexts. Although one could argue that these scores might not be high enough to be entirely reliable, it is worth noting that even a moderate increase in the likelihood of a correct answer is beneficial compared to a system that makes predictions without any knowledge of the other person. Future research could explore ways to improve this percentage and further validate the approach.

The results of both questionnaires regarding how patients felt while filling in the questionnaire, were quite high. Therefore, we can state that discomfort will not have played a role and the questionnaire can be stated as intuitive and easy to complete.

Looking at the suggestions people gave at the end of the survey, it is recommended to give more specific options to answer or give the option 'none of the above. This could enable the participant to truly express their preference.

While the insights are valuable, several limitations must be discussed. First, the relationship between the linked participants may have influenced their responses. It remains unclear whether different types of relationships between participants affect the ability to predict sound preferences. Future research should explore this aspect to determine if and how differences in relationships affect sound preference estimations.

Second, the design of the surveys may have impacted participants' responses. Some participants reported difficulties in selecting from the limited range of provided answers. To address this, usability tests could be useful in determining the most effective way to present answer options to participants. Future research will focus on optimizing how these possible responses are displayed.

4.4.4 CONCLUSION

This study investigated individual sound preferences and the ability to estimate the sound preferences of others, highlighting the importance of personalized soundscapes. The findings indicate that the questionnaire effectively captures individual sound preferences, which supports the need for tailored soundscapes rather than a generalized approach.

The results show that estimating the sound preferences of someone closely related also results in a representative outcome in over half of the cases. While this suggests a reasonable level of accuracy, further iterations are needed to enhance the reliability of these predictions across different contexts. To address this, patients should have the option to provide feedback throughout the day if they are unsatisfied with the soundscape.

Overall, the questionnaire is effective and intuitive, but future research should focus on improving prediction accuracy and optimizing answer options to refine usability and reliability.

ANSWER TO SUB-RQ3

How can we personalize the system so that it is tailored to the unfulfilled psychological needs?

Using a questionnaire that is based on Nature, Human and Technological sounds as input for the soundscape system is effective to personalize the soundscape system. It is possible to estimate the sound preferences of others, resulting in representative results.

DESIGN BRIEF

This chapter presents the Design Brief of this project. The insights from previously conducted research provided the foundation for this brief. The problem statement is presented, followed by the design goal and the interaction visions. From now on, the focus is on the design intervention which is referred to as a 'system'.

5.

5.1 PROBLEM STATEMENT AND DESIGN GOAL

This section introduces the Design Brief based on insights from previous research. The problem statement and the design goal are presented.

5.1.1 PROBLEM STATEMENT

CRITICALLY ILL PATIENTS IN INTENSIVE CARE UNITS EXPERIENCE STRESS DUE TO THE UNFAMILIAR ENVIRONMENT, UNWANTED SOUNDS AND A LACK OF STIMULATION, WHICH RESULTS IN AFFECTED PSYCHOLOGICAL NEEDS(*).

(*) With affected psychological needs, we refer to the following:

- Lack of autonomy
- Lack of comfort
- Lack of recognition
- Lack of stimulation

The following insights are obtained through the research explained in the previous chapters.

Context

ICUs are specialized hospital wards, designed to provide intensive care and monitoring of critically ill patients. Although the complex machinery and bright lights contribute to the care, it can be intimidating for patients who are already in a vulnerable state. The sterile setting lacks the comfort and familiarity of their home environment. Next to that, patients often feel isolated from their family and friends, contributing to feelings of loneliness and anxiety. Combined with the fact that the ICU environment offers little sensory stimulation, which can cause boredom, depression and loneliness, an intervention is needed to optimize the ICU context.

Unwanted Sounds

The loud, constant beeping of alarms, monitors and other medical devices creates a soundscape that can be very disruptive. These sounds vary in volume, length and frequency, which makes it difficult for patients to rest or sleep. In addition, the frequent movement and conversations of HCPs add to the noise levels and disruptions of patients. Although these are essential for patient care, they can further stress and disorient the patient. Figure 24 shows an empathy map, which is created to visualize the current impact of the soundscape on the patient.

5.1.2 DESIGN GOAL

Understanding the specific factors that contribute to patients' stress enables us to develop targeted design interventions. Addressing the issues formulated in the problem statement provides us with a baseline to create a design goal:

TO CREATE A SYSTEM(1) IN THE ADULT ICU THAT FULFILS THE UNFULFILLED PSYCHOLOGICAL NEEDS(2) OF CRITICALLY ILL PATIENTS(3) BY AUGMENTING(4) THE SOUNDSCAPE(5) DURING THEIR ADMISSION.

1. A set of connected things or devices that operate together.
2. The thing you must have for a satisfactory life.
3. Person who receives medical care.
4. Process of increasing the size, value, or quality of something by adding to it.
5. Addition of sounds that guide or influence the visitor's psychological perception of the auditory environment.

The design goal is aimed at mitigating the stress factors in the ICU environment and enhancing patient care.

Requirements

The design goal is translated by us into specific design requirements that will guide the design phase and implementation of the solution.

- The system must motivate its users to listen to the augmented soundscape in the ICU.
- The system must provide the right soundscape at the right moment.
- The characteristics of the new soundscape system need to be described as follows, according to the research of Louwers et al. (2024):
  - Personalized: Tailored to user needs
  - Humanized: Enabling human interactions
  - User-friendly: Concepts for multiple users
  - Integrated: Necessity to integrate in workflow
  - Familiar: Familiar interaction with the system

Nonverbal cues: Cry, grimace, show signs of distress, discomfort or confusion.

Body movement: They might try to move despite being advised to remain still.

Engagement: Some might engage with their care through asking questions, while others might seem passive.

- Fear
- Anxiety
- Confusion
- Loneliness
- Hope
- Pain

Figure 24: Empathy-Map of ICU patients

5.2 SYSTEM DESIGN AND INTERACTION VISIONS

This section explains why the design intervention should take the form of a system and outlines the intended interaction visions within this system.

5.2.1 SYSTEM DESIGN

As the design goal suggests, the outcome of the project will be a system, aiming to improve patient wellbeing. Balaji (2021) refers to a system as: "a collection of components whose performances are interrelated. Invariably, the product of an engineering enterprise is a system". The different components of the system are visualized in Figure 25, as a black box. This black box is a technique to test a system from the user's perspective, without having precise knowledge of the internal workings of the application (Ehmer & Khan, 2012). It focuses on the input that goes into the system, and the output that is produced.

Figure 25: Visualization of the system as a black box

Input

The different key stakeholders, as introduced in Chapter 2, need to be considered in terms of ability and timing to interact with the system. The context study, described in Chapter 3, learned us that the primary focus of the system should evolve around patients, without neglecting the high authority of the HCPs in the environment and the presence of the loved ones.

Output

The output of the system is a soundscape that is tailored to the preferences and needs of the patient. Chapter 4 provided us with insights regarding integrating the individual sound preferences that will be used to create the output of the system.

Following the problem statement, the design goal and the systemic design approach, the following main design question is formulated:

Main DQ:

HOW TO CREATE THE RIGHT INTERACTIONS BETWEEN THE KEY STAKEHOLDERS AND THE SOUNDSCAPE AUGMENTATION SYSTEM IN THE ICU?

5.2.2 INTERACTION VISIONS

After establishing the reasons for the design intervention as a system, we need to explore the interactions of the key stakeholders with the system.

Interaction visions are presented in Figure 26, focusing on the key stakeholders of the context. The main objective of the interaction visions is to create a rich representation of the moods, feelings or experiences that the interactions with the future product should bring to the user (Pasman et al., 2011). They will be used during the design phase to generate ideas and to reflect on whether the final design delivers the envisioned interactions.

Patient Interaction

It should feel like a cool breeze on a hot day.

Interaction qualities:
- Spontaneous
- Relief
- Helpful

HCP Interaction

It should feel like the rising sun at the start of the day.

Interaction qualities:
- Helpful
- Calming in the background

Loved Ones Interaction

It should feel like planting seeds in a community garden.

Interaction qualities:
- Helpful
- High indirect added value

Figure 26: Interaction Visions of key stakeholders

IDEATION

This chapter presents the results of different brainstorm techniques during the Ideation Phase, focusing on the main design question presented in Chapter 5. These results together with the selection of the idea direction is needed to understand the decisions regarding the conceptualization phase.

6.

6.1 BRAINSTORM SESSIONS

This section focuses on generating ideas by asking 'How-to' questions, followed by a co-creation session. Both brainstorming techniques are used to start the ideation phase.

6.1.1 HOW-TO'S

Method

The design brief, explained in Chapter 5, was used to create multiple 'How-to' questions, How-to's are created to support brainstorming (Zijlstra, 2020). Those are questions starting with 'How-to', enabling the researcher to create a diverse set of ideas. The following How-to's are formulated that relate to the soundscape system:

1. How to reach the patient?
2. How to best approach the patient with sound?
3. How to discover the psychological patient needs?
4. How to link the input with the output of the system?
5. How to integrate the system into the HCPs' workflow?

Together with a fellow IDE student, who was not involved in this thesis, multiple ideas were created using the 'How-to's'. When writing down ideas, there was no judgement yet on whether it would be a good idea or not (Heijne et al., 2019). This mindset is the right one for the diverging stage, to ensure that the researcher is not held back in the creative process.

Results

The results of the How-to session are detailed in Appendix C.1. See Figure 27 for an example. Notable findings from the session include:

- Effective communication is build up through techniques that ensure clear communication and trust building.
- Different types of sound have a different impact on patient mood and behaviour.
- There are multiple technologies for identifying psychological needs, such as a personality test or visual images.
- Carefully dealing with patient data is very important.
- There are some requirements for incorporating the system into the workflow of HCPs, including low effort.

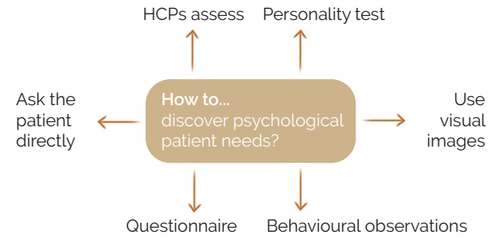


Figure 27: Example of one How-to question with answers

Discussion

During the How-to session, several interesting discussions took place. One significant topic was the way the patient data is used, by linking the input with the output (question 4). Deliberations on which data to use and the timing of its exchange highlighted the vulnerability of the target group. It is therefore decided that a soundscape augmentation system should be developed with these considerations in mind.

The session highlighted that soundscape augmentation can be a powerful tool to reduce patient stress, but only if it is carefully adapted to the context. Adapting the soundscape system to individual patient preferences is crucial, as outlined in Chapter 4. Various methods for identifying these preferences were discussed and after evaluating them, a questionnaire is recommended for its ability to provide immediate patient feedback.

Integrating the system into the HCPs' workflow was acknowledged as a challenge, but necessary for enhancing patient experience. Useful suggestions included a user-friendly design and providing training and support for HCPs.

Conclusion

The How-to session focused on various aspects of the system. Effective communication is crucial in patient care, especially for ICU patients who are critically ill and cannot express themselves easily. This includes both active listening and non-verbal communication to be able to build trust between the patient and the HCP. The session did not touch on the different moments of admissions, which is a requirement of integrating the system effectively, according to the context study (Chapter 3). Therefore, a co-creation session was needed to answer the How-to's more in-depth.

6.1.2 CO-CREATION SESSION

Due to the lack of focus on the different moments regarding patient admissions in the How-to session, a co-creation session was organized.

Method

The co-creation session took place at the Faculty of Industrial Design Engineering at the TU Delft and lasted one hour. Five participants were involved in the session as a resource group. None of them had knowledge of the ICU upfront. They were asked to sign a consent form before the session began (Appendix C.2) and think along and share their ideas and opinions while following a structure created by the researcher (Appendix C.2). This structure is used to make the participants acquainted with the ICU environment and let them produce ideas that are focused on this particular environment, following the guidelines from Heijne et al. (2019). Once all the necessary forms were signed, the researcher made sure every participant understood the aim of the research and was aware of the possible risks and possibilities. The session focused on the possible interactions with the soundscape system before, during and after the ICU admission.

Results

The results of the co-creation session are shown in Appendix C.2. Figure 28 shows a diagram, as a result of the session. The axes of the diagram were predefined by the researcher: feasibility of implementation and originality of ideas. The ideas were developed by the resource group, and the researcher assigned themes to these ideas. The themes are visualized in the figure. Figure 29 shows an impression of the session.

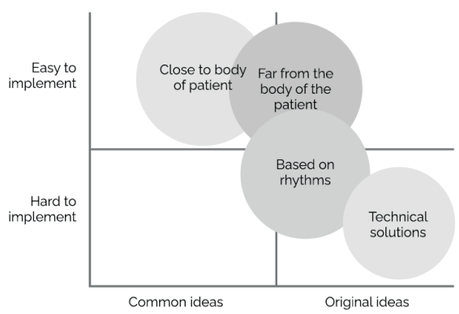


Figure 28: Diagram of the results of the co-creation session

Discussion

The co-creation session explored a personalized soundscape system across three different ICU admission phases: before, during and after being hospitalized. Participants, initially unfamiliar with the ICU context, were able to empathize with patients and HCPs through the use of photos and stories of the context.

The group discussed optimal timing and methods to introduce the system to the patient. It became clear that patients should be approached when they feel safe and calm. In emergencies, loved ones should provide patient's sound preferences. Both statements are in line with the research conducted in Chapter 4.

Regarding the ICU admission itself, discussions centered on the physical space around the patient. Original ideas were placed farther from the patient, while common ideas were closer to the patient. Given the complex healthcare system in the Netherlands, as explained in Chapters 2 and 3, common ideas are more useful as they are more likely to be implemented in the ICU context.

Finally, while extending benefits beyond the hospital stay, the researcher noticed that this was too challenging for the novel resource group. This part of the session was therefore kept very brief, allowing more time for evaluating ideas using the diagram as shown in Figure 28.

Conclusion

The co-creation session successfully explored the development of a personalized soundscape system for ICU patients across various stages of their ICU admission. Key findings included the importance of introducing the system when patients feel safe and calm and allowing loved ones to provide input during emergencies. Common ideas for integrating the system in the ICU context were prioritized over more original ideas due to the implementation feasibility. Challenges in imagining post-hospitalization benefits highlighted the need for further research in this area. Overall, the session provided valuable insights used to create ideas.

Figure 29: Impression of the co-creation session with fellow students

6.2 IDEA SELECTION

The insights of the conducted research combined with the brainstorming sessions, led to multiple ideas. After several discussions with the Supervisors about the feasibility of the ideas, three main ideas evolved (Figure 30). This section focuses on the selection method 'Plus, Minus, Interesting' (PMI) to discover which idea was considered as most valuable.

Method
The PMI method was used to evaluate the ideas by assessing their positive aspects (Plus), drawbacks (Minus) and intriguing (Interesting) elements (Sharma & Priyamvada, 2017). This method allows researchers to compare various ideas and identify the most feasible elements.

Results
Table 9 provides an overview of the results of the PMI session. The three different ideas are evaluated considering the five characteristics of the soundscape augmentation system: personalized, humanized, user-friendly, integrated and familiar, as explained in Chapter 3.

Discussion
The PMI method provided insights into the strengths and weaknesses of the ideas. After careful consideration, idea 3 stands out as the most promising idea, especially when combined with insights from ideas 1 and 2.

Idea 1 provides a useful improvement through the use of sonic ambiences but does not accommodate the diverse patient preferences. Idea 2 offers a valuable personalization method through tailored personas, yet its limited scope does not cover all patient needs. Idea 3 focuses on real-time personalization, which makes it the most promising idea. Integrating the strengths of all three ideas will help create a system that effectively meets the unfulfilled psychological needs of critically ill patients.

Conclusion
Idea 3 is identified as the most promising for improving the ICU experience due to its real-time personalization based on user data. By integrating the strengths of ideas 1 and 2, the solution will more effectively address the unfulfilled psychological needs of ICU patients.

	Plus	Minus	Interesting
Idea 1	Instant input of the barriers to a positive ICU experience, as described in Chapter 4.	The psychological needs of each patient vary greatly per event, making it difficult to state that psychological needs are fulfilled with one baseline, aiming to cover everyone.	Incorporating sonic ambience qualities offers a direct approach to fulfilling psychological needs.
Idea 2	Persona profiles are based on real data of people.	Sound preferences are not reflected well enough; only a limited number of personas are possible, which say more about the person than the sound preferences.	Profile-based personas could lead to a comprehensive soundscape
Idea 3	The input in the system can be translated directly to the output.	It is technically difficult to determine how the four axes will combine in the soundscape.	The input can directly be translated to the output, which creates an opportunity for creative ways of input.

Table 9: Overview of results PMI section regarding 3 main ideas

Figure 30: Overview of the three main ideas

CONCEPTUALIZATION

This chapter bridges the initial ideation phase (Chapter 6) and the final design (Chapter 8). It is crucial in outlining the chosen concept's development and demonstrating how usability tests have influenced the design.

7.

7.1 CONCEPT DEVELOPMENT

This section provides a detailed description of the development of the concept. It starts by explaining the design considerations that were needed to create a system architecture diagram.

7.1.1 DESIGN CONSIDERATIONS

The design considerations are organized into four key categories: Personalization, Integration in the HCP workflow, User-friendliness and Design principles.

Personalization

Building on insights from Louwers et al. (2024b), personalization is an essential characteristic for designing effective augmentations to ICU soundscapes. To explore how to personalize the system, a survey study was conducted to gather data on patient sound preferences. The study identified the value of using a questionnaire that includes categories such as nature sounds, human sounds, and technological sounds. This questionnaire can be completed by the patient or their loved ones if the patient is unable to do so. The gathered data will then be used to create a soundscape tailored to the patient's preferences.

Next to that, our investigation into different ICU admissions (Chapter 2) revealed that the system must distinguish between patients admitted on a scheduled basis and those admitted in emergencies. Scheduled admissions allow more time for detailed data collection, whereas emergency admissions require a more rapid system deployment.

Integration in the HCP workflow

For the soundscape augmentation system to be effective and sustainable in the context, it must be integrated properly into the workflow of the HCPs. Insights from the context study (Chapter 3) and patient experiences (Section 4.2) indicate that a designated HCP should be responsible for managing and adjusting the soundscape according to the patient's real-time condition.

Furthermore, the context study revealed that HCPs heavily rely on alarms and must not be distracted by additional sounds. To respect this need, the soundscape should be designed to be experienced exclusively by the patient, using directed speakers. This ensures that the patient benefits from the soundscape without disrupting the focused environment, necessary for HCPs.

User-friendliness

To ensure that the system is both effective and widely adopted, it must be user-friendly for patients, loved ones and HCPs. It should be designed with simplicity in mind, requiring minimal effort to understand the system. Tasks such as selecting or adjusting sound options should be intuitive and quick.

Next to that, the system should include mechanisms for continuous feedback from the patient, either directly or through observations by HCPs. This feedback loop allows for the ongoing adjustments of the soundscape to better meet the patient's needs as their condition continuously evolves.

Design principles

The design process was guided by several principles, including simplicity, accessibility, mental models and affordances. These principles, detailed in Appendix D.1, ensure that the system remains user-friendly and effective.

7.1.2 INTERACTION MOMENTS

Considering how and when the key stakeholders interact with the product is crucial to designing an effective soundscape augmentation system. Using the design considerations as a guideline, a system architecture diagram is created to define the optimal interaction moments of the key stakeholders with the system (Figure 31).

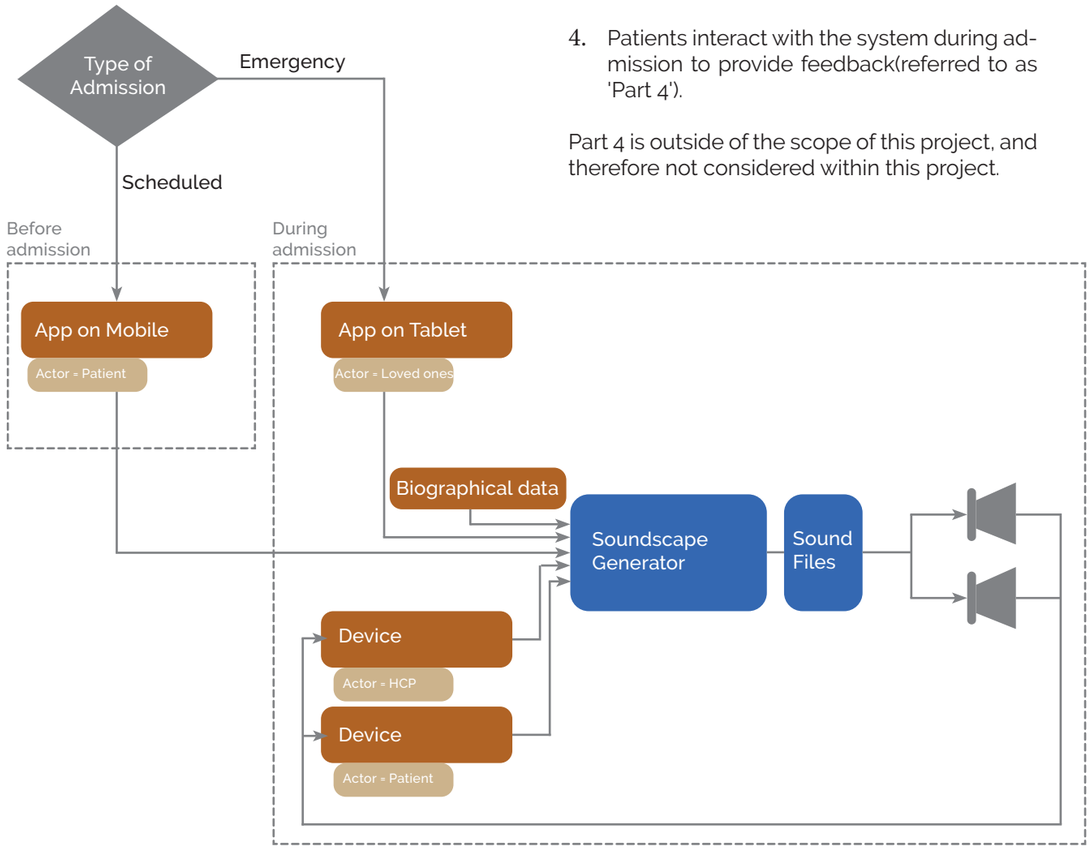


Figure 31: System architecture diagram which is used to define the most important interaction moments

According to the system architecture, four key interaction moments are derived:

1. Patients interact with the system before the admission if it is an elective-surgical admission (referred to as 'Part 1').

2. Loved ones interact with the system at the start of the admission if it is a medical (non-surgical) admission or an emergency-surgical admission (referred to as 'Part 2').

3. HCPs interact with the system during admission to provide feedback (referred to as 'Part 3').

4. Patients interact with the system during admission to provide feedback(referred to as 'Part 4').

Part 4 is outside of the scope of this project, and therefore not considered within this project.

7.1.3 PROTOTYPING

These interaction moments are used as a guideline to create the UI designs, starting with use cases (Appendix D.2). Creating use cases is a technique used in software development to capture the functional requirements of a system. It represents the interactions between users (actors) and the system itself to achieve specific goals (Interaction Design Foundation, 2024). These use cases are translated into Wireframes (Appendix D.3), used to create the UI designs.

As identified during the exploration of interaction moments, there is an opportunity to engage with the patients even before their admission. To facilitate this, the existing digital tools used by Erasmus MC were reviewed, leading to the selection of the Digizorg App. This App already provides patients with easy access to their medical data (Erasmus MC, 2024), making it a logical platform for further development.

The decision to integrate the concept into the Digizorg App, rather than developing a new one, was driven by several factors. First, the App is already embedded in the patient journey, minimizing the need for patients to learn a new system.

Additionally, the App's current interaction model aligns well with the envisioned design; it does not require immediate responses to patient inputs, which fits well with the intended use of the concept. Also, the App has the proper security mechanisms in place to make sure the patients' data is handled correctly.

To explore and refine the concept, several prototypes were created (Figure 32). These prototypes included digital screens through which users could navigate. The purpose of these prototypes was to test the viability of the concept and gather preliminary feedback from the key stakeholders. The prototyping process was iterative; initial prototypes were tested and refined based on feedback from peers, supervisors and key stakeholders, allowing the researcher for continuous improvement of the concept.

For a detailed explanation of the prototypes, see Appendix D.4. The usability tests with the SoundTool are explained in the next section, particularly focusing on the user experience and interaction patterns observed during the evaluation.

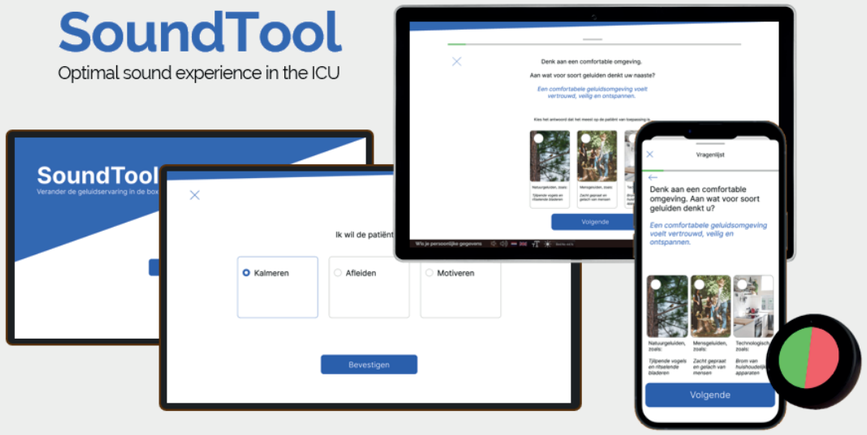


Figure 32: Overview of the concept created called SoundTool

7.2 USABILITY TESTS

This section focuses on the usability tests conducted with the concept shown in Section 7.1. It starts with the design questions we ask ourselves to create fitting usability tests. First, the usability test with the prototypes made for parts 1 and 2 is discussed. It is followed by the usability test with the prototypes made for part 3.

7.2.1 DESIGN QUESTIONS

Regarding the interaction moments presented in Section 7.1, two key principles arose: user engagement and user-friendliness. In line with these principles and the main design question introduced in Chapter 5, two specific design questions were developed. Both aim to provide insights that guide the creation of the final design.

The first sub-design question is as follows:
HOW DOES USER ENGAGEMENT VARY BETWEEN USING TEXT, VISUALS, AND A COMBINATION OF BOTH IN AN APPLICATION?

This sub-design question is addressed in Section 7.2.2.

The second sub-design question is as follows:
WHAT IS THE MOST EFFICIENT AND INTUITIVE WAY FOR HCPS TO INTERACT WITH THE SYSTEM?

This sub-design question is addressed in Section 7.2.3.

USABILITY TESTS ARE CONDUCTED TO GAIN FEEDBACK FROM REAL USERS, HELP UNCOVER BUGS, UNDERSTAND THE AUDIENCE, LEARN WHETHER THE PRODUCT WORKS AS EXPECTED AND TO SEE HOW USER-FRIENDLY THE PRODUCT IS.

7.2.2 USABILITY TEST PART 1 AND 2

A usability test is performed to find out whether user engagement varies between using text, visuals or a combination of both, according to sub-design question 1.

METHOD

Participants
8 students from TU Delft, recruited through the researcher's network, participated in the study.

Procedure
The usability test started with an introduction explaining the study's goal and encouraging participants to think out loud. After signing the consent form (Appendix E.1), participants answered pre-test questions about their identity, age, and profession. Then they interacted with three prototypes in a randomized order to avoid bias. The user scenario involved preparing for surgery and using an app to set sound preferences during admission.

Tools
Three prototypes designed in Figma were used (Figure 33):

- Prototype 1: Text-only
- Prototype 2: Visual-only
- Prototype 3: Combination of text and visuals

Questions
After interacting with the prototypes, participants answered the following:

1. How was your experience while completing the task?
2. What do you think of the user interface?
3. What do you think of the language used?
4. What do you think the app will do with your answers?
5. Where in the app do you expect to see the answers you have given?
6. Is there anything that would stop you from using the product?

Metrics
Participants completed a handout (Appendix E.1) rating prototypes on user expectations, motivations, ease of use, and comprehensibility, using Harris Profiles (Boeijen et al., 2021) on a scale from -2 (totally disagree) to +2 (totally agree).

Analysis
Responses from the handouts were analysed to determine which prototype showed the highest user engagement. Since part 2 is used in the same manner as part 1, the results of the prototypes of part 1 can directly be applied to part 2 as well. As a result, the prototypes from part 2 will not be included in this usability test.

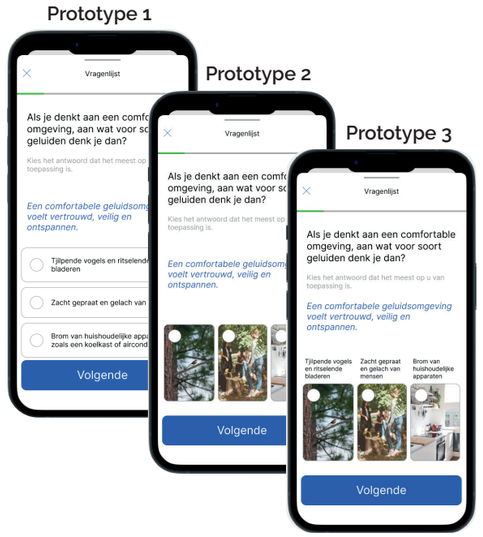


Figure 33: Prototypes used to conduct usability test with

RESULTS

The results of the Harris Profiles can be seen in Appendix E.2. Table 10 summarizes the findings by presenting the scores for the different criteria.

CRITERIA	PROTOTYPE		
	1	2	3
This product meets my expectations.	13	13	14
This product motivates me to complete the questionnaire.	-6	2	6
This product is easy to use.	10	8	13
This product is easy to understand.	7	1	15
Total	**24**	**24**	**48**

Table 10: Summary of results of the Harris Profiles

Next to the Harris Profiles, feedback from participants during interviews highlighted several areas for improvement:

- The goal of using the product should be more clear. We learned that this goal should be integrated into the introduction pages of the App.
- It was unclear how many questions were needed to fill in. Although this was attempted to visualize with the bar on top, extra indication is needed. This will also be integrated in the introduction pages of the App.
- The sound category should be visualized more clearly on top of the page because participants mentioned that they did not read this part.
- The options were not always enough for the participants to engage with. It is therefore suggested to make sure that the text and image should be proposed as an example of the sound category, rather than the option to choose.

Discussion

This usability test considered the usability of three different concepts to test which concept has the highest user engagement:

Prototype 1: Information presented textual
This concept showed moderate engagement. Participants who preferred detailed information appreciated the depth, but overall engagement levels were lower compared to the other concepts. Many participants mentioned that the information felt overwhelming and therefore they were not willing to read everything. They needed something to scan, leading to a lower average time spent on the information in the App.

- Strengths: Effective in conveying detailed information to users who prefer to read.
- Weaknesses: The lack of visual elements made the content less engaging. Although the text is written in B1 language, it could become overwhelming for people because they want to quickly grasp key points.

"THERE IS TOO MUCH TEXT ON THE PAGE, SO I DID NOT READ IT IN DETAIL."
Participant 2

Prototype 2: Information presented visually
This concept showed higher engagement levels compared to the text-only concept, with users spending more time interacting with the concept. However, while visuals were engaging and easy to navigate, participants imagined the context in the visual, rather than the sound. This could lead to misinterpretation.

- Strengths: Highly engaging for people who prefer quick, visual information. The concept was effective in capturing attention.
- Weaknesses; Some users expressed frustration with the lack of accompanying text to provide additional context, which could lead to misunderstandings.

"THIS ONE IS MORE ABOUT THE ENVIRONMENT THAN IT IS ABOUT THE SOUNDS."
Participant 4

Prototype 3: Combination of text and visuals
This concept, which combined text and visuals, ranked highest in user engagement according to the Harris Profiles. Users found this concept the most intuitive because they could quickly grasp key points through visuals while gaining more information through the text.

- Strengths: Participants reported higher satisfaction and overall engagement.
- Weaknesses: This concept could provide information overload, which was expressed by some participants.

"AH, NOW IT'S THERE! YES, THIS COMBINATION MAKES IT MUCH CLEARER."
Participant 3

During the session, several participants asked "What kind of sounds are related to this?", indicating that they needed sound examples. Given the weakness of concept 3 (information overload), a potential solution is to integrate actual sound examples, offering a better user flow through the questions. This is in line with a study performed by Özcan & Egmond (2009), supporting the idea that providing actual sound examples, rather than just descriptions or visual symbols, can help prevent information overload and ensure that users have a clear understanding of the sounds related to a product. Additionally, Mayer's (2009) research suggests that people learn more effectively when information is presented through multiple sensory modalities (e.g., visual, auditory) rather than a single one. By providing sound examples along with textual and visual information, a better understanding of the differences between the options in the questionnaire can be achieved.

Conclusion

As a result of the usability test, concept 3 was ranked higher than the other concepts: it provides users with multiple entry points into the content, making it accessible and engaging for different users. In addition, the integration of both text and visuals created a more user-friendly experience, which was reflected in the higher usability scores. Users felt that they could better understand and retain information, which is crucial for patient engagement before admission and loved one engagement at the start of the admission. They expressed the need for sound examples, which is recommended as it can increase user engagement. These outcomes were in line with the literature. Therefore, it could be concluded that concept 3 results in higher user engagement, which will be the guideline for creating the final design.

7.2.3 USABILITY TEST PART 3

A usability test is performed to find out which way HCPs should interact with the system that is most effective and intuitive for them, according to sub-design question 2.

Method

- **Participants**: 6 HCPs at EMC and 4 HCPs at FG were recruited. All of them are working as ICU nurses for at least 5 years.

- **Procedure**: The usability test started with an introduction explaining the study's goal and encouraging participants to think out loud. After signing the consent form (Appendix E.1), participants answered pre-test questions about their identity and profession. Then they interacted with two prototypes in a randomized order to avoid bias. The user scenario involved interacting with a digital device to adjust the sound environment in the ICU to reassure the patient during a blood draw.

- **Tools**: Two prototypes designed in Figma were used (Figure 34):
  - Prototype 1: Focused on the desired behaviour of the patient
  - Prototype 2: Focused on the intended event happening in the ICU room

- **Questions**: After interacting with the prototypes, participants answered the following:

1. How was your experience while completing the task?
2. Would this product fit your workflow? If not, what would you want to have changed?
3. What do you think of the location of the product?
4. Is there anything that would stop you from using this product?
5. On a scale of 1-5, how mentally demanding was the task?

- **Metrics**: Participants from EMC completed a similar handout as in the previous test rating prototypes on user expectations, motivations, ease of use, and comprehensibility, using Harris Profiles (Boeijen et al., 2021) on a scale from -2 (totally disagree) to +2 (totally agree). The participants from FG underwent the same usability tests as those in EMC but answered additional questions during the interview (Appendix E.3) and did not complete the Harris Profiles.

- **Analysis**: Responses from the handouts were analyzed to determine which prototype was considered as most intuitive for HCPs.

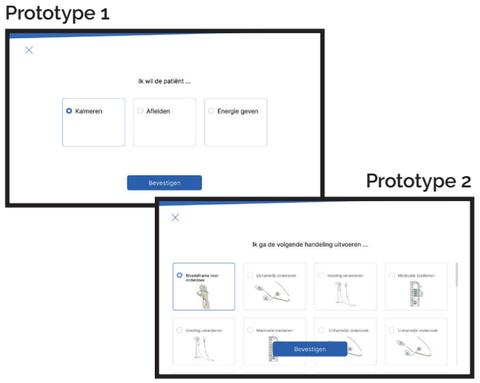


Figure 34: Prototypes used to conduct usability test with

Results

The results of the Harris Profiles can be seen in Appendix E.2. Table 11 summarizes the findings by presenting the scores for the different criteria.

Criteria	Prototype	
	1	**2**
This product fits well with the way I work.	9	2
This product motivates me to personalise the sound experience.	11	-3
This product is easy to use.	11	1
This product is easy to understand.	12	7
Total	**43**	**7**

Table 11: Summary of results of the Harris Profiles

Next to the Harris Profiles, feedback from participants during interviews highlighted several areas for improvement:

- For the first prototype, "calming" and "distracting" are important aspects. However, "energizing" is not the right term; "stimulating" or "motivating" would better capture the intended goal.
- The visibility of important features (buttons) needs to be improved to ensure they are easily noticed and understood.

Discussion

This usability test considered the usability of two different concepts to test which interaction is most intuitive for HCPs.

Prototype 1: Focused on the desired behaviour of the patient

This concept showed high engagement, reflected in the Harris Profile as well as the interview outcomes. This concept aligns well with the expectations of HCPs, who are accustomed to focusing on patient behaviour. Based on this behaviour, they decide what their next step will be. Regarding the user interface, it is suggested to replace the term 'energize' with 'stimulate', as this terminology is more familiar to HCPs in their daily practice; They indicated that terms like 'motivate' or 'stimulate' are more commonly used in contexts such as physiotherapy compared to 'energize'.

It is important to consider the frequency of use, as this is a learning process. The HCPs saw value in integrating this concept into their workflow, but further research is needed to determine if the frequency of use is optimal in the current form. Additionally, feedback from HCPs suggested that the location of the digital design should be adjusted; from outside the box to inside the box. HCPs noted that when they are inside the box, they are in a better position to observe and make decisions about their approach, as they can see more details than from outside the box. This adjustment would also enhance the usability of the device, as patient behaviour can change when HCPs are physically present in the box.

- Strengths: This concept aligns well with HCPs' focus on patient behaviour. The participants recognized the value of this device into their workflow.
- Weaknesses: The frequency of use needs further evaluation. While participants saw potential value, there is a need for additional research to determine if the current frequency of interactions is optimal for integration in the HCP workflow.

"THEY ARE VERY SHORT, CLEAR ASSIGNMENTS. "
Participant 2

Prototype 2: Focused on the intended event happening in the ICU room

This concept showed low engagement, reflected in the Harris Profile as well as the interview outcomes. One of the primary issues identified was the lack of personalization in the system. HCPs expressed concerns that the system did not account for the individual patients. They noted that, as they know their patients best, they were sceptical about how the system could accurately assess and address varying patient reactions to different procedures. This lack of personalization led to a general distrust in the system's ability to make appropriate judgements, which could hinder its adoption and use in real practice.

Another concern was the overwhelming number of options presented by the prototype. Participants reported feeling confused by the excessive choices available. The list was considered as incomplete, making it impractical for HCPs who would face delays while searching for the right options before entering the box. The combination of frequent interactions and the high amount of options was seen as a burden, despite participants knowing that they would eventually became more accustomed to the system. Moreover, the high amount of small tasks required in the box made it challenging for HCPs to operate effectively. This operational difficulty makes it a concept the HCPs would not use.

- Strengths: The structured focus on specific events could, in theory, provide a framework for managing patient care scenarios. However, this strength was not enough to overcome the concept's limitations.
- Weaknesses; The primary weakness is the lack of personalization; HCPs expressed concerns that the system did not consider the individual differences between patients, which is crucial in the ICU where personalized care is essential. In addition, the high amount of options is considered as a weakness, making the concept less intuitive.

"I AM TOO DISTRACTED BY THE ICONS, TOO MANY OPTIONS. I WANT TO DECIDE WHY I TURN ON SOUNDS. I KNOW THE PATIENT, NOT THE COMPUTER."
Participant 6

Conclusion

As a result of the usability test, concept 1 was considered as more intuitive for HCPs. The HCPs expressed higher engagement with this concept, as evidenced by the Harris Profile scores and participant feedback. The primary strength of concept 1 is that it aligns with the workflow of HCPs, which focuses on patient behaviour. Therefore, this concept addresses the needs of the HCPs, which is crucial for successful adoption and integration into routine use.

In contrast, concept 2 faced several challenges related to personalization, complexity and usability. These issues contributed to a lower level of engagement and acceptance among HCPs, highlighting the need for a more intuitive and personalized approach.

Given these findings, concept 1 was chosen as the preferred design due to its ability to meet user expectations, its ease of use, and its potential to integrate in the workflow of HCPs. Future iterations will build on the strengths of this concept.

7.3 BRAND IDENTITY

This section focuses on the brand identity of the final design.

7.3.1 BRAND IDENTITY

Following the usability tests, valuable insights were gathered that informed the refinement of the concept. These tests highlighted the need for a cohesive brand identity that resonates with both patients, loved ones and HCPs, ensuring that the concept is not only functional but also engaging. Therefore, a new brand identity had to be developed, focusing on the Information Architecture of the concept (user, content and context, see Section 7.1.2). Appendix F shows several iterations.

This new identity will be reflected in all aspects of the product's design, from the user interfaces to the tone of communication. The goal is to create a consistent and positive experience for the users.

AMADÉ
AANGENAAM LUISTEREN

Amadé
The design of the Soundscape Augmentation System will be 'Amadé - Aangenaam Luisteren'. The name 'Amadé' comes from Wolfgang Amadeus Mozart, a sound composer in many genres. The name reflects the brand's vision of creating impactful soundscapes. It emphasizes that the system is not primarily about music but combining various sounds into a composition.

Brand Promise
Amadé's reason for being is to enhance well-being of patients in healthcare settings by providing personalized soundscapes, tailored to individual needs. It promises to reduce stress and improve comfort of patients by delivering personalized soundscapes.

Brand Values
Empathy
Amadé understands and responds to the needs of patients, loved ones and HCPs.
Innovation
Amadé uses advanced technology for the well-being of patients.
Reliable
Amadé ensures effective performance in healthcare settings.

Brand Personality
Amadé aligns with sincerity, which means that the brand resonates deeply with their consumers and it is being perceived as honest, genuine and dependable (Sung & Kim, 2010). This personality trait aims to create a strong emotional connection with users, which is crucial for building long-term relationships and maintaining user loyalty in healthcare.

This brand personality is being translated into a colour palette and visual attributes, used to create the UIs. This colour palette, the rounded friendly font and edges and the feedback mechanism evokes feelings of comfort and trust, responding to the users' intuition.

7.3.2 TONE OF VOICE

The tone of voice is a critical aspect of the brand identity that shapes how users perceive and interact with the system. For Amadé, the overall tone of voice is designed to be sincere, supportive and accessible, ensuring that all communications are aligned with the brand's promise to improve patient comfort. The following part outlines how the tone of voice is applied to the four different parts of the system:

1. Patients, before admission
When communicating with patients, the tone of voice is reassuring and informative, aiming to make users feel comfortble and well-prepared. The language used is calm and supportive, which helps to alleviate any anxiety or uncertainty they may have. Example: "We are here to help you feel comfortable and prepared".

2. Loved ones, start of admission
For the loved ones of patients, the tone of voice is empathetic, gentle and supportive, recognizing the emotional challenges that they may be facing. The language is compassionate and understanging, offering comfort while encouraging their participation in patient's care. Example: "We understand this is a difficult time. Your input will help".

3. HCPs, during admission
When addressing HCPs, the tone of voice is professional, clear and responsive. The language is precise and direct, ensuring that the critical infromation is communicated effectively. This approach respects their expertise.

4. Patients, during admission
Regarding patients, the tone of voice should be empowering and supportive. This ensures the feeling that they are being cared for as they navigate they navigate the complexities of the admission process.

With the brand identity now established, the final design will be proposed in the next chapter, incorporating the feedback from the usability tests and aligning with the newly defined brand vision.

FINAL DESIGN

This chapter presents the final design of Amadé. It is an iterated concept based on the insights gained from the research and design phases. It is presented through its key functionalities, storyboard and user interfaces. An evaluation test is conducted with ex-ICU patients, which is described in detail.

8.

8.1 THE SOUNDSCAPE AUGMENTATION SYSTEM

Amadé is a soundscape augmentation system for patients in the Adult ICU that aims to reduce stress and improve the comfort of patients during admission. This section presents Amadé through three key functionalities, followed by an explanation of the hardware and software components.

8.1.1 KEY FUNCTIONALITIES

Personalized soundscapes

Based on input from the patients, loved ones and HCPs, Amadé creates personalized soundscapes tailored to patient needs. Sound preferences are gathered through initial questionnaires covering the categories of nature, human and technological sounds. The soundscape generator customizes the soundscape based on these preferences and adapts it in real-time, integrating feedback from patients and HCPs. Patients are empowered by giving them the final responsibility and decision-making in their hands regarding their sound environment.

Adaptive sound management

Amadé dynamically adjusts the sound levels and content, based on the patient's sound preferences. This includes lowering the volume during critical procedures, enhancing certain sounds to help relaxation and including eventfulness in the sound composition to distract the patient from the current situation. The system is responsive and continuously adapts to changes in the patient's environment and needs.

Integration and control of HCP

Amadé is seamlessly integrated into the ICU workflow, allowing HCPs to easily control and adjust the soundscape. Based on their requirement of the desired behaviour of the patient, the system modifies the sound environment. Their insights into the patient's condition are of great value, making their input a key functionality. This integration ensures that soundscapes are both supportive and aligned with the patient's clinical needs.

8.1.2 HARDWARE COMPONENTS

The technological implementation of the soundscape generator requires a seamless integration of both hardware and software components. On the hardware side, the system uses high-fidelity speakers to deliver a personalized soundscape. We do not want to confuse the patient or direct their attention in a specific direction. Therefore, the speakers will be placed close to the patient's head. It is chosen to attach the speakers to the DIN rail of the Dräger ceiling care system (Figure 35). Through this attachment, the speakers are not disrupting the care environment. Next to that, power outlets are required, which are available at the back of the Dräger ceiling care system. These speakers are placed on both sides of the head to ensure an immersive and controlled auditory experience. It is chosen to not use directional speakers as it can be of value for loved ones to also experience the generated soundscapes. For wireless and secure communication between the soundscape generator and the speakers, Wi-Fi is needed.

Figure 35: Dräger ceiling care system at EMC

As learned from Van Houwelingen (2022), the requirements for the speakers in the ICU include that they do not have batteries and should be powered by sockets. The selected speakers are the Sonos One SL Duo Pack White (2x) because these speakers can connect over Wi-Fi, are powered by sockets and a hanging system is available (Figure 36).

Figure 36: Sonos One SL Duo Pack White (photo by Sonos)

8.1.3 SOFTWARE COMPONENTS

The software architecture is even more important, involving advanced algorithms for real-time sound modulation and adaptive sound management. The system runs on a secure server platform, connecting to external sound databases. No existing patient management systems are required, which helps to reduce integration complexity and minimise disruptions to the current workflow. Furthermore, incorporating biographical data of the patient is avoided because accurately estimating a patient's stress level is highly complex. This complexity makes it challenging for the system to reliably interpret and respond to individual patient needs, potentially leading to inaccurate or ineffective outcomes. Therefore, the system focuses on real-time data and events rather than relying on detailed biographical data. This allows the soundscape generator to access an extensive library of sounds while not intruding on the patient management system.

Depending on the system's requirements and the context in which it will be used, multiple architectural styles can be considered for software development (Appendix G). The best applicable architectural style for the software of the soundscape generator is event-based architecture. This style defines application data as a stream of events. These events are changes in states, which is triggered when a user takes an action. The advantage of an event-based architecture is its ability to ignore non-critical events (IBM Developer, n.d.), which is particularly beneficial in an ICU environment where continuous activity takes place. In addition, this architecture is well-suited for this environment, where real-time responsiveness and scalability are important.

Components

Event-driven architecture typically consists of four components:

1. Event
The event is the significant change in the state of an object that occurs when users or system components take action. Within our system, events could include changes in patient sound preferences, environmental conditions or input from HCPs.

2. Event handler
The event handler is a software routine, which handles the occurrence of an event.

3. Event loop
The event loop controls the interaction flow between an event and the event handler, ensuring that events are processed in the correct sequence and timing.

4. Event flow layers
The event flow layer is built on three layers; Event producer, Event consumer, and Event channel (also called Event bus).

- Event Producer: responsible for detecting and generating events. In our system, event producers are:
  - Patient sound preferences
  - Environmental sensors monitoring the ICU environment
  - HCP input based on patient needs and clinical decisions

- Event Consumer: Responsible for consuming the events produced by the event producers. In our system, the primary event consumer is the soundscape generator, which adjusts the sound environment based on the incoming events. For example, it may lower the volume in response to an emergency or increase the volume when additional HCPs enter the room for consultations.

- Event channel: transfers events from the event generator to the event consumer. It acts as the communication pathway, ensuring that events are delivered efficiently and in real time.

8.1.4 IMPLEMENTATION

The generator operates by combining nature sounds, human sounds and technological sounds and adjusting them in real-time according to the patient's condition and preferences. The implementation of the system is explained through the use of an equation, incorporated in a visualisation of the system.

The Equation

Consider a soundscape S_0 and sound files M_n that serve as 'masks'. These masks can be added to the soundscape. By combining S_0 with for example M_1, S_1 is created. This new soundscape is the result of the system in the real-world environment. But now we still miss the subjective metrics in the equation. Therefore, the mask is multiplied by Q, which adds the perceptual metric to the equation. Finding the optimal mask M by incorporating the individual preferences Q_x (x represents a user of the system) and real-time response of HCPs (H_x) and patients (P_x), creates a new soundscape that might be perceived better.

$$S_n = S_0 + M_n Q_x H_x P_x$$

S_n = Augmented Soundscape
S_0 = Current Soundscape
M_n = Mask
Q_x = Input from the questionnaire
H_x = Input from HCPs
P_x = Input from Patients

The outcomes of the input of the patients or loved ones Q_x are directly linked to the soundscape generator: The distribution of preference for nature, human and technological sounds for the different sonic ambience types (comfortable, pleasurable, motivational and stimulation) results in a combination of sound files, tailored to patient preferences.

The HCPs have been designated to provide feedback in real-time. They are given the options 'Calm down', 'Distract' and 'Motivate'. The first option relates to the comfortable and pleasurable types. The second option uses an increase in eventfulness in the soundscape. This way, patients are calmed down but distracted from the current situation. The third option relates to the types motivation and stimulation.

HCP options to choose:

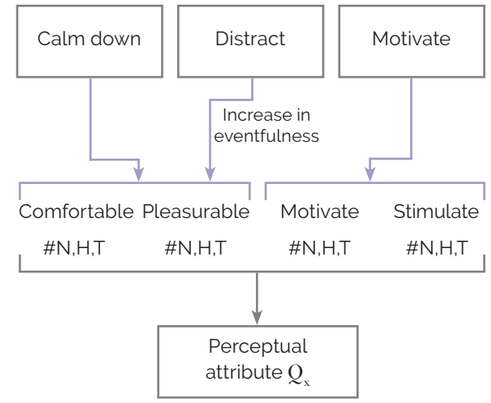


Figure 37: The construction of different components

Figure 37 shows how these options relate to the sonic ambience types and are used to create the perceptual attribute Q_x. Using a similar approach in part 4 of the system is recommended.

Schematic Visualisation

Figure 38 shows a schematic visualisation of the soundscape augmentation system, focusing on how to best implement the event-driven architecture in the system.

It includes a data acquisition system that is responsible for providing ambient soundscape data, i.e. the sound pressure levels in the ICU environment. These sounds are coming from the acoustic environment. The system makes use of a database of sound files that are used as maskers for the soundscape. These sound files are based on nature, human and technological sounds, from which the perceptual metric is taken via the questionnaires. The mask figuration system filters not only the right sound files, but also includes volume levels, amplitudes and frequency. Next to that, the data acquisition system makes use of contextual data (i.e. timing of shift changes of HCPs).

Given the data from all actors, the ambient soundscape data and contextual data, the soundscape generator generates an augmented soundscape. This is converted into sound files, which are then transmitted to the speakers. Feedback loops are shown as both HCPs and patients can provide real-time feedback. This feedback is then used to generate a new soundscape based on these new events and data.

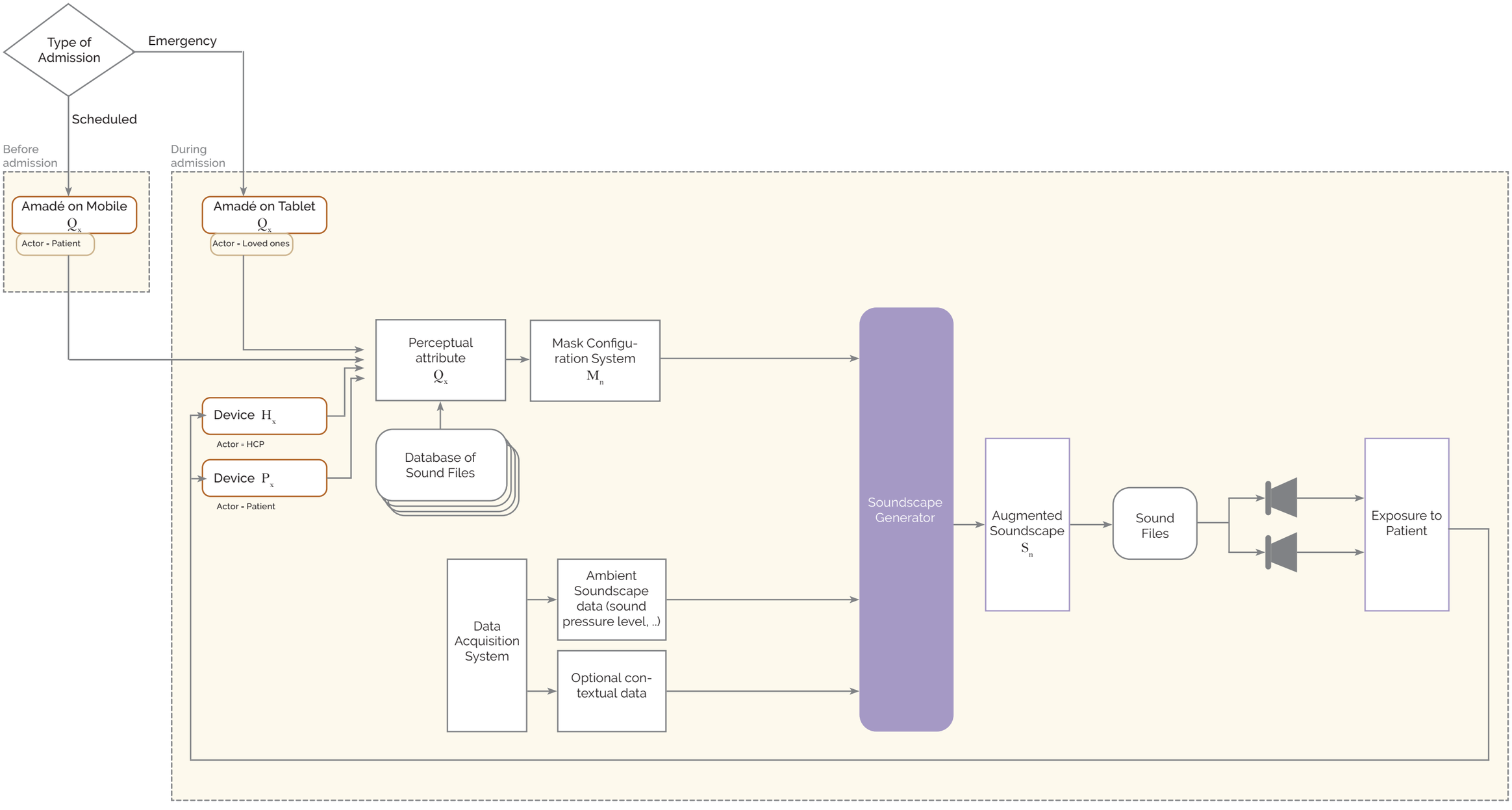


Figure 38: Overview of the Soundscape system with its input and output

8.2 STORYBOARD

Creating storyboards is a valuable tool that not only helps the designer to get a grip on target groups, context, product use and timing, but also in communicating about these aspects (Van der Lelie, 2005). This section shows the storyboard of Amadé (Figure 39).

The different parts of the system, as explained in Section 7.1.2, are visualised using the following colours:
Part 1 -
Part 2 -
Part 3 -
Part 4 -

Please scan the following QR-code for a video of Amadé:

Figure 39: Storyboard of the system

SCHEDULED ADMISSION

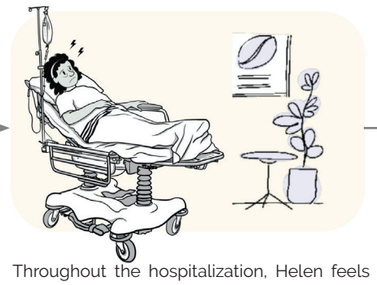
Helen plans her surgery. She is aware of the fact that she needs to spend a couple of days in the ICU to be monitored closely to detect any complications quickly.

She finds it stressful and wants to prepare well. The doctor advised her to enter her sound preferences in the Amadé app, which is linked to the ICU environment.

EMERGENCY ADMISSION

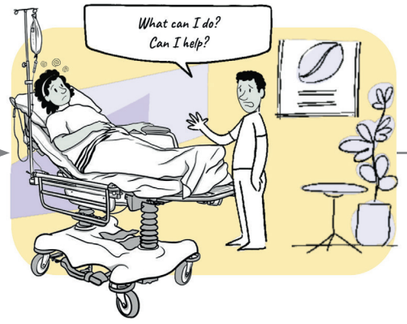
Helen has had a car accident. Due to multi-organ failure, she is urgently taken to the hospital.

Helen is hospitalized. She is admitted to the ICU for continuous monitoring and pain relief.

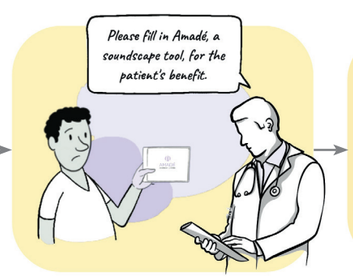


Throughout the hospitalization, Helen feels stressed due to the unfamiliar environment, unwanted sounds and a lack of stimulation.

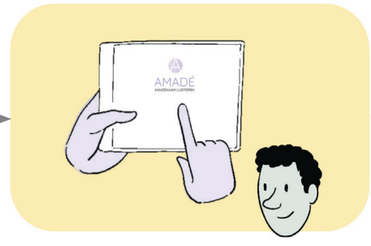
Helen is in a state of delirium; a period of confusion. She lost track of where she is and which day it is. She has hallucinations; seeing and hearing things that others do not perceive.



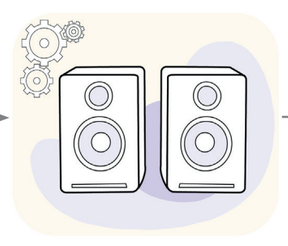
Frank, Helen's husband, comes over to visit her. He notices that his wife is very confused and does not recognise him. He feels helpless.



The ICU nurse tells Frank that he can help his loved one by entering her sound preferences into the Amadé app.



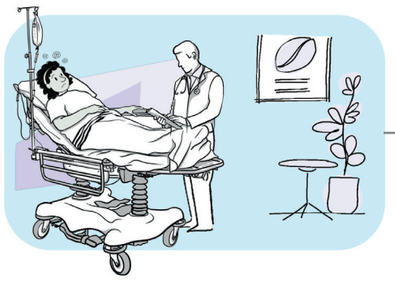
The questionnaire makes Frank feel useful in a situation where he cannot do much. It will not take long as he rather spends time with his wife.



The system uses the input from the patient/loved one to create the right fit for the personalized soundscape. Two speakers next to the bed are used to expose the patient to the new soundscape.

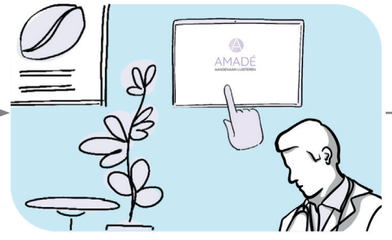
The system exposes Helen to a personalized soundscape, based on either her own entered sound preferences (before admission) or the estimated sound preferences (at the start of admission).

The sounds distract Helen from the current situation and let her mind wonder. It makes her hospital stay more comfortable as her stress level is reduced.



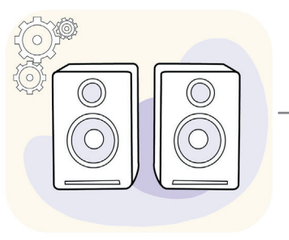
The ICU nurse Jason visits Helen. He is going to drain her lungs. He knows this is uncomfortable for most of the patients and so is keen to distract her.

He decides to change the soundscape, aligning patient's needs with clinical needs.



Jason uses the Amadé device in the box to change the soundscape. He chooses 'distract the patient'.

Whenever Helen wants to change the soundscape, she can enter her preferences in Amadé.



The system uses the input from the HCP and the patient to create the right fit for the new soundscape.

Although Helen still experiences stress due to the uncertain future, Amadé makes her feel more comfortable throughout her stay.

8.3 USER INTERFACES

This section presents the user interfaces (UI) created for Amadé. It starts with an overview of all parts and is followed by the UIs in detail.

8.3.1 OVERVIEW OF USER INTERFACES

An overview of all UIs of Amadé is presented in Figure 40. They are all designed with a focus on the right tone of voice, as explained in Section 7.3.2.

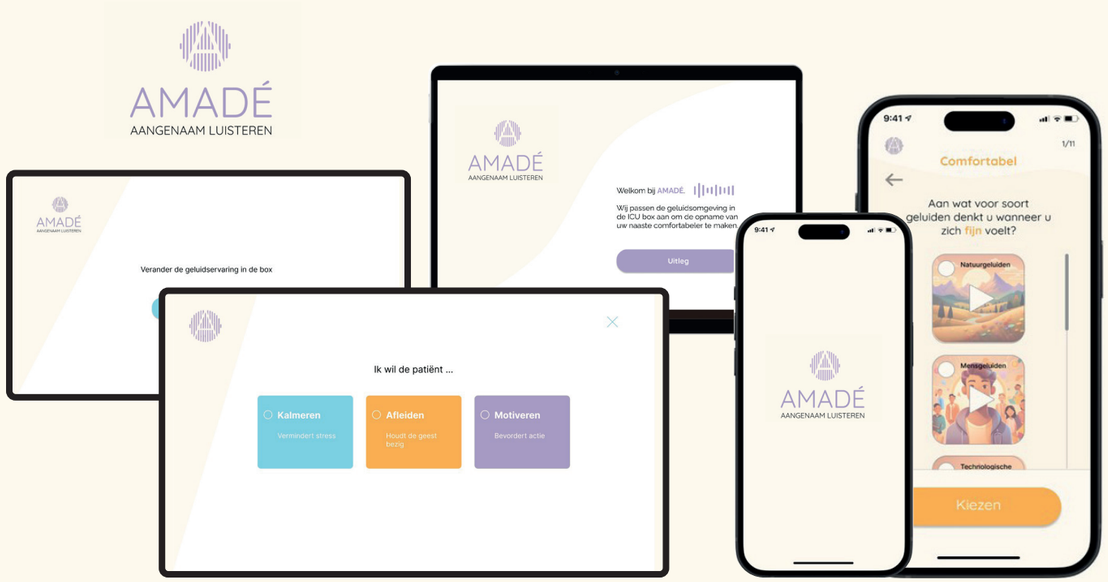


Figure 40: Overview of the user interfaces

8.3.2 PART 1

Actors: Patient, Amadé app on mobile.
Purpose: To communicate their sound preferences as input for the system.

The app starts with welcoming screens, followed by an explanation of the goal of Amadé. The user flows through 11 screens with questions regarding the four sonic ambience types. It ends with a confirmation screen.

8.3.3 PART 2

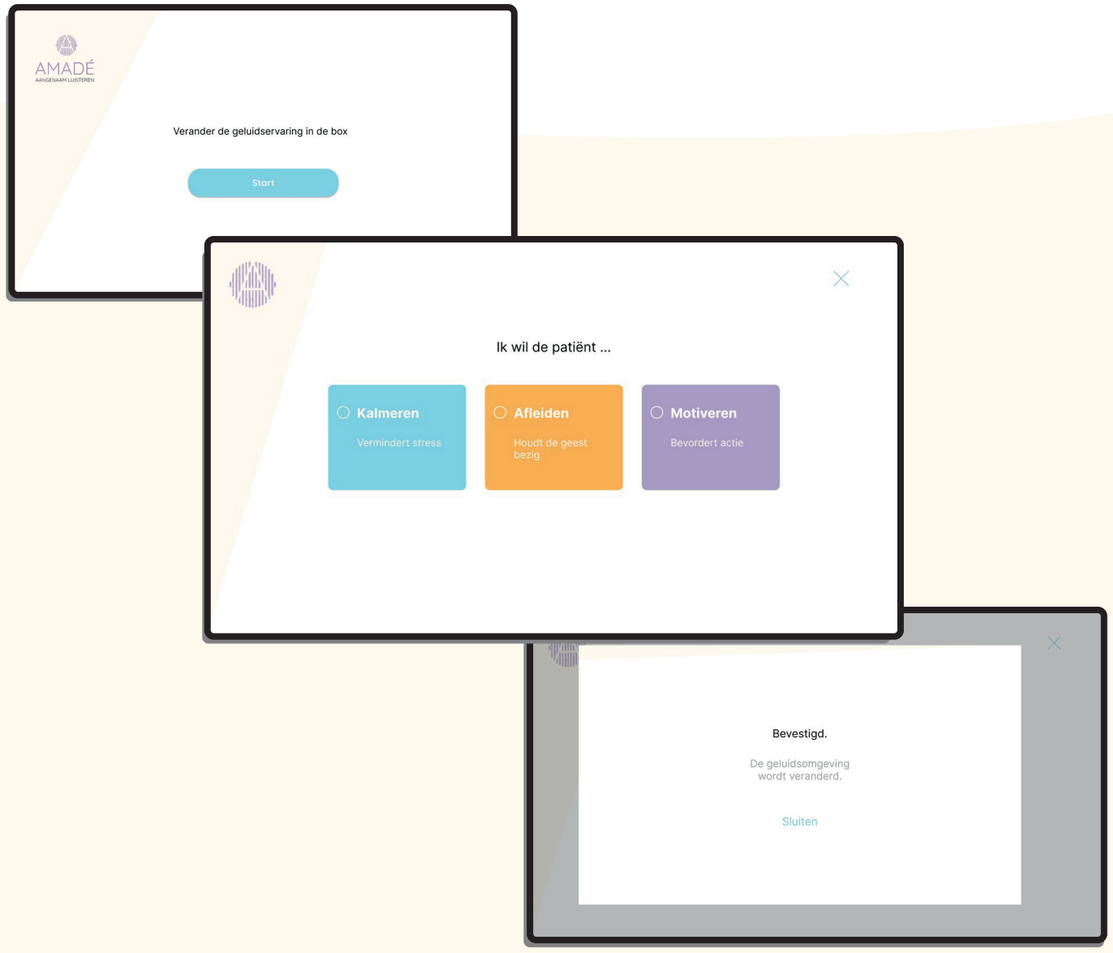
Actors: Loved ones, Amadé app on tablet.
Purpose: To communicate the sound preferences of patients as input for the system.

This user flow starts in the already existing interface of the tablet in the ICU. After an introduction regarding the goal and the questions, the user enters their sound preferences.

8.3.4 PART 3

Actors: HCPs, Amadé app on device in the box.
Purpose: To change the soundscape in the box, based on desired behaviour of the patient.

This user flow is kept short; with only two clicks, you completed the whole flow.



8.4 EVALUATION

This section provides the evaluation test to assess whether the system's design has met the design goal.

8.4.1 GOAL

The goal of the evaluation test was to assess whether the design solution has met the design goal (including desired interactions). Therefore, the following research question should be answered through user testing:

How does the concept help fulfil the unfulfilled psychological needs of critically ill patients?

The following desired interaction qualities (Chapter 5) were used as metrics to evaluate the desired interaction with the design:

- Spontaneous
- Relief
- Helpful

8.4.2 METHOD

Participants
Five ex-ICU patients, recruited through the network of the researcher and the supervisors, participated in the study. Ex-ICU patients were targeted because they were the ones that could empathize most with the target group. Recruiting patients in the ICU was not possible due to ethical constraints.

Procedure
The evaluation test included the following four phases:

1. Interview questions regarding the ICU stay, related to their sound perception in the ICU.
2. Use case to interact with Amadé.
3. Qualitative data: Interview questions regarding their experience with Amadé.
4. Quantitative data: Questionaire to conclude, focusing on the experience with Amadé.

A script was used to guide participants through the test to ensure that instructions were the same for every participant (Appendix H). Four out of five participants successfully interacted with the online prototype, leading us to skip part 2 for one of the participants.

Tools
The Amadé app was created in Figma and used to conduct the online evaluation test.

Data collection
Several techiques were used to collect data during the user test: thinking out loud, interviews and observations were used to collect qualitative data. AttrakDiff was used to collect quantitative data (AttrakDiff, n.d.). AtrakDiff is a standardized test, aiming to evaluate the user experience of an interface.

8.4.3 RESULTS

To create an overview of the test results, qualitative data such as notes of thinking out loud and interviews were clustered into a Plus-Minus-Interesting table. The quantitative data was plotted in a diagram.

Qualitative data
Figure 41 shows a table with the most important results of the qualitative research.

	Plus	Minus	Interesting
Participant 1	It is very good that Amadé has a preoperative focus.	It depends a lot on the context. For example, if it is an operation that involves a lot of emotions because you might have cancer, then this feels more like something you have to do, instead of helping you.	Music therapy has a biochemical effect; neurotransmitters are released.
Participant 2	I was not informed beforehand about the sound environment in the ICU, which I think could have been helpful during admission.	The sound intensity was way higher than expected, so it is very important to take that into account.	I was most disturbed by the conversations between the HCPs in the room.
Participant 3	I am not someone who complains often. I did not dare to ask for different sounds, because I did not want to bother them. Amadé could definitely help with that.	It is technically difficult to determine how the four sound categories will combine in the soundscape.	As no explanation about the sounds in the ICU had been given, I was startled by every alarm. Explanations beforehand could have helped.
Participant 4	I can definitely see the benefits of Amadé.	If you do not know the situation before, it is difficult to assess the new information through Amadé.	I was completely unprepared for the sound environment in the ICU. I often asked what each sound meant, bothering the HCPs.
Participant 5	New sounds, such as music, have helped me bring back good memories. I think that is why Amadé could have helped me.	It has to be explained verbally because the purpose is not quite clear to me yet.	I miss an overview of the different sound categories on the initial screens.

Figure 41: Overview of the most interesting quotes of the qualitative research

Quantitative data
The AttrakDiff test is used to evaluate how the ex-ICU patients perceive the interfaces (Figure 42). It allows a researcher to judge the hedonic and pragmatic qualities of a digital interface;

- Pragmatic usability; usability of the product
- Hedonic-stimulation usability; stimulation generated by the system
- Hedonic-identification usability; identification of the user with the system
- Overall attractiveness

It is chosen to reduce the completion of the test, by using 10 items instead of 28. This shorter version still covers the four important qualities.

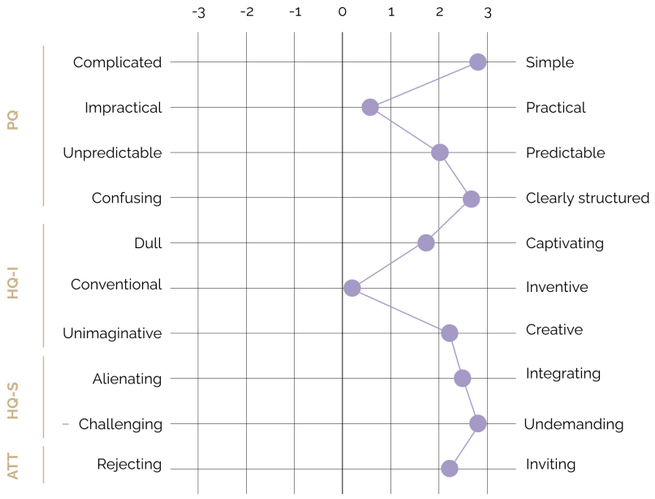


Figure 42: Overview of the outcomes of the quantitative data

8.4.4 DISCUSSION

4 out of 5 ex-ICU patients who participated in the evaluation test, successfully interacted with the Amadé. This allowed us to analyse their experiences, both qualitative and quantitative. The one participant who could not interact with the prototype faced technical challenges, highlighting a potential issue in future accessibility.

The primary goal of this evaluation was to assess the usability and user experience of Amadé from an ex-ICU patient perspective. They could empathize with the ICU target group. Overall, the study achieved its goal, as participants provided valuable insights into their sound perception in the ICU environment and their experience with Amadé. The AttrakDiff results indicated a positive user experience, while qualitative interviews highlighted a clear need for patients to have an overview of the current sounds in the ICU environment, which could better prepare them for their stay.

From the qualitative analysis, several common themes were found; First of all, all participants mentioned that they were unprepared for the sounds they encountered in the ICU. All of them mentioned that they would benefit from it, especially when being prepared for the non-critical alarms that still go off. Three out of five participants mentioned they would have appreciated sounds that could distract them from their current situation. Notably, one participant mentioned that music therapy has a biochemical effect, leading to physical improvement in recovery. Future research should explore whether an augmented soundscape with our conceptual framework could have similar benefits.

Interacting with the app also provided insights into how sound preferences could be entered into the app. Participants mentioned that they thought the questions were quite similar, but they were not bothered by them. One participant mentioned that he would have liked to know which sound categories are present in the app so that he could estimate how far he would be.

The quantitative data revealed several insights; Overall, Amadé was perceived positively, with high scores for simplicity, structure and challenge. Interestingly, Amadé was evaluated as neither conventional nor inventive, which could have been related to the fact that the app does not provide information on the current alarms yet. Furthermore, Amadé was rated low in practicality, likely since the effectiveness of Amadé in real settings has not been demonstrated yet. Some participants expressed a strong interest in knowing whether its benefits had already been proven, reflecting their interest to see its effect in practice. This positive curiosity indicates that participants were not only open to the app but also keen to understand how it improves the ICU environment.

A limitation of the study was the small sample size, with only five participants, which restricts the generalizability of the findings. Furthermore, one participant's inability to interact with the online prototype points out a need for clear instructions on how to interact with the system. Given the strong emphasis on sound perception in the ICU, future iterations of Amadé could benefit from an overview of the current soundscape in the ICU.

The results of the evaluation test align with previous studies that highlighted the overwhelming sensory experience in the ICU. This evaluation test showed that preparing patients for the ICU soundscape and offering real-time modifications could be beneficial. However, unlike earlier studies that focus mostly on clinical interventions, such as changing clinical things that have to be done, this study suggests that a human-centered approach like Amadé could offer a better environment, tailored to patient needs.

8.4.5 CONCLUSION

To conclude, the evaluation test of Amadé with ex-ICU patients has provided meaningful insights for future iterations of the app. The concept helps fulfil the psychological needs of patients by making them feel more prepared, relaxing, distracting or stimulating them in the environment and giving them the power to decide on what they want to hear. The interaction qualities were mentioned throughout the evaluation test, which indicates that the right interaction with the system is established.

Recommendations for the Amadé app
Based on the outcomes of both qualitative and quantitative data, the following adjustments to the app are recommended:

- There should be an overview of the current soundscape in the ICU, including examples of the sounds present. This will better prepare the patient for their admission and enhance their understanding of the Amadé concept, fostering greater trust in the system.
- It would be helpful to display an overview of the different question categories alongside the number of questions beforehand. This will allow users to navigate through the list more easily, as they will have a clearer idea of which questions and how many are still to come.
- The questions in the 'comfortable' category seemed too similar to each other. Since these appear at the beginning of the questionnaire, this could confuse the user.

FUTURE VISION

This chapter describes the overall conclusion of the project by presenting final recommendations and a reflection on the project. Additionally, the relevance of the project is discussed.

9.

9.1 VALIDATION OF AMADÉ

This section evaluates the final design based on three criteria for success; feasibility, desirability and viability of the design.

Feasibility

Feasibility is the possibility that something can be made, done or achieved, or is reasonable (Cambridge, 2090). For Amadé to be feasible, it must integrate seamlessly into the existing ICU workflow, requiring minimal disruption of the current workflow. HCPs need to be aware of the benefits of the system so that they are willing to engage with it. The interactions of HCPs with the UIs of the system have therefore been minimized to ensure that they are willing to use it.

Regarding the hardware and software components, implementation of Amadé is considered feasible, but only if it meets specific requirements; it must not obstruct other equipment (hence it is connected to the DIN Dräger rail), it must be easy to clean (aligning with existing policies on cleaning non medical devices in the ICU), and it must be cost-effective (not integrating with existing ICU systems contributes to this).

However, we are cautious about how sound preferences are currently collected. While the questionnaire from this thesis provides a clear structure, future research is needed to determine if other approaches may be more effective. The system must ensure that the questionnaire is not too long, as users prefer a shorter process due to many other preparations required before and during admission. One participant noted, "I would use the product to prepare myself, but only if it is of this length or shorter". Despite these considerations, the overall evaluation of Amadé has been positive, supporting its potential for successful implementation.

Desirability

The desirability measures how well Amadé meets the needs and expectations of its users (patients, HCPs and loved ones). It is validated by assessing whether the design goal is met and whether the desired interaction qualities occur during use. This project aimed to design and validate a soundscape augmentation system that reduces the stress experienced by patients in the Adult ICU, by answering the main research question: How might we create a system in the Adult ICU that fulfils the unfulfilled psychological needs of critically ill patients by augmenting the soundscape during their admission?

By addressing the unfulfilled psychological needs of patients, their values and needs are prioritized. During the evaluation of Amadé, users reflected on their own admissions and expressed that they believed the interactions with the system would be beneficial during their stay. However, they mentioned that future research into the effectiveness of the system on the wellbeing of patients should be conducted, in order to increase acceptance of patients, HCPs and loved ones. All stakeholders emphasized this need to be able to fully engage with the system.

Viability

The viability of Amadé concerns the long-term sustainability of the system within the Adult ICU environment. It validates whether the system can be maintained and scaled over time while delivering value to both patients and healthcare institutions. Amadé is considered cost-effective on a societal level because it has the potential to improve recovery times and shorten ICU admissions.

However, the ultimate effect of the system on the stakeholders is not known yet. If the system achieves the impact that is envisioned, it can be considered valuable. Future research is thus necessary to confirm this long-term viability.

For Amadé to succeed as a soundscape augmentation system in the Adult ICU, it must meet the criteria of feasbility, desirability and viability. The system must be practical and easy to implement within the constraints of the ICU, align with the needs and expectations of the stakeholders and be economically sustainable in the long term. By carefully validating these criteria, Amadé can be considered as a valuable system in the ICU to reduce stress and improve the comfort of patients.

9.2 RECOMMENDATIONS

This section provides final recommendations for the healthcare domain to conclude the delivery phase of the thesis. It draws upon the concept evaluation to identify starting points for further development.

Part 4

One aspect of Amadé that has not been researched yet is part 4 of the system; the interaction of patients with the system during admission. While it is established that patient feedback is essential for creating an optimal ICU experience, the implementation of this part has not been defined and tested yet. It is crucial to consider the following requirements: a significant portion of ICU patients have limited or no mobility, many are visually impaired, and the ICU environment must be minimally disrupted to not disturb clinical needs. Integrating this component into the system will create a feedback loop, enabling realtime optimization of the soundscape based on the patient's input.

Sound preferences

Currently, the soundscape augmentation system uses a questionnaire which is focused on four sonic ambience types, established from the literature study. It is recommended that future research focuses on exploring different methods for receiving sound preferences from patients. While Amadé had been validated as desirable, the phrasing of questions could benefit from an update that emphasizes the psychological aspects of sound preferences. Thus, future studies should concentrate on refining the approach.

Biographical data

Throughout the project, the use of biographical data was explored through discussions with HCPs and literature review. It proved challenging to assess whether a person's stress levels could be assessed through only patient data (without asking the patient for confirmation). Future research should explore whether such data (i.e. increased heart rate and oxygen saturation) should influence the adaptive soundscape. However, a potential drawback is that incorporating this data could complicate the system, as it would need to integrate with existing ICU systems.

Conduct tests with patients

To build trust among patients and HCPs regarding the system, it is necessary to show them the system's effects. To achieve this, various tests must be conducted; different sound files need to be created, and their effects must be demonstrated. Additionally, it is important to test the transitions between the different soundscapes, as these shifts can potentially cause confusion or disorientation. The results of these tests will help determine the timing, duration and automatic reset to the baseline soundscape.

Expand to other domains

The design has been developed for the ICU environment, which is a critical setting where there is focus mostly on the physical rather than the emotional wellbeing of the patient. Given the potential of soundscape augmentation to positively impact psychological wellbeing, it would be valuable to explore its application in other environments where such effects are needed. Investigating other domains where people might experience emotional discomfort, could reveal additional areas where the system could have beneficial effects. Examples of such domains could be:

- Palliative care: Environments focused on providing comfort to patients with serious illnesses. Tailored soundscapes could support a peaceful environment.
- Mental health facilities: Settings where patients are treated for psychological issues. Tailored soundscapes could reduce anxiety and stress.
- Nursing homes: Facilities for elderly people where confusion may occur. Soundscapes could help create a calming environment, tailored to the needs of these people.

The general 'soundscape augmentation' that is not necessarily linked to individual needs may have applications in the following domains:

- Waiting areas: Public spaces where people are waiting for their appointments. Soundscape augmentation could provide comfort for people.
- Supermarkets: A shopping environment which benefits from soundscape augmentation because it can create comfort for people.

9.3 REFLECTION

This section provides a reflection on the initial assignment, the design goal, relevance for the healthcare domain and the relevance for the design field.

Reflecting on the initial assignment

The initial assignment of this thesis was to design and validate a soundscape augmentation system and user interface for intensive care patients (Appendix I). Throughout the research, it became clear that a personalized approach was needed to fulfil the psychological needs of patients because these vary from one person to person and do not arise at the same time for everyone. Additionally, the type of admission differs per patient, which highlighted the need for a personalized approach. A general approach in the ICU would thus not provide the same outcomes. By redefining this challenge in the design brief, even more valuable insights into the problem emerged.

Reflecting on the design goal

It can be concluded that the final design successfully achieves the formulated design goal (Section 8.4). The design fulfils the unfulfilled psychological needs of critically ill patients by augmenting the soundscape during admission. The four defined interaction moments enabled us to design the user interfaces in the ICU. Implementing the soundscape generator should reduce patient stress, thereby fulfilling the project's primary objective.

Relevance for the healthcare domain

The project is situated in the healthcare domain, a field where patient care is the most important. Nowadays, this domain is mainly focused on providing clinical needs, with less focus on psychological needs. This project within this domain provides this field with a personalized approach, which is tailored to the needs of patients. The domain still provides challenges, such as the need to integrate products seamlessly into the healthcare flow, which adds complexity to the design process. However, these challenges should not hinder the progress, as the potential benefits of the project are significant. This project was not only about creating a new technology but also ensuring that it would be the right fit within the highly regulated and sensitive context of healthcare.

Reflecting for the design field

This thesis presents an innovative approach to designing a soundscape augmentation system within the field of healthcare. By exploring and validating the user interfaces, potential users were able to express their needs and expectations of the system. This thesis offers recommendations that can be directly applied in the design field, contributing to both research and design by validating knowledge that is directly applicable in practice.

Moreover, this research addresses a gap in the existing literature field by providing a design framework for the user interfaces of a soundscape augmentation system. By addressing this gap, the thesis provides practical guidelines for future research and design interventions, enhancing human-centered design in healthcare.

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APPENDIX

A. QUALITATIVE THEMATIC ANALYSIS

This appendix includes the quotes from the thematic analysis and the clusters that are created with those quotes.

A.1 QUOTES FROM QUALITATIVE ANALYSIS

Patient Perspective

Positief

Quote	Code
Ipad gekregen. Televisie kijken en muziek luisteren en communiceren.	Afleiding
Foto's paardensport en kaartjes. Telefoon en televisie. Boek lezen, drinken, lego.	Afleiding
Beetje tv kijken of muziek op Iphone luisterboek.	
Telefoon. Oortjes.	Afleiding
Tv bij het bed, muziekje luisteren, radio, klassiek muziek, ja fijn, zeker in die toestand.	Afleiding
Oortjes of koptelefoon voor privacy (het niet horen over anderen)	Afleiding
Mensen om me heen als afleiding	Afleiding
Fijn om naar buiten te kijken. Grote ramen, binnenhofje.	Afleiding
Klok. Gaf wel houvast. En een datum. Geen behoefte aan afleiding alleen kijken naar de klok.	Afleiding
Dat de deur dicht kon was heel lekker. Bezoek was er veel.	Afsluiten van de rest
Het is wat je verwacht. Raarder als het doodstil was en geluid staat voor mij wel voor gezelligheid. Twee mensen die een gesprek hebben, bevestiging van je bent op een normale plek. Menselijker.	Alarmen
Piepjes wen je wel aan.	Alarmen
Algemeen gevoel was positief en een soort soap.	
Veel morfine.	Algemeen
Herinneringen aan IC maar niet naar gevoel.	Algemeen
Wazige dagelijkse herinnering	Algemeen
Super modern super mooi.	
Je hoort helemaal niks.	Algemeen
Voelde me echt een koning.	
Veiligheid en rust.	Algemeen
Bezoek was prettig.	
Luchtpijp door keel met knopje. Beetje praten	Bezoek
Vriendin had een boekje bij gehouden	Documentatie
Foto's en veel over hebben. Grote impact op familie.	
PICS-F.	Documentatie
Documentatie niet zelf gedaan. Goed gedaan en aanraden.	Documentatie
Documenteren is wel fijn	Documentatie
Verpleegkundige heeft selfie gemaakt. Wel realistisch met buizen in mn lijf. Laten zien hoe heftig het is.	Documentatie
Moeder had een dagboekje bijgehouden.	Documentatie

Negatief

Quote	Code
Behoefte aan drinken, naar buiten kijken.	Afleiding
Behoefte aan eenzaamheid	Afsluiten van de rest
Alarmen van apparatuur. Niet fijn, went wel, je weet waarvoor het is.	Alarmen
Piep geluiden apparatuur. Kwam wel een beetje terug in de dromen.	Alarmen
Alarm, wel vervelend als het een kwartier duurde.	Alarmen
Er was altijd lawaai. Onrust.	Alarmen
Piepen en groen lichtje. Infuus ding hoorde je wel heel de tijd, maar niet heel erg. 's nachts is het storender en verder het licht.	Alarmen
Je wordt nerveus van de alarmen.	Alarmen
[...] the noise made me crazy be-cause it was there every moment of the day[...] when you are lying down and you can't see anything, what's happening there, and there are every moment alarms, you don't understand at all	Alarmen
[...] (medical alarms) means for me stress, stress, stress, stress, very stressful moments and not being able to sleep	Alarmen
Too tired, too much noise.	Alarmen
alarms are an emergence because that's what alarm represents for me [...]	Alarmen
the alarm tells me there's a problem [...] you feel it like, like a threat and you're afraid	Alarmen
Algemeen gevoel was een nachtmerrie	Algemeen
Dagelijkse herinneringen zijn 1 wazige droom.	Algemeen
Gevoel heftige situatie.	Algemeen
Wat gebeurt er allemaal met mij. Het was chaotisch en hectisch.	Algemeen
what if there's something wrong with me?[...]"	Angst
Na morfine wel saaier. Had rust nodig. Daarna druk en chaotisch. Veel variabeler.	Behoefte aan rust
Behoefte aan rust. Geen prikkel. Muziek kon ik helemaal niet aan en heel emotioneel.	Behoefte aan rust
Behoefte aan steun	Behoefte aan steun
Onrustig. Niet eigen beleving. Paniek over iemand naast je.	
Lawaai en paniek.	Bezig met anderen
Hoorde verplegers over andere patienten praten. Maakte me zorgen om hem.	Bezig met anderen

Positief	
Moeder heeft gefilmd. Fijn om terug te kijken en te zien in welke status je was. Terug kijekn naar iets waar je een soort black out van hebt. Een positief delier. Fijne dromen. Nu niet echt meer last.	Documentatie
	Fijne dromen
Verpleging was fijn en goed	Fijne verpleging
Goeie band met verpleging maar wel afdwingen	Fijne verpleging
Prima heel content met hoe de verzorging was. Ze nemen alle tijd voor je.	Fijne verpleging
Fijn communiceren. Meer zien dan een zieke jongen.	Fijne verpleging
Hele goede IC. Goed verzorgd. Veel aandacht.	
Verzorging was goed.	Fijne verpleging
Ze doen veel moeite om jou te motiveren. Ze waren wel heel intensief aanwezig en ze zijn er om mensen heel goed te laten voelen. Heel behulpzaam	Fijne verpleging
Hele lieve zorgen.	
Onpersoonlijk door de corona bescherming.	Fijne verpleging
Piepende apparaten horen erbij. En ik vroeg gewoon wat het betekende.	Geluid
Regengeluiden om in slaap te komen. Werkte redelijk okay.	Geluid
Luisteren naar de patient. Arts deed dat. 'er is een weg'. Heel veel houvast. Je mag hier blijven.	Gemoedsrust
Zeker wel gevoel van tijd, kon naar buiten kijken	Gevoel van oriëntatie
De klok wel goed in de gaten gehouden. Raam, geen dag licht,	Gevoel van oriëntatie
Gevoel van tijd had ik wel door. Het was 's nachts rustiger.	Gevoel van oriëntatie
Haren kammen is heel fijn. Beter uitzien. Lichamelijke aandacht en verzorging. Je wordt zo slap.	Lichamelijke verzorging
Geïsoleerd. Geluidsdicht.	
Super luxe. Bevoorrecht	Omgeving
Heel veel geslapen, heel moe. Koste heel veel engergie.	Slapen
Slapen op de IC wel. Niet als probleem.	Slapen

Negatief	
Verpleegkundige wilde rustig krijgen op een boze manier.	Boze verpleging
Bang om dood te gaan.	De dood
Geen documentatie. Jammer om dit niet meer te zien.	Documentatie
Wilde de zuster niet belasten.	Documentatie
Overal heel de tijd drukte. Er was wel een bepaald ritme, meer of minder mensen die rond liepen.	Drukte
Eten vreselijk vies. Paar maanden geduurd.	Eten
Daarna niks meer kunnen was het aller ergste.	Fysiek beperkt
Niet kunnen bewegen opgesloten in je lichaam. Ademen was heel zwaar. Denk dat ik ging stikken. Niet de kracht om de knop in te drukken.	Fysiek beperkt
Niet kunnen praten. Leren praten.	Fysiek beperkt
Alles koste kracht	Fysiek beperkt
Geluiden slecht aankunnen	Geluid
Pompen. Kon ik wel plaatsen, wel in de zorg gewerkt. Er is een geluid wat ik niet thuis kan brengen. Verpleegkundige horen praten.	Geluid
Altijd wel geluid. Piepjes, zoomen, praten van mensen en kuchen etc. Morfine trip wel het geluid van de TV.	Geluid
Boxje. Zee van geluid.	Geluid
Brommend geluid van Wim en Wilma. Of airco. Niet storend. Maar verpleegkundigen op de gang horen, praten en lachen. Wilde ik toen niet horen.	Geluid
Dichtbij de overleg ruimte. Overleggen over de patient. Raar.	Geluid
In het begin allemaal gepiep en geluid. Geen idee wat het betekent. Vragen aan de verpleegkundige.	Geluid
Ze zetten de radio aan maar vooral voor zichzelf. 100% NL ofzo	Geluid
Het enige wat je hebt is je bel knop. Als je de knop kwijt bent heel vervelend. Knop drukte en niet werkte. Hoe kan ik nu uitleg geven wat er aan de hand is. Geluid maken met het ding.	Geluid

Positief	
Heel veel geslapen. Bijna alleen maar. Geen last van de andere.	Slapen
Sociaal contact. Bezwaard voelde om hulp te vragen. Mentale ondersteuning	Sociaal contact
Menselijke aandacht was fijn	Sociaal contact
Veel mensen om me heen is fijn	Sociaal contact
Super belangrijk sociaal contact. In mijn geval. Super fijn als ik wat aandacht kreeg en een kort praatje. Sociale aandacht.	Sociaal contact
Krankzinning. Toen ik goed ver heen was. Het deed het echt super goed. Ik kon dingen ruiken die mensen niet konden ruiken.	Zintuigen geprikkeld
Veilig gevoel door aanwezigheid familie	Sociaal contact

Negatief	
Je wordt iedere keer gestoord door medicatie. Slapen was beangstigend. Niet meer durven te slapen.	Slapen
Ik miste wel het sociaal contact. Je zat echt in een bubbeltje. Miste echt heel erg het sociale.	Sociaal contact
Sociale miste een beetje. Ook begrijp ik het en is het niet een koffiezaak.	Sociaal contact
Behoefte aan emotionele support	Sociaal contact
Behoefte aan gesprekken voeren met zuster. Veel vragen. Eenzaam.	
Onzekerheid. Naar huis willen.	Sociaal contact
Vastgebonden. Heel onprettig en handschoenen om handen.	Vastgebonden
Dagelijkse herinnering als toeschouwer. Lag helemaal vast. Katheter	Vastgebonden
Je hoort de verpleging heel de dag en deuren gaan open en dicht.	Veel rumoer
Iemand aan de overkant lag 's nachts te roepen	Veel rumoer
1 onaardige verpleegster	Verpleging
Communicatie tussen verpleging kan beter	Verpleging
Verpleging was heel streng	Verpleging
Nare ervaringen met verpleging. Heel boos over opmerking.	Verpleging
Deken weg en terug. Zeker verward.	Verward
Ik wist niet waar ik was, ik dacht in een laboratiorium	Verward
Besef kwijt	Verward
Levendige dromen.	Verward
Heel de tijd scherp groen lichtje.	Zintuigen geprikkeld
Heel gevoelig voor geur. Koffie stonk.	Zintuigen geprikkeld

Negatief	
Geluiden gehoor die er niet waren. Horror.	Geluid
Geen gevoel van dag en nacht.	Gevoel van oriëntatie
Klok. Dag en nacht wel door elkaar gegaan.	Gevoel van oriëntatie
Heel weinig gevoel van tijd. Veel slapen. Niet bezig met de tijd. Had niet het idee dat het nodig was.	Gevoel van oriëntatie
Gordijnen waren altijd dicht. Besef van tijd is niet echt een ding.	Gevoel van oriëntatie
Het voelde of het altijd donker was. Ik hield de tijd wel in de gaten. En de datum.	Gevoel van oriëntatie
Er wordt niet echt aangekondigd dat je 'gaat slapen' het is meer op eigen initiatief	Gevoel van oriëntatie
Plotseling verlies privact, wassen is best wel heftig	Impact
Er was niks om je te kalmeren.	Moeilijk te kalmeren
Geur was echt verschrikkelijk. Het stonk naar poep.	Omgeving
De termen horen maar je weet niet wat het betekent.	
Duidelijkheid miste. Ik had heel veel vragen	Onduidelijk
Ze discussiëren niet waar je bij bent.	Onmacht
Ik was heel afhankelijk	Onmacht
Gevangen gevoel. Je ligt en je ligt. Af en toe een praatje	Onmacht
Je wordt geleefd door de diensten van de verpleegkundige.	Onmacht
it's out of my control because I'm in that bed being helpless [...] that is something you have to surrender to submit to	Onmacht
I couldn'tjind the cause of the alarm. Ifelt a little panic inside. What's happening? This is the start of going of dying or whateuer. All kinds of things go through your head [...] I didn't understand what's happening and what were the results of what's happening.	Onwetend
Heel veel pijn, te weinig pijnbestrijding	Pijn
Pijn, verwarring	Pijn
Voelde me heel vies. En schaamte dat ik de controle kwijt was (kotsen).	Schaamte
Heel veel gekke dromen. Herhaalden zich ook. Groene poppetjes. In een latere fase bedacht ik een heel ontsnappingsplan.	Slapen
Nachten waren wel lang. Iets gevraagd om te kunnen slapen. Geven dat niet voor 12 uur. Had een klok, te vroeg uitgewerkt.	Slapen
Slaapt nooit goed. Te licht.	Slapen
Niet echt kunnen slapen. Elk uur gekeken.	Slapen

HCP Perspective

Quote	Code
Psychological	
"My patient had acute leukemia, There is no nice way to deal with it."; "When they have to say goodbye to loved ones."	Prospect
"They are laying there for a long time without prospect."	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
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Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
Being pessimistic about the future	Prospect
"Patients often feel confused when they wake up after sedation."	Cognitive ability
"He didn't know where he was because of reduced brain activity."	Cognitive ability
Being confused	Cognitive ability
Being confused	Cognitive ability
Being confused	Cognitive ability
Being confused	Cognitive ability
"There is no clear information for patients."	Sense of control
"Patients experience uncertainty about their own body such as what kind of prognosis in the short and long term."	Sense of control
Lack of information	Sense of control
Lack of information	Sense of control
"Because of their medical situation, mostly they are not able to do what they want."	Physical ability
Not able to do what they want	Physical ability
Not able to do what they want	Physical ability

Quote	Code
Psychological	
"A visit from grandchildren or their dog brings the most joy in the regular (ICU) life of patients."	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
Interacting with loved ones	Interaction with people
"Real contact with either staff or family in peace can have a reassuring effect."	Being reassured by others
Feeling of being cared for	Being reassured by others
Feeling of being cared for	Being reassured by others
Feeling of being cared for	Being reassured by others
Feeling of being cared for	Being reassured by others
Feeling of being cared for	Being reassured by others
"Patients who cannot move their finger one day lift their hands the next day. It is very rewarding for patients. You can see that patients are very happy with the progress they make."	Prospect
Making progress	Prospect
Making progress	Prospect
Making progress	Prospect
Making progress	Prospect
"When I am in the room and talking to patients, they feel comfortable as there is someone they can talk to and some distraction."	Distraction
Distraction through conversations	Distraction
Distraction through conversations	Distraction
Distraction through conversations	Distraction
"TV and music help patients to feel less pain."	Cognitive ability
Sensory stimulation	Cognitive ability
Sensory stimulation	Cognitive ability
Sensory stimulation	Cognitive ability
"They feel safe when they are getting attention from professionals."	Sense of safety
Being watched by professionals	Sense of safety
Being watched by professionals	Sense of safety
Being watched by professionals	Sense of safety
"It is important for patients to make it more like home. Bringing some nature inside is one way to make it more feel like home."	Sense of safety

Not able to do what they want "Especially when they are on a ventilator, they are frustrated because it's uncomfortable and hard to express what they are feeling."	Physical ability
Hard to express feelings	Communication
Hard to express feelings	Communication
Hard to express feelings	Communication
"I think the fear is the most difficult for ICU patients. When you hear their stories about nightmares and hallucinations, what they see is very frightful."; "They feel anxious and tense because they are afraid of pain. Not only when they are in pain but also worrying about experiencing it again."	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
Fear of pain, trauma, hallucination, delirium	Traumatic experiences
"It's all white and no warm colors or anything."	Distraction
Having nothing to do	Distraction
Depressing environment	Distraction
Depressing environment	Distraction
Having nothing to do	Distraction
Having nothing to do	Distraction
"If they want to look outside, all they see is the building next to the hospital, so it's not really interesting."	Distraction

"Watching TV helps patients to realize that they are back in the world again. They can see some familiar things from TV."	Sense of safety
Familiar things	Sense of safety
"My patients are content when they understand where they are and what the situation they are going through after I explained."	Sense of control
"They are happy when they say what they want because it is closest to what they normally do and provides them a sense of control."	Sense of control
Being in control of the situation	Sense of control
Being in control of the situation	Sense of control
Being in control of the situation	Sense of control
Being in control of the situation	Sense of control
"It is very important that they can feel protected from people walking in when they are naked and have somebody taking care of their appearance."	Feeling like oneself (dignity)
There is a moment when the nurses pay attention to them. We put a patient in a chair with makeup on and that is a very cheerful moment for her."	Feeling like oneself (dignity)
Dignity	Feeling like oneself (dignity)
In de loop van de jaren ontwikkel je een hele set aan grapjes om soms de spanning er eventjes af te halen, om te kijken of je mensen aan het lachen kan krijgen. Dan slapen ze vaak ook wat beter. Is het idee dan, of het echt zo is weet ik niet.	Distraction
"Ik zou het ook heel vervelend vinden als ze op de gang over mij aan het praten waren. Dus ik vind dat de patiënt het recht heeft om te horen hoe het met hem gaat en wat de plannen zijn, voor zover hij dat kan begrijpen natuurlijk."	Sense of control
Bij patiënten die hier langer liggen probeer je een rustmoment in te bouwen; een momentje voor hunzelf. Als bijvoorbeeld de fysio komt stuur ik ze weg en zeg ik dat ze rond 13 a 14 uur terug kunnen komen.	Sense of safety
Ik doe veel in overleg, want het is wel iemands lijf. Ze raken al zoveel zelfcontrole en zelfzorg kwijt hier. Ik wil niet datgene afnemen waar ze zelf nog iets over te zeggen hebben.	Sense of control

"When patients are getting better, the only thing in their head is how is it at home. (. . .) they cannot ask their child how things are whenever they want to. It is not easy for patients to pick up the phone and ask their loved ones, and they could be tense because of that."	Interaction with people
Being separated from loved ones	Interaction with people
Being separated from loved ones	Interaction with people
Being separated from loved ones	Interaction with people
Being separated from loved ones	Interaction with people
"Patients would feel embarrassed with nurses. Nurses don't mind because it is their daily job. But for patients, it is not their daily job to release their stool while they are lying in bed."	Feeling like oneself (dignity)
"Misschien denken ze wel: familie moet zich ook uiten, die moeten het ook kwijt. Dus doe maar gewoon; ik ben moe, maar ik lig in ieder geval.	Interaction with people
"Je moet wel eens waken voor de autonomie van een patiënt. Dus soms moet je ook wel eens zeggen: dat kan nu niet, daarom en daarom."	Interaction with people
"Je weet dat sommige patiënten er last van hebben. En dan moet je op een zeker moment toch wel ingrijpen. Soms zeggen ze wel: nou wil ik even rust."	Interaction with people
Vooral buitenlandse mensen vinden het moeilijk om te zeggen dat men fftjes niet mag komen. Vaak zeg ik gewoon waar de familie bij staat: meneer als u het teveel vindt, moet u het ook gewoon zeggen. Dan gaat er wel een lichtje branden bij de familie."	Interaction with people
"Jammer genoeg zijn patiënten niet zo heel erg assertief. Dus je moet meer kijken of ze rust willen of niet."	Interaction with people
"Waar ik me altijd over verbaas is is dat er toch wel veel op de gang besproken wordt over de patiënten. De dokters staan in een nisje, en drie stappen verder staan ze voor de andere deur. Ik kan me zo wel voorstellen dat de patiënt die in box 1 ligt hoort wat er over de patiënt in box 2 gezegd wordt."	Sense of safety

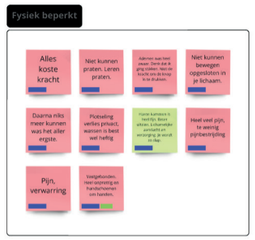
Physical	
"Just +B78:B120lying in one position for a long time, it can be very uncomfortable and painful. And every tube and catheter they have in the urinary bladder, in mouth, nasogastrictubes through the nose, the drips in their arms, and bandages around their drips are all sources of discomfort."	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort

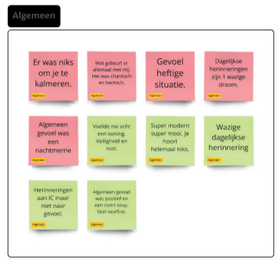
Physical	
"Everyone who can sleep at night feels better during the day."	Sleep and environment
Feeling restored	Sleep and environment
Feeling restored	Sleep and environment
Feeling restored	Sleep and environment
Feeling restored	Sleep and environment
Feeling restored	Sleep and environment
"Feeling less pain."	(General) pain and discomfort
Comfort	(General) pain and discomfort
Comfort	(General) pain and discomfort
Comfort	(General) pain and discomfort
Comfort	(General) pain and discomfort
Soms hangen er ook foto's. Dat is ook fijn om te zien, ook voor ons. Dan zie je hoe je patiënt dus eigenlijk was.	Distraction

Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
Pain and discomfort	(General) pain and discomfort
"If I get it (the way patients are mobilized), I would scream. It's painful for patients."	(General) pain and discomfort
Painful intervention	(General) pain and discomfort
Painful care	(General) pain and discomfort
"Patients have their most pain in the last days of their ICU admission. Because they are often sedated before, and in their last days of ICU, they are awake and aware of everything."	When having pain
When having pain	When having pain
"Being on a ventilator is very uncomfortable."	When having pain
"Because they are very sick."	Illness
Being sick	Illness
Being sick	Illness
Being sick	Illness
Being sick	Illness
Being sick	Illness
"For patients, it feels like they are running a marathon every day. They have to work, work, work, then finally they can rest. Sometimes they are sad and unhappy that they have to get out of bed and have to do things."	Illness
Being exhausted	Illness
"The ventilator always makes a sound. You have the noise with every breath you take, it's quite a lot of noise for 24 hr."	Sleep and environment
"The strong beam right above the bed is for us to see what we are doing but probably not nice for patients to sleep."	Sleep and environment
Interferences	Sleep and environment
Interferences	Sleep and environment
Interferences	Sleep and environment
"Mijn patiënt vandaag lag vanmiddag best hard door zijn telefoon te praten. Dat vind ik niet erg, maar daar zou iemand nog wel last van kunnen hebben."	Noise
"Sommigen houden de deur relatief open, voor hunzelf, dat ze makkelijk de kamer op kunnen. Terwijl de patiënt dan de geluiden van de gang hoort en ons ook kan horen. Die letten wat minder op wat de invloed van geluid op de patiënt is die wil slapen."	Noise
"Als iemand een patiënt heeft die zeg maar soort van klaagt over de herrie op de gang, dan wordt dat ook wel gezegd van jongens een beetje rustig want we maken wel heel veel herrie."	Noise
"Ik denk dat je in je nisje te dicht bij de patiënt zit. Want als je daar zit: dan komt er weer een chirurg om te vragen hoe het gaat, dan weer een fysiotherapeut, diëtist, of apotheker. Je wordt de hele tijd gestoord. De patiënt hoort dat natuurlijk allemaal."	Noise
Ik denk dat als je een was-moment bij je patiënt hebt of als je je patiënt onderzoekt, dat het goed is als die deur dicht zit. Dan heb je echt even een moment met je patiënt.	Feeling like oneself (dignity)
Als iemand hier bloot ligt en die gewassen wordt, dan draai ik liever even de lamellen open in plaats van dat je deur opendoet en die secretaresse komt langs en iedereen komt langs...	Feeling like oneself (dignity)

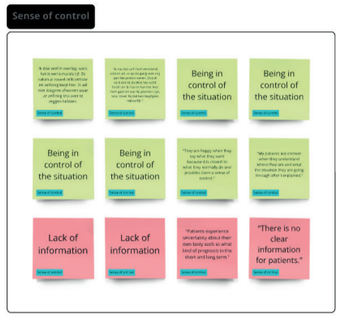
A.2 CLUSTERS WITH QUOTES

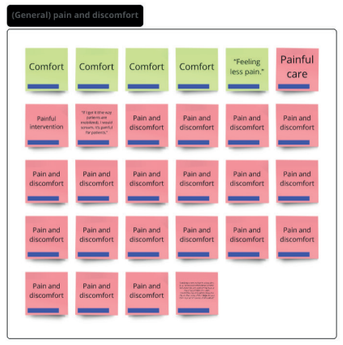
Patient perspectives

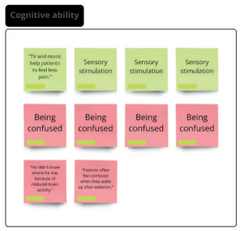


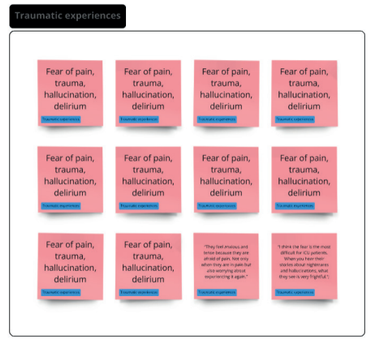


HCP perspective









B. RESULTS SOUND PREFERENCES

This appendix includes the questions and results of the sound preferences surveys

B.1 QUESTIONS IN SURVEYS

Survey 1
- Wat is je naam?

Comfortable
- Als je denkt aan een comfortabele omgeving, aan wat voor soort geluiden denk je dan?
- Welke geluiden dragen in een comfortabele omgeving bij aan je gevoel van ontspanning?
- Welke geluiden doen je denken aan 'thuis' in een comfortabele omgeving?

Pleasurable
- Als je denkt aan een aangename omgeving, aan wat voor soort geluiden denk je dan?
- Welke geluiden dragen in een aangename omgeving bij aan je gevoel van ontspanning?
- Als je op zoek bent naar een aangename sfeer, welke geluiden creëren dan een gevoel van verbondenheid met de omgeving?

Motivating
- Als je denkt aan een motiverende omgeving, aan wat voor soort geluiden denk je dan?
- Welke soort geluiden motiveren je en geven je energie?
- Welke geluiden helpen je om geconcentreerd te blijven?

Stimulating
- Als je denkt aan een stimulerende omgeving, aan wat voor soort geluiden denk je dan?
- Als je op zoek bent naar inspiratie, welke geluiden roepen dan inspiratie op?
- Als je inspiratie nodig hebt, welke geluiden prikkelen dan je verbeelding en creativiteit?

For reference
- Geef aan welke categorie geluiden in het algemeen uw voorkeur heeft om te ontspannen:
- Geef aan welke categorie geluiden in het algemeen uw voorkeur heeft om tot actie te komen:
- Hoe mentaal veeleisend was het invullen van de vragenlijst?
- Hoe succesvol was je in het beantwoorden van de vragen?
- Hoe voelde je je tijdens het invullen van de vragenlijst?

Survey 2
- Wat is je naam?
- Over wie vul je deze lijst in?

Comfortable
- Als hij/zij denkt aan een comfortabele omgeving, aan wat voor soort geluiden denkt hij/zij dan?
- Welke geluiden dragen in een comfortabele omgeving bij aan zijn/haar gevoel van ontspanning?
- Welke geluiden doen hem/haar denken aan 'thuis' in een comfortabele omgeving?

Pleasurable
- Als hij/zij denkt aan een aangename omgeving, aan wat voor soort geluiden denkt hij/zij dan?
- Welke geluiden dragen in een aangename omgeving bij aan zijn/haar gevoel van ontspanning?
- Als hij/zij op zoek is naar een aangename sfeer, welke geluiden creëren dan een gevoel van verbondenheid met de omgeving?

Motivating
- Als hij/zij denkt aan een motiverende omgeving, aan wat voor soort geluiden denkt hij/zij dan?
- Welke soort geluiden motiveren hem/haar en geven hem/haar energie?
- Welke geluiden helpen hem/haar om geconcentreerd te blijven?

Stimulating
- Als hij/zij denkt aan een stimulerende omgeving, aan wat voor soort geluiden denkt hij/zij dan?
- Als hij/zij op zoek is naar inspiratie, welke geluiden roepen dan inspiratie op?
- Als hij/zij inspiratie nodig heeft, welke geluiden prikkelen dan zijn/haar verbeelding en creativiteit?

For reference
- Hoe mentaal veeleisend was het invullen van de vragenlijst?
- Hoe succesvol was je in het beantwoorden van de vragen?
- Hoe voelde je je tijdens het invullen van de vragenlijst?

B.2 RESULTS

Survey 1 (n=40)

SOUND CATEGORY	Comfortable [amount]	Pleasurable [amount]	To Relax	Motivate [amount]	Stimulate [amount]	To Activate
NATURE	73	54	36	67	38	6
HUMAN	43	65	4	41	52	26
TECHNOLOGICAL	4	1	0	12	30	8

This table shows the amount of answers given per sound type.

Survey 2 (n=34)

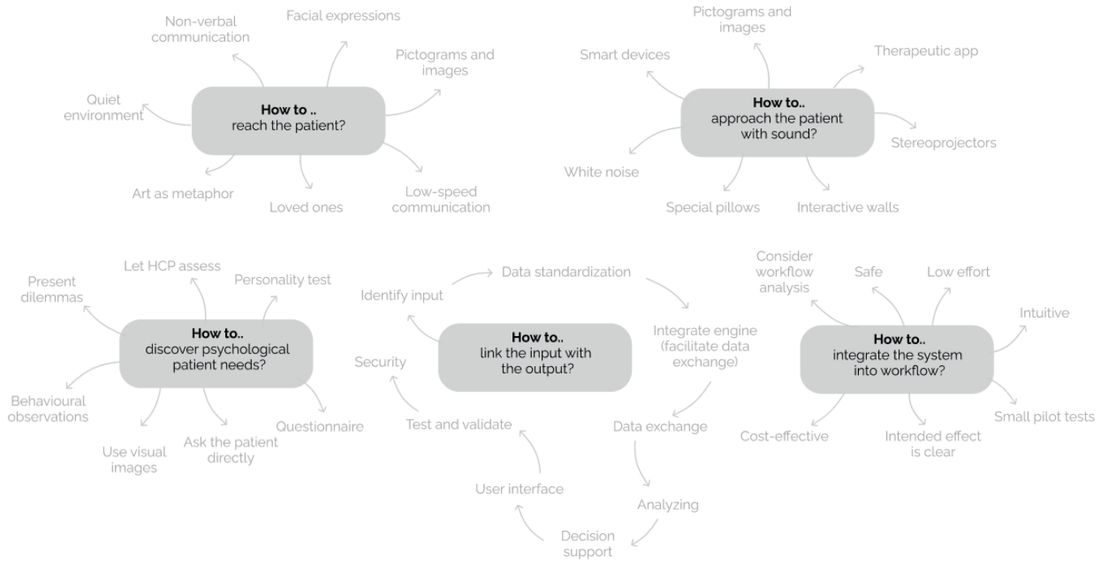
SOUND CATEGORY	To Relax	To Activate
TRUE [AMOUNT]	128	113
%	62,75	55,39
FALSE [AMOUNT]	76	91
%	37,25	44,61

This table shows the amounts of TRUE/FALSE answers, which is related to the previous table.

C. BRAINSTORM SESSIONS

This appendix includes the methods of the brainstorming sessions

C.1 HOW-TO SESSION



C.2 CO-CREATION SESSION

Consent to participate in co-creation session and to use the outcomes of the co-creation session

graduation project

I agree to participate in the co-creation session conducted by and recorded by Lindy Kok as part of her graduation project about augmenting soundscapes in Intensive Care environments.

I understand and consent to the use and release of the recording by Lindy Kok. I understand that the information and recording is for research purposes only and that my information will not be used for any other purpose and will only be viewed by those working on the graduation project of Lindy Kok. I relinquish any rights to the recording and understand the recording may be copied and used by Lindy Kok without further permission.

I understand that participation in this session is voluntary and I agree to immediately raise any concerns or areas of discomfort during the session.

Please sign below to indicate that you have read and you understand the information on this form and that any questions you might have about the session have been answered.

Name participant

Signature

Date

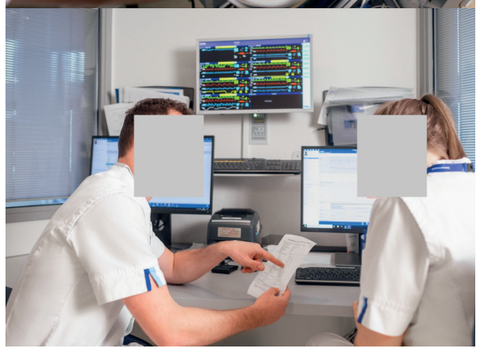
[11-04-2024]

Time:	What?	What to say:
11:00-11:05	Welcome & Consent	
11:05-11:10	Introduction problem & IC	Probleem: Patiënten ervaren stress door ongewenst geluid, lichtomstandigheden, communicatieproblemen en gebrek aan stimulatie. De huidige geluidservaring op de IC is niet optimaal voor herstel van patiënten. *Indien ze niet weten wat IC is:* *Maar wat is de Intensive Care?* In Nederland speelt de intensive care een cruciale rol bij het bieden van geavanceerde medische zorg aan patiënten met levensbedreigende aandoeningen of ernstige verwondingen. De intensive care afdeling (ICU) is een gespecialiseerde ziekenhuisafdeling voor de zorg voor ernstig zieke patiënten die levensondersteuning nodig hebben en patiënten met een extreem hoog risico op orgaan falen en overlijden (Ervin, J. N,2018). Effectieve intensieve zorg vereist preventie, vroegtijdige waarschuwings- en reactiesystemen en een multidisciplinaire aanpak voor, tijdens en na het IC-verblijf. Dit wordt versterkt door het feit dat, terwijl sommige patiënten op de IC worden opgenomen als onderdeel van geplande procedures, zoals hart- of hersenchirurgie, de meerderheid van de patiënten onverwacht binnenkomt als gevolg van een reeks kritieke aandoeningen, waaronder een hartstilstand of levensbedreigende ongevallen.
11:10-11:15	Flower association IC	
11:15-11:25	Introduction into concept	Nu ben ik gevraagd een systeem te ontwikkelen dat resulteert in een verbeterd herstel van patiënten. Ik focus hierbij op een verbeterde geluidsomgeving door geluid toe te voegen. Dit geluidssysteem is effectief wanneer het voldoet aan vijf karakteristieken, waarvan ik er één wil uitlichten: personalized soundscape. Ik weet over dit deel hoe het werkt, welke geluiden ik moet gebruiken en wanneer, maar ik weet nog weinig over de interactie met het systeem. En daar heb ik jullie bij nodig.
11:25-11:43	In-depth	Voorbeeld: Pieter heeft altijd in een stedelijk gebied gewoond
3	[Before admission] Hoe?	
3	[Before admission] Wanneer?	
3	[During admission] Hoe?	
3	[During admission] Wanneer?	
3	[After admission] Hoe?	
3	[After admission] Wanneer?	
11:45-11:50	Sticker: hits & dots	Kies de ideeën die jou het meeste aanspreken
11:50-12:00	C-box	Plaats de dot-ideeën op de goede plek


Afblijven
alleen voor
research


Fentanyl
NU!


01:211




MAGNET
CARDIOSAVE


tijdens
LUISTERBOEK
GELUID BUITEN (RAAM OPEN)
KOPTELEFOON OORTJES
PADDESTOEL (vd kamer)
DAG-NACHT RITME (SCHEMA)
VOGELTJES fluiten
UIT HOOFDDEEL VAN BED
LOPEN DOOR DE GANG
BIJ EEN NOODGEVAL
ONTSMETTINGS ALCOHOL
ALARM
Mobiel naar bijv. ingang
Communiceren met personeel
Handdoekjes met woorden bedrukken
Podcast
Immersive experience
SPOTIFY PLAYLIST
PRATEN MET AMBULANCE BEGELEIDER
Tijdens aan ingang
Wachtruimte
In het kussen
voor een operatie
IN DE AMBULANCE
VOOR
Spreekuur in het bad
op het moment dat je niet kan zien maar wel kan horen
TV
moment bewust in de IC
coma.
OP STRAAT
VR Bril
THUIS
UIT EEN KNUFFEL
INGANG VAN ZIEKENHUIS TOT INGANG KAMER
IN MUTS
MUZIEK INSTRUMENTEN LIVE
In het bad
IN HET ZIEKENHUIS
Intensive Care
Ziekenhuisbed
Spanning
Apparatuur
Scherm
Infuus
Prikjes

D. CONCEPTUALIZATION

This appendix includes the design principles and use cases used to create wireframes and the concept in detail.

D.1 DESIGN PRINCIPLES

The design process was guided by several principles, including simplicity, accessibility, mental models and affordances.

Simplicity
Simplicity in UX design is considered as creating interfaces that are straightforward to navigate. It should benefit the user experience, as it allows them to achieve their goals with minimal effort. This is especially important in our system where the interaction time with the system should be minimized.

Accessibility
Accessibility in UX design is considered as allowing users of all abilities to understand, use and enjoy the product (Kaur, 2021). It should be the right fit for the right user at the right moment. This principle made us create a tone of voice for each part of the system.

Mental models
Mental models are what the users believe about the system at hand (Nielsen & Chan, 2024). The mental models help the user predict how a system will work, and, therefore, influence how they would interact with an interface. This principle made us create a storyboard to explore the mental models the users would have.

Affordances
Affordances are the characteristics of a product that suggest how it should be used (Interaction Design Foundation, 2024). This is a relationship between the capabilities of a user and the properties of a product. In our system, the affordances are carefully considered, especially when designing the implementation of the product in the context.

Sources:

Kaur, A. (2021, December 7). Accessibility guidelines for UX Designers - UX Collective. Medium. https://uxdesign.cc/accessibility-guidelines-for-a-ux-designer-c3ba775539be

Nielsen, J., & Chan, M. (2024, August 19). Mental models. Nielsen Norman Group. https://www.nngroup.com/articles/mental-models/

Interaction Design Foundation. (2024, April 16). What are Mental Models? The Interaction Design Foundation. https://www.interaction-design.org/literature/topics/mental-models

D.2 USE CASES

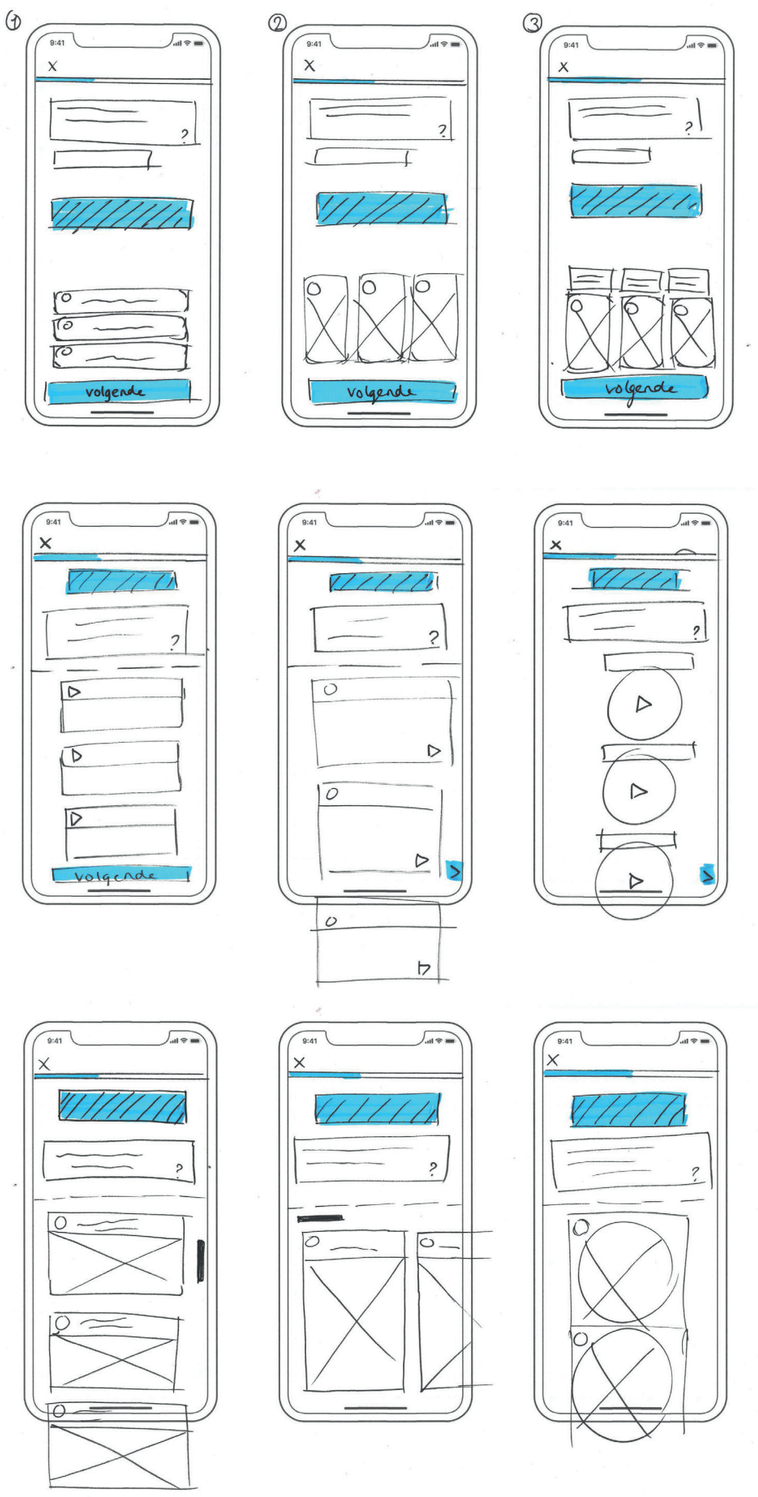
1 - Patient at Home, Before Admission
Actors: Patient, DigiZorg app (patients will get in contact with this app already and it is easy to integrate it in an already existing app.
Purpose: To communicate their preferences as input for the system
Initial condition: Patients has the DIgiZorg app installed on their device
Terminal condition: Patient's sound preferences are saved into the DigiZorg system and will be used during any future ICU admission
Primary steps:
Login to the app
Access the tool
Navigate to 'vragenlijsten'
Select the 'vragenlijst geluidsvoorkeuren'
Start 'vragenlijst geluidsvoorkeuren'
Answer the questions
Save preferences
Confirmation
Return to homescreen
Alternative scenarios:
Incomplete answers; the app prompts: 'You have unanswered questions. Do you want to answer them before exiting?'
In need of help: 'help' button (on any screen) to access guidance

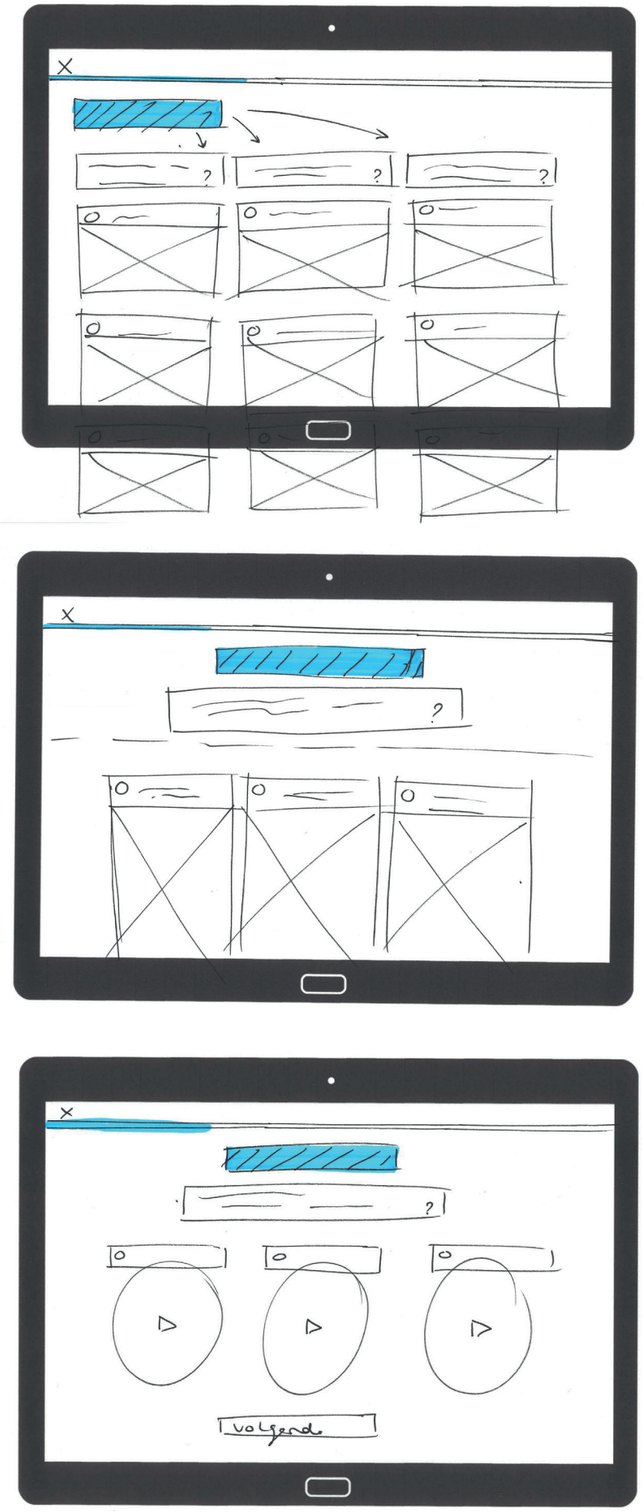
2 - Loved one at ICU, Start of Admission
Actors: Loved one, Digital interface = tablet (which is already present in the ICU)
Purpose: To communicate their perception of the preferences of the patient as input for the system
Initial condition: Loved one (contact person) is authorized to access the patient's digital interface
Terminal condition: Patient's sound preferences are saved into the DigiZorg system and the soundscape reflects the patient preferences
Primary steps:
Login to the app
Access the tool
Navigate to 'vragenlijsten'
Select 'contact person'
Select the 'vragenlijst geluidsvoorkeuren'
Start 'vragenlijst geluidsvoorkeuren'
Answer the questions
Save preferences
Confirmation
Return to homescreen
Alternative scenarios:
Incomplete answers; the app prompts: 'You have unanswered questions. Do you want to answer them before exiting?'
In need of help: 'help' button (on any screen) to access guidance

3 - HCP at ICU, During Admission
Actors: HCP, digital device next to the door of the patient room + monitor between patient rooms
Purpose: Indicating the type of action they will perform on the patient
Initial condition: Digital interface is turned on
Terminal condition: Type of action of HCP is used as input for the system; the soundscape changes based on this action that required specific needs. After 4 minutes, the soundscape returns to baseline
Primary steps (concept 1):
Access the tool
Select the intended behaviour of the patient
Confirmation
Enter the patient room
Primary steps (concept 2):
Access the tool
Select the action you will perform
Confirmation
Enter the patient room
Alternative scenarios:
The action or intended behaviour is not visible: nothing changes in the soundscape

4 - Patient at ICU, During Admission
Actors: Patient, interface is physical product next to bed
Purpose: to give direct feedback regarding the soundscape at a specific moment
Initial condition: Product is turned on and connected to the system
Terminal condition: The soundscape changes based on the feedback given by the patient (baseline of soundscape changes based on the feedback)
Primary steps (product with buttons):
Interpret the buttons on the product
Click on the button that represents your feedback
Alternative scenarios:
Changed soundscape is not preferable; give more feedback
Buttons do not work; request HCP

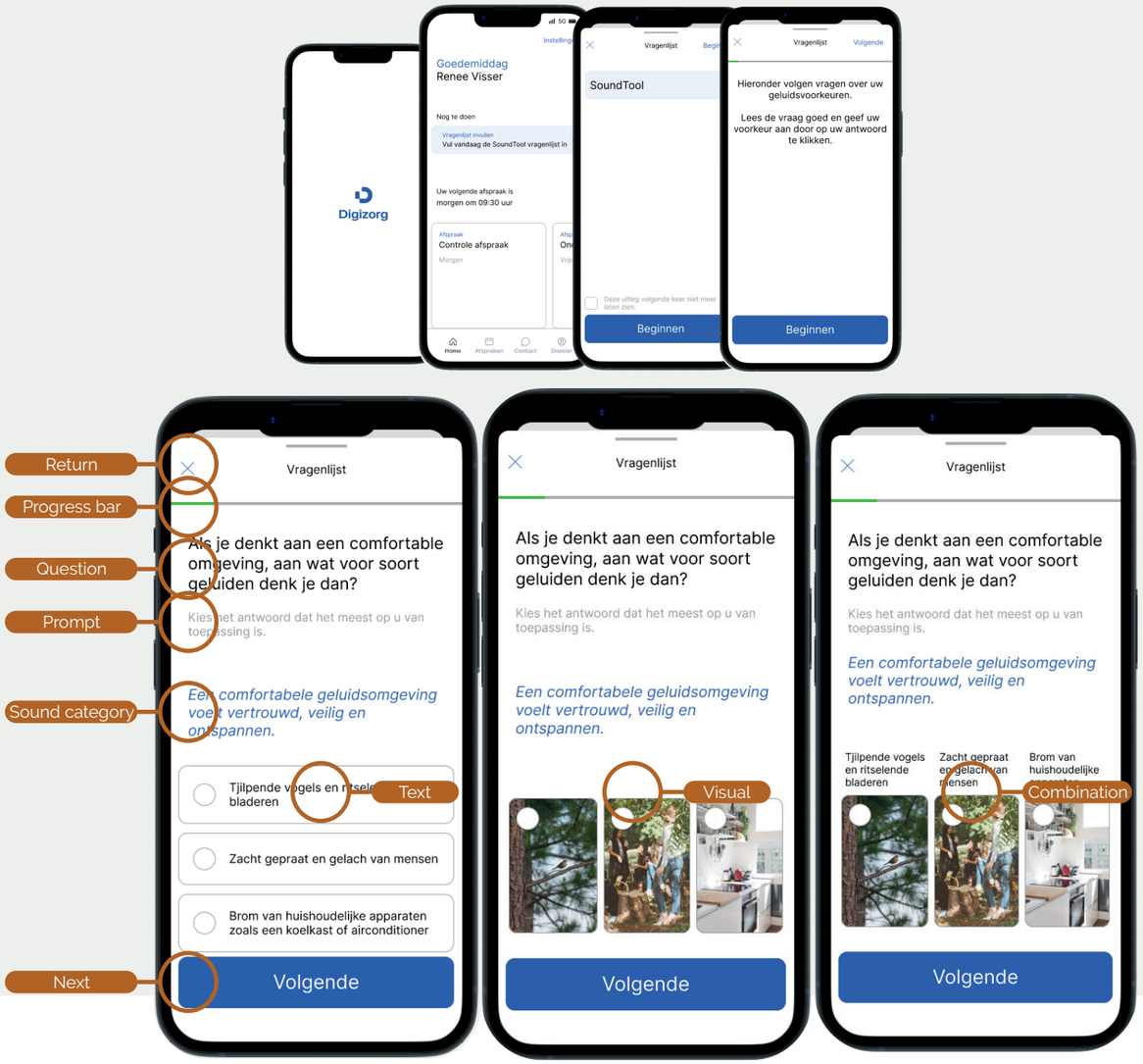
D.3 WIREFRAMES





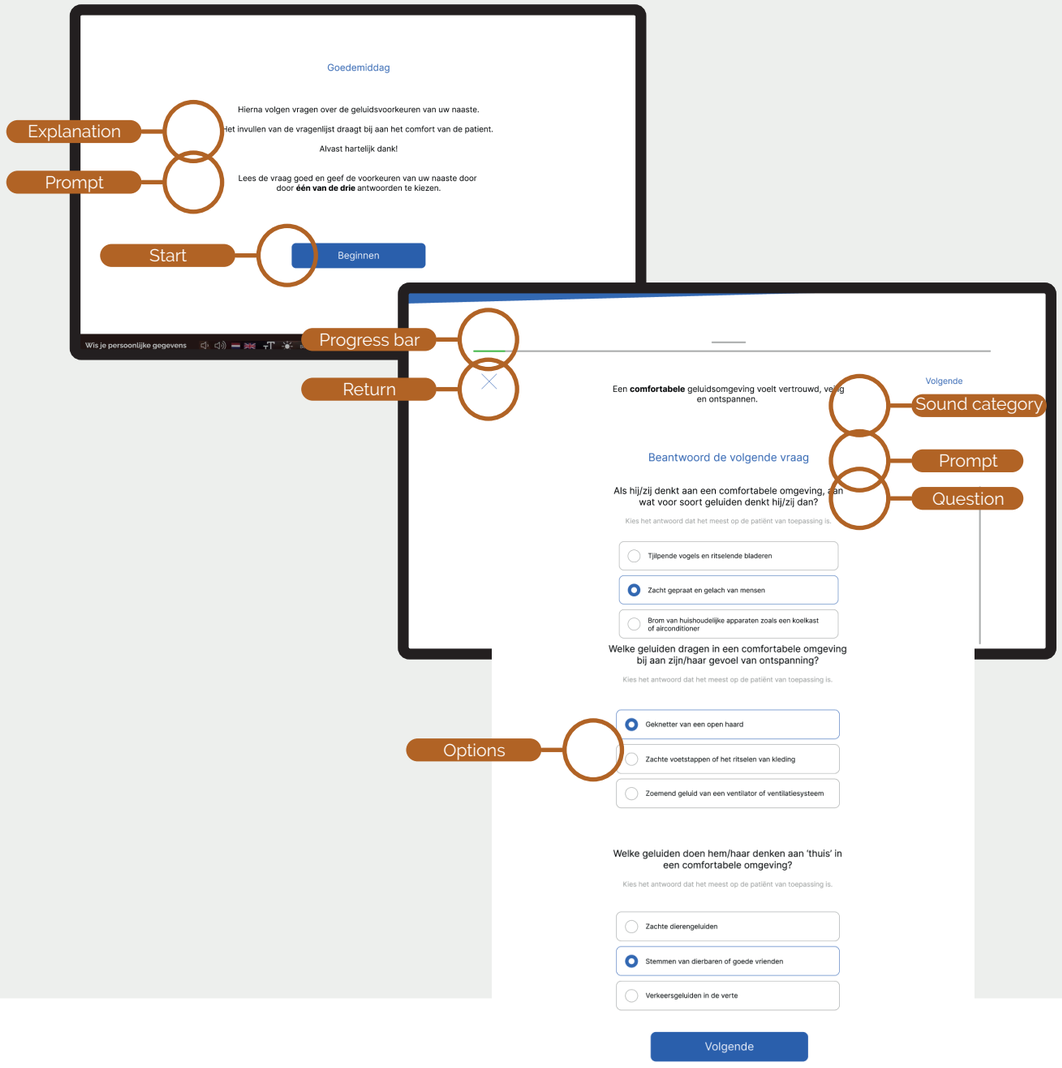
1. PATIENTS, BEFORE ADMISSION

Actors: Patient, DigiZorg app.
Purpose: To communicate their sound prefe-rences as input for the system.



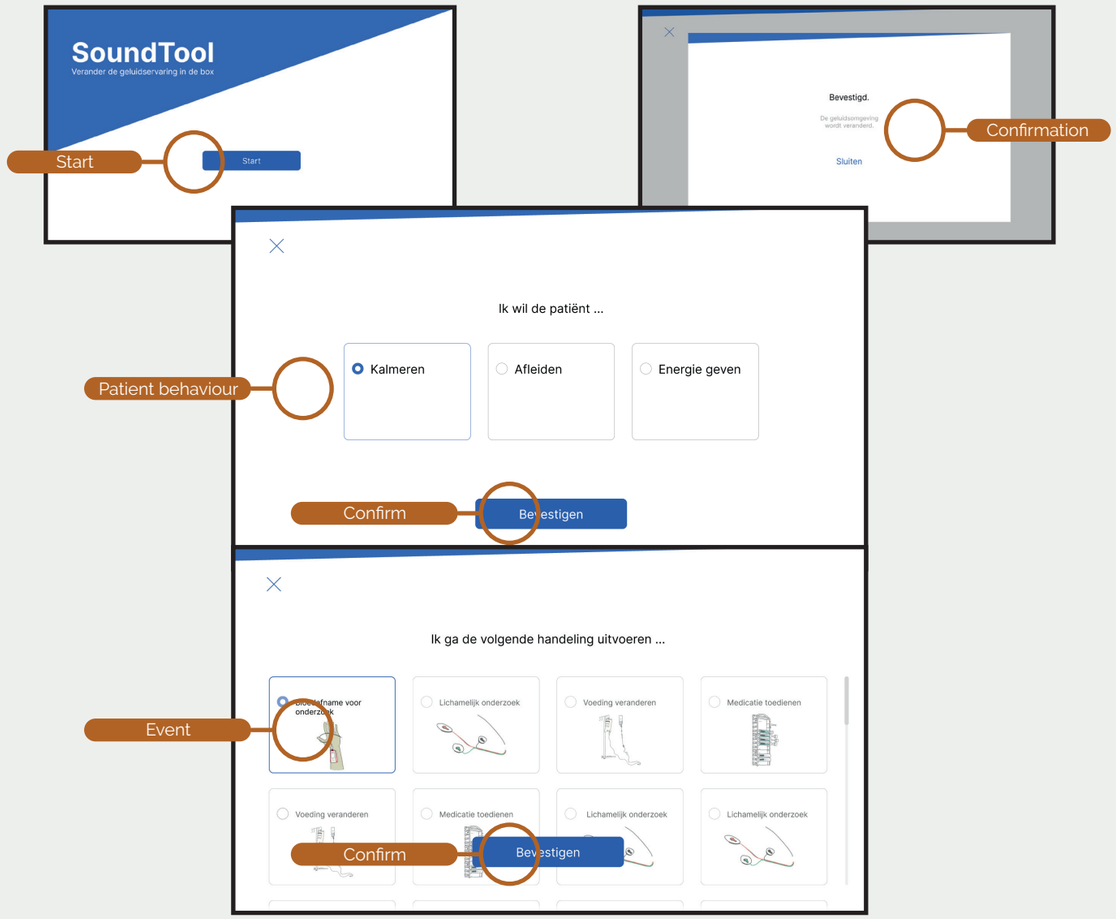
2. LOVED ONES, START OF ADMISSION

Actors: Loved one, Tablet in ICU
Purpose: To estimate the sound preferences of their loved one as input for the system



3. HCPS, DURING ADMISSION

Actors: HCP, digital device next to the door
Purpose: To indicate the behaviour/event to change the soundscape in the room



E. USABILITY TESTS

This appendix includes the handouts and the Harris Profiles used during the usability tests.

E.1 HANDOUT USABILITY TEST 1

Consent form

U wordt uitgenodigd om deel te nemen aan een onderzoek getiteld Soundscape Experience. Dit onderzoek wordt gedaan door Lindy Kok, studente aan de TU Delft.

Het doel van dit onderzoek is om het productidee te evalueren met de gebruiker en zo de effecten van het ontwerp in kaart te brengen. Het zal ongeveer 15 minuten duren. De gegevens worden alleen gebruikt voor onderzoeksdoeleinden en worden geanonimiseerd voor publicatie in het archief van de TU Delft. We vragen u om gebaseerd op een scenario het product te gebruiken. Daarna vragen we u om antwoord te geven op een aantal vragen over de ervaring met het product.

De sessie wordt door middel van een geluidsopname opgenomen.

Zoals bij elke activiteit is het risico van een inbreuk op gegevens altijd mogelijk. Uw antwoorden in dit onderzoek zullen naar ons beste vermogen vertrouwelijk blijven. We minimaliseren eventuele risico's door uw antwoorden te anonimiseren en te beveiligen in een beveiligde online omgeving. Daarnaast worden uw persoonlijke gegevens na afloop van het project verwijderd.

Uw deelname aan dit onderzoek is geheel vrijwillig en u kunt op elk moment terugtrekken.

Als u tijdens of na dit onderzoek vragen heeft, kunt u contact opnemen met de verantwoordelijke onderzoeker Lindy Kok via L.K.Kok@student.tudelft.nl.

Teken hieronder om aan te geven dat u de informatie op dit formulier hebt gelezen en begrepen en dat eventuele vragen over de sessie zijn beantwoord.

Naam deelnemer:

Handtekening

Invulblad Concept 1

Naam: .....

Concept 1	-2	-1	1	2
Dit product voldoet aan mijn verwachtingen.				
Dit product motiveert mij om de vragenlijst in te vullen.				
Dit product is makkelijk te *gebruiken*.				
Dit product is makkelijk te *begrijpen*.				

Voorbeeld

Concept X	-2	-1	1	2
abcdefg			■	■
abcdefg		■		

Invulblad Concept 2

Naam: .....

Concept 2	-2	-1	1	2
Dit product voldoet aan mijn verwachtingen.				
Dit product motiveert mij om de vragenlijst in te vullen.				
Dit product is makkelijk te *gebruiken*.				
Dit product is makkelijk te *begrijpen*.				

Invulblad Concept 3

Naam: .....

Concept 3	-2	-1	1	2
Dit product voldoet aan mijn verwachtingen.				
Dit product motiveert mij om de vragenlijst in te vullen.				
Dit product is makkelijk te *gebruiken*.				
Dit product is makkelijk te *begrijpen*.				

E.2 HARRIS PROFILES

This product meets my expectations.

Participant	Concept 1 -2	Concept 1 -1	Concept 1 1	Concept 1 2	Concept 2 -2	Concept 2 -1	Concept 2 1	Concept 2 2	Concept 3 -2	Concept 3 -1	Concept 3 1	Concept 3 2
1			■	■			■	■			■	■
2			■	■			■	■			■	■
3			■				■				■	
4			■				■				■	
5			■	■			■	■			■	■
6			■	■			■	■			■	■
7			■	■			■	■			■	■
8			■	■			■	■			■	■
Total	13				13				14			

This product motivates me to complete the questionnaire.

Participant	Concept 1 -2	Concept 1 -1	Concept 1 1	Concept 1 2	Concept 2 -2	Concept 2 -1	Concept 2 1	Concept 2 2	Concept 3 -2	Concept 3 -1	Concept 3 1	Concept 3 2
1			■				■	■			■	■
2			■				■	■			■	■
3		■				■				■		
4		■					■	■			■	■
5		■				■				■		
6	■	■				■				■		
7		■					■				■	
8	■	■				■					■	■
Total	-6				2				6			

This product is easy to *use*.

Participant	Concept 1 -2	Concept 1 -1	Concept 1 1	Concept 1 2	Concept 2 -2	Concept 2 -1	Concept 2 1	Concept 2 2	Concept 3 -2	Concept 3 -1	Concept 3 1	Concept 3 2
1			■				■				■	
2			■	■			■	■			■	■
3			■	■			■	■			■	■
4			■				■				■	
5			■	■			■	■			■	■
6			■				■				■	
7			■				■				■	■
8		■				■					■	■
Total	10				8				13			

This product is easy to *understand*.

Participant	Concept 1 -2	Concept 1 -1	Concept 1 1	Concept 1 2	Concept 2 -2	Concept 2 -1	Concept 2 1	Concept 2 2	Concept 3 -2	Concept 3 -1	Concept 3 1	Concept 3 2
1			■		■	■					■	■
2			■	■		■					■	■
3			■	■			■	■			■	
4			■			■					■	■
5			■	■			■	■			■	■
6		■					■				■	■
7			■			■					■	■
8		■					■				■	■
Total	7				1				15			

This product fits well with the way I work.

Participant	Concept 1 -2	Concept 1 -1	Concept 1 1	Concept 1 2	Concept 2 -2	Concept 2 -1	Concept 2 1	Concept 2 2
1			■	■		■		
2			■				■	
3			■			■		
4			■	■			■	
5			■				■	
6			■	■			■	
Total	9				2			

This product motivates me to personalise the sound experience

Participant	Concept 1 -2	Concept 1 -1	Concept 1 1	Concept 1 2	Concept 2 -2	Concept 2 -1	Concept 2 1	Concept 2 2
1			■	■			■	
2			■				■	
3			■	■	■	■		
4			■	■		■		
5			■	■		■		
6			■	■		■		
Total	11				-3			

This product is easy to *use*.

Participant	Concept 1 -2	Concept 1 -1	Concept 1 1	Concept 1 2	Concept 2 -2	Concept 2 -1	Concept 2 1	Concept 2 2
1			■	■			■	■
2			■	■			■	
3			■			■		
4			■	■		■		
5			■	■			■	
6			■	■		■		
Total	11				1			

This product is easy to *understand*.

Participant	Concept 1 -2	Concept 1 -1	Concept 1 1	Concept 1 2	Concept 2 -2	Concept 2 -1	Concept 2 1	Concept 2 2
1			■	■			■	■
2			■	■			■	■
3			■	■			■	
4			■	■			■	■
5			■	■			■	
6			■	■		■		
Total	12				7			

E.3 ADDITIONAL QUESTIONS FOR FG HCPS

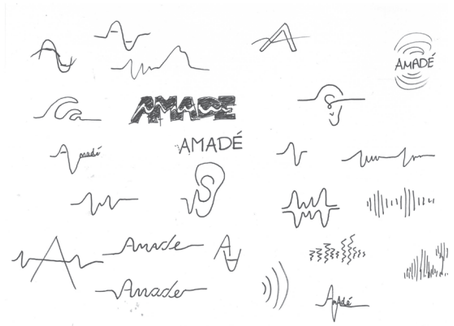
1. Wie ben je en wat is je beroep?
2. Hoelang werk je al op de IC?
3. Wat voor zorgsystemen (computersysteem) worden aangeboden aan patiënten?
4. Sta je weleens stil bij de geluiden op de IC?
5. Ik ben benieuwd met welke intenties je een handeling gaat uitvoeren bij de patiënt? Voorbeeld: Welke staat van de patiënt zou je willen zien wanneer je bloed gaat prikken? En andere scenarios?
6. Welke intenties zijn er allemaal mogelijk?

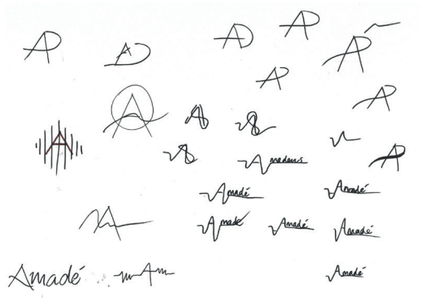
Uitleg over geluidssysteem..

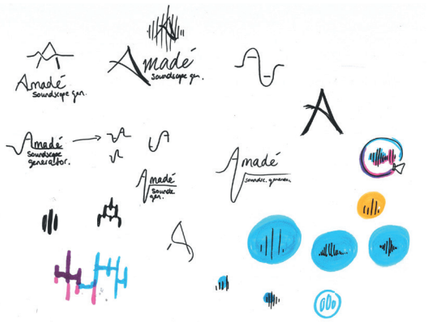
7. Wat verwacht je dat er gebeurt als je op 'X' klikt?
8. Bevat het product nu alle intenties die je zou verwachten op de IC? En waarom?
9. Wat vond je goed / minder goed aan de ervaring?
10. Zou dit product in je workflow passen? Zo niet, wat zou je veranderen?
11. Vind je de locatie van het product passend? Zo niet, waar zou je hem liever zien?
12. Is er iets dat je ervan zou weerhouden het product te gebruiken?

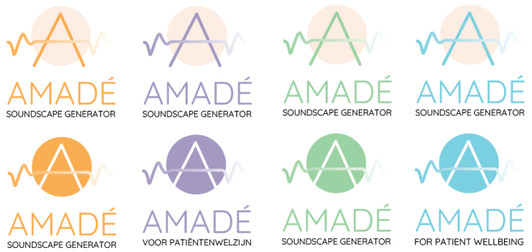
F. ITERATIONS AMADÉ

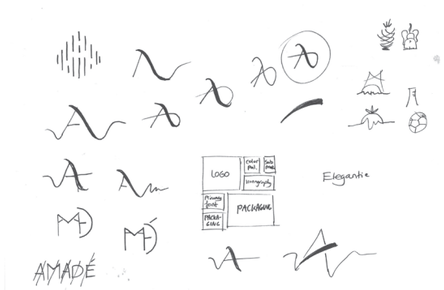
This appendix includes the logo iterations of Amadé, on which the UIs are based.











AMADÉ
AANGENAAM LUISTEREN

G. SOFTWARE ARCHITECTURAL STYLES

This appendix includes the different architectural styles that were considered throughout the design phase.

Due to the complexity of the system, software architecture is essential. It ensures that the system meets its functional requirements, such as security and reliability. Multiple architectural styles have been considered while focusing on the advantages of each style, using Hou (2023). The following table shows the advantages of several styles:

Architectural style	Description	Advantage
Client server	The client sends a request	Scalability, security, reliability
Layering	Breaking down the system into layers	Helps to organize code and makes it easier to maintain over time
Pipe and filter	Separating the processing tasks into multiple independent components	Handling large amounts of data
Master-Slave	One master controls one or more nodes to perform specific tasks	It allows for efficient distribution of workload across multiple nodes
Domain Driven Design	Focus on the business logic of the software, rather than just the technical implementation	A clear understanding of the domain
Component Based	Emphasizes the use of reusable software components	It breaks down a system into smaller, more manageable components
SOA	Create modular, reusable services that can be easily integrated with other services	Services expose their functionality through interfaces, which can be accessed by other services or applications
Event Driven (EDA)	Events are broadcasted to other components of the system, which can subscribe to them and act on them as needed	Rapid and efficient communication between different components

H. EVALUATION TEST PROCEDURE

This appendix includes the procedure of the evaluation test of Amadé.

PHASE 1

Introduction text with consent form.

Interview questions regarding sound perception in the ICU:

1. Who are you?
2. When were you admitted to the ICU?
   o What was the reason for your admission?
   o How long was the admission?
   o In which hospital was the admission?
   o Were you alone in the room?
3. What memories do you have of the sound environment in the ICU?
   o Positive/negative?
4. Did you do anything to change the sound environment?

PHASE 2

Use Case: You will have surgery soon. After the operation, you will be admitted to intensive care. This has been agreed with you. Your doctor recommends a new app that helps you prepare your admission. Please interact with the app and think out loud.

PHASE 3

Interview questions after interacting:

5. How did you find the experience of using the app?
6. Is it clear what the purpose of completing the questionnaire is?
7. Would it add anything to your sense of preparation?

Note that each test has been introduced as a conversation, which leads to other questions being asked during the test. These are not included in this appendix.

PHASE 4

The AttrakDiff questionnaire included the following questions on a scale of -3 to 3:

- Complicated - Simple
- Impractical - Practical
- Unpredictable - Predictable
- Confusing - Clearly structured
- Dull - Captivating
- Unimaginative - Creative
- Alienating - Integrating
- Undemanding - Challenging
- Rejecting - Inviting

EXTRA QUESTIONS

The extra questions for the participant who could not interact with the app were as follows:

- When were you admitted to the ICU?
  o What was the reason for your admission?
  o How long was the admission?
  o In which hospital was the admission?
  o Were you alone in the room?
  o Can you describe your overall experience during your stay in the ICU?
- Sound environment
  o How would you describe the sound environment in the ICU?
  o What specific sounds did you find most annoying/disturbing? Why?
  o Were there any sounds that you found reassuring? Can you give an example?
- Effects of noise
  o How did the noise in the ICU affect you during and after your stay?
  o Did the noise affect your recovery? If so, how?
- Preparation and adaptation
  o Were you informed in advance about the noise environment in the ICU?
  o What would you have liked to know before coming to the ICU?
  o Did anyone in the ICU (e.g. an HCP) help you to cope better with the noise?
  o Do you have any suggestions for reducing the noise?
- Have you done anything yourself to cope with the noise? Can you tell us about it?
- Does the noise from the ICU still bother you now that you are back home?
- Is there anything else you would like to share?

I. PROJECT BRIEF

This appendix includes the project brief from the start of the project.

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Lindy Kok **Student number** 4804082

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Design and validation of a soundscape augmentation system and user interface for intensive care patients.

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

The central goal of the project is to design a soundscape augmentation system and digital user interface that enhances the IC environment for patients. The project is situated in the domain of healthcare, specifically within intensive care units. The primary stakeholders include critically ill patients in the ICUs, their relatives and healthcare providers (nurses and doctors). IDE's Critical Alarms Lab, Philips Design and Erasmus MC are collaborating within this project.

Key stakeholders' interests are focused on improving the overall wellbeing and experiences of ICU patients. The improved soundscape has to reduce stress and enable comfort, motivation and stimulation. Relatives are interested in the wellbeing of their loved ones and their overall experience during their ICU stay. Healthcare providers are concerned with the impact of the ICU environment on patient recovery.

Opportunities lie in the potential to positively influence patient experiences, which would lead to improved health outcomes. Collaborating with Philips Design and Erasmus MC provides access to expertise, resources and real-world insights from medical and design professionals.

Limitations may include the challenge of designing a system within an interdisciplinary project, including design, medical and technical perspectives. The practical operability of the system withing the constraints of an ICU setting combined with medical and ethical considerations need serious condiserations.

➔ *space available for images / figures on next page*

introduction (continued): space for images

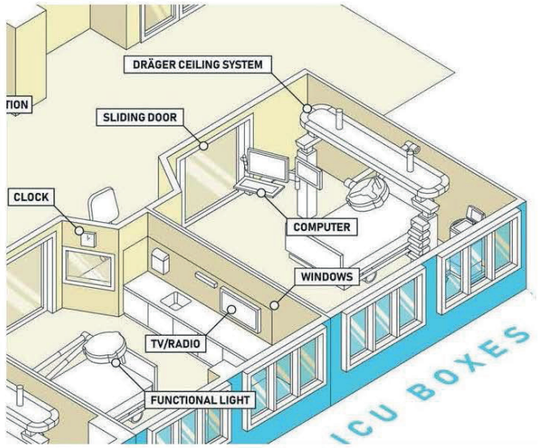


image / figure 1: ICU Boxes in Erasmus MC

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

The current problem within the described context is the negative psychological impact on intensive care unit patients due to environmental factors. The project aims to address these effects. The goal is to design and validate a soundscape augmentation system and user interface for the Erasmus MC Adult ICU.

The ICU patients face stress caused by issues such as challenging sound conditions, difficulties in communication and a lack of stimulation. These factors can contribute to feelings of isolation, fear and uncertainty. The existing soundscape in ICUs may not be contributing to the wellbeing of patients. Because the patients are often unable to do things that stimulate them, it is crucial that the soundscape is beneficial for patients.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design and validate a soundscape augmentation system architecture and digital user interface to improve the current soundscape for patients of the Erasmus MC Adult ICU.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

The project approach involves a collaboration between me and the IDE's Critical Alarms Lab, Philips Design and Erasmus MC. The research and design methods could involve field research with nurses and doctors and industry experts, user scenarios and journey maps, interaction visions, co-creation, digital user interface design, system architectures, UI prototyping and usability testing. First I will start with literature reviews and interviews.

To help me succeed, weekly supervision of two IDE researchers is provided as well as support of an external Philips Design UX/UI designer. I can visit the Philips's High-Tech Campus in Eindhoven, have access to the adult ICU Erasmus MC, nurses and doctors (under supervision) and access to previous ICU graduation projects within Critical Alarms Lab to build on.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting**, **mid-term evaluation meeting**, **green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	February 13
Mid-term evaluation	9th April 2024
Green light meeting	11 June 2024
Graduation ceremony	18 July 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

There are several ambitions that motivated me to do this project: