IMPROVING THE DAILY ICU EXPERIENCE

FROM A CRITICALLY ILL PATIENT'S PERSPECTIVE

MASTER THESIS
BY EVA VAN HOUWELINGEN

ACKNOWLEDGEMENTS

My main focus is to improve people's lives through design. This project gave me the chance to do so. The ICU environment is complex, intense and usually very distant from my daily life, I was strongly drawn to this. It is also an environment where design can be beneficial to the patients. When Elif explained this graduation opportunity, it caught my attention. Gijs informed me of the details of the project, but in reality, he shared his enthusiasm and I knew this was cut out for me.

The project did not start as planned due to a medical complication. However, there was never a moment that I did not enjoy working on it. And after my recovery, it all went very smoothly.

During my graduation, my main goal was to experience, learn and experiment as much as possible. I liked how the project challenged me to do things I had never done before. As an Integrated Product Design student, I was less familiar with the Design for Interaction approach used during the project. Along the road, I learned how to set up and document a research study and use the gathered insights in a meaningful way. Next to showcasing and further developing my design skills, I was also able to develop new skills in software programs such as P5.js and Touchdesigner.

The first thing that interested me was the context of the project, the ICU. The second thing that attracted me was sound. The project allowed me to learn so much more about sound and sound perception. When hearing a sound, I now sometimes wonder, 'Would this sound be pleasurable in the ICU environment?'.
And thirdly, I enjoyed the project's focus on humans. Naturally, this allowed me to contact, talk, and test with many people. I would like to thank all of them.

I would like to start with a big thank you to my chair and mentors.
Elif, many thanks for your guidance and straightforward tips. You challenged me by always asking me to do a little better or a little more.
Gijs, thank you for all the time and effort you put into this project. I liked our sparring sessions; your guidance made the project better and more to the point.
Thank you, Jasper, for your in-depth knowledge, ideas and get-the-job-done mentality.
I always felt inspired after our meetings and filled with fresh energy and ideas.

I want to thank all former patients for sharing their experiences with me and for their continuous dedication and interest in the project.
Thanks to all the experts consulted for making time and sharing their knowledge, wisdom and tips, pushing me further.

Thank you, all nurses and healthcare professionals I have spoken to and observed. Especially Sebastian Wagener, thank you for all your help and thoughtfulness. Thanks to all who attended the co-creation session for your trust in the project and tips.

I want to thank all the participants and share my special gratitude to Marie Eline Moritz, who helped me for two full days during the evaluation of the design intervention.

Also, I want to thank my friends and family, who probably know as much as I do about this topic, as I love to talk about things that excite me. I am incredibly grateful for all your help, opinions, ideas and acting skills. I could not succeed without you.

There is still so much to discover, and there are a lot of challenges ahead, but I am confident that this project can contribute to the first steps toward a more human-centred ICU.

GRADUATION PROJECT

MSc Integrated Product Design
Delft University of Technology
Faculty of Industrial Design Engineering

AUTHOR

E.V. van Houwelingen (Eva)

SUPERVISORY TEAM

Chair Prof. dr. E.Ozcan Vieira (Elif)
Mentor G.L.M. Louwers MSc (Gijs)
Mentor Dr. J. van Bommel (Jasper)

DELFT UNIVERSITY OF TECHNOLOGY

Faculty of Industrial Design Engineering
Landbergstraat 15
2628 CE Delft
The Netherlands
www.tudelft.nl

EXECUTIVE SUMMARY

The intensive care unit (ICU) is a dehumanizing technical environment causing complications that are all captured in the term post-intensive-care syndrome (PICS). The patient's well-being could be improved by moving away from this hostile environment toward more patient-centred care. Therefore this report explores how to improve the daily ICU experience from a critically ill patient's perspective.

Environmental influences in the ICU, like noise exposure, are important contributors to PICS (Abuatiq, 2015). Hearing is the most prominent sense of ICU patients. Thus, the Erasmus ICU is designed to keep sound out. It has been shown that there is no clear relationship between reduced volume levels and physiological improvement (Drahota et al., 2012), and the absence of sound does not necessarily create a positive environment (Truax, 1984). Therefore, this project aims to consider sound in a positive manner since sound is only perceived as noise when it does not fit the patient's state of being.

After many former patients were interviewed and an Erasmus MC ICU nurse was observed, it turned out that it is hard for patients not to focus on their feelings of frustration, loneliness, discomfort, shame, panic, confusion etcetera and still keep a positive mindset. Thus, the design aimed to redirect the patient's focus by connecting the patient to the environment.

The Thirteen Fundamental Needs for Human-Centered Design typology was utilized as a source to design a positive experience for the ICU environment. Six fundamental needs (Stimulation, Recognition, Relatedness, Autonomy, Security, and Comfort) were uncovered. Strengthening these needs could improve the patients' experience.

Mapping a patient's daily routine showed that need fulfilment changes according to the eventfulness, the presence, or absence of people or sound inside the ICU. A patient's journey revealed that the absence of people right after leaving causes the most harm to the patient. Thus, the decision was made to focus on this transition moment.

Eventfulness can be determined by measuring sound pressure levels (SPL) in dB in the ICU. So the transition moment from an eventful (high SPL) to an uneventful (low SPL) environment can be detected and vice versa.

New visual/auditory stimuli were developed. These can be introduced to benefit patients' recovery (Arbabi et al., 2018). The stimuli consist of sounds of nature in combination with a nature-based projection. The audio and the visual stimuli change according to the SPL in the room. This design intervention helps guide the patient into the new environment. It is a subtle way to notify the patient that something is happening. Furthermore, it can distract the patient (when bored or during treatment) and decrease the difference between higher and lower sound pressure levels.

The design was developed, embodied, and finally tested in a simulated ICU environment. The evaluation of the design intervention showed that all participants appreciated the design intervention, mainly because they were distracted from boredom, stress/anxiety, negative thoughts (loneliness) or discomfort. It made the experience more comfortable or relaxed.

Finally, three use cases were presented, redirecting the focus from anxiety, boredom, and loneliness. Additionally, recommendations were made.

GLOSSARY

ICU	Intensive Care Unit
HCP	Health Care Professional
PICS	Post-Intensive-Care Syndrome
SPL	Sound Pressure Levels
PLP	Pressure Level Peaks

The illustrations are created by the author, unless otherwise indicated.

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1.
INTRODUCTION

This chapter introduces the assignment, the goal of this project and explains the design approach.

1.1 ASSIGNMENT AND GOAL

The project focuses on the patients' experience in Adult Intensive Care Units (ICUs) at the Erasmus Medical Centre in the Netherlands. The project forms part of the VitalSounds: Sounds for clinical well-being PhD trajectory of the Critical Alarms Lab (CAL) at the faculty of Industrial Design Engineering and Erasmus MC hospital.

The main aim of the VitalSounds project is to understand if and how we can enhance the fulfilment of the psychological needs of critically ill patients by offering a restorative, patient-centred IC environment.

This project's goal is to contribute to this research by exploring a *possible design intervention to improve the daily ICU experience from a critically ill patient's perspective.*

This project is a collaboration between Philips, the Erasmus MC and Delft University of Technology (TU Delft). The project is conducted at the Erasmus MC IC Volwassenen (ICV), ICU for Adults. The context of this project will therefore be the Erasmus MC ICV, being recently renovated and a modern representation of hospitals. Experimental studies are conducted at the Industrial Design Engineering (IDE) faculty of TU Delft.

1.2 APPROACH

The core of the design process to create *a possible design intervention to improve the daily ICU experience from a critically ill patient's perspective* is set around the double diamond method (Figure 1). When the goal was set and the design brief written (Appendix 1), I needed to know more about the context. In the first phase, it was important to explore the context until a problem statement could be formed.

Discover

A literature study helped me to become familiar with the environment to gain knowledge about the ICU, the ICU patients and their experience of the ICU. The next step was to better understand their perception of the ICU. It became clear that sound would play an essential role in contributing to the perception of the ICU. Aside from the literature research, I also analysed the ICU box, patients, and the ICU experience first-hand.
As a starting point, I started mapping the context (Stappers, Sanders, 2004). I got a good impression of the ICU patient experience using this method. To understand the users and their needs, I interviewed eleven former patients. Moreover, I observed a nurse for two days in the ICU at the Erasmus MC. In doing so, I fully experienced the ICU environment myself. I was able to understand the patient's experience second-hand and also the nurses' perspective. Observing creates the opportunity to better understand the patients' needs, the daily routine, and the related sounds at the ICU.

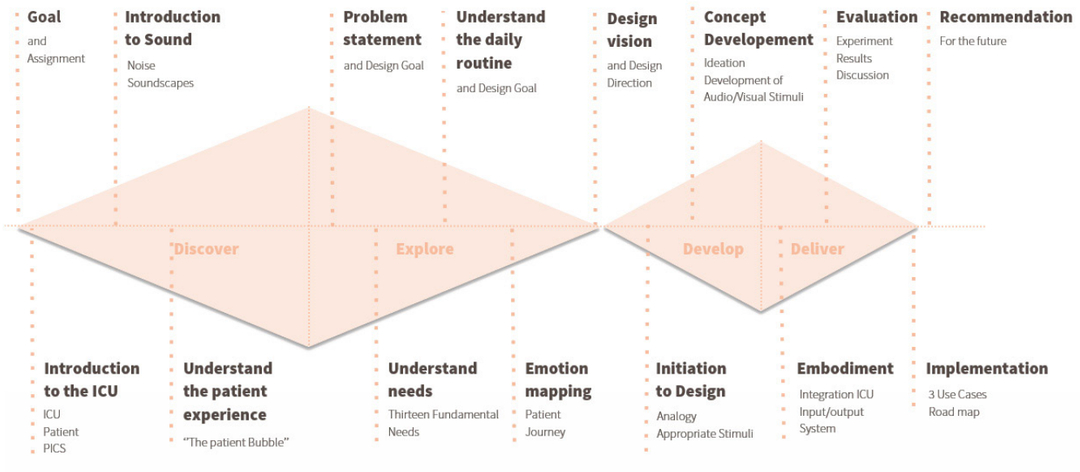


Figure 1: The design process.

Explore

After a period of discovery, it was time to scope down the focus. In this second iteration circle, I conducted a questionnaire filled in by twelve former patients. 'The patient experience' overview and emotion maps highlighted the opportunities for a design vision.
All gathered insights from fieldwork and literature combined did serve as the basis of the design opportunities. From there, the first ideation phase began, during which the possible design directions were explored.
The first diamond was completed when the design direction and the characteristics of the solution were decided. In the next phase, I could start exploring different design solutions.

Develop

The second half of the diamond started. With the direction being clear, only the concept needed to be developed. For example, whether the intervention would be auditorial or also visual. We continued to diverge. Exploring ''The sound of care", or perhaps better ''The best sound for care", and the type of visual experience. A co-creation session was organised with the ICU nurses, and multiple experts were consulted to make the right decisions and for inspiration.

Deliver

Low and high-fidelity prototypes were created and tested to select and evaluate the concept(s). The final concept was further embodied and eventually evaluated. Due to strict regulations, this final concept could not be tested with actual ICU patients. For this reason, a simulated ICU environment was created to test with participants in the most realistic way possible. Then the concept was finalised, and further recommendations were provided.

2.
INTRODUCTION TO AN ICU STAY

This chapter gives an introduction to the Intensive Care Unit (ICU). The goal is to give a clear image of what an ICU is, what type of ICU is within the scope, the purpose of an ICU and sensory perception of an ICU. Furthermore, patient well-being is discussed to give some more context to understand the severity of an ICU stay and its impact on patients' lives.

2.1 THE ICU

When a patient is critically ill and potentially recovering from a life-threatening situation, the patient is then admitted to the highest intensity of care in the hospital: critical care. 71.214 adult ICU patients were admitted to critical care in Dutch intensive care units (ICUs) in 2020 (Stichting NICE, 2021).

Critical illness is defined as acutely impairing one or more vital organ systems to such an extent that there is a high probability of imminent or life-threatening deterioration in the patient's condition (Stichting NICE, 2021). ICU patients, therefore, need careful guarding and treatment.

Disrupted or failing organ systems (e.g. lungs, liver, kidneys) can be supported or replaced; ICU medicine can facilitate this. After patients leave the ICU, they are either admitted to general hospital wards or discharged from the hospital partially or entirely.

Generally, this is what happens in the ICU, but not all ICUs are the same.

2.2 SILENT ICU AT THE ERASMUS MC

There are a variety of different ICU environments in hospitals in the Netherlands and across the world. For this project, the scope is set on the Erasmus MC ICU. Over the years the Erasmus MC has made a great effort to make its ICU boxes more comfortable and safe for ICU patients and Healthcare Professionals (HCPs).

Currently, the patients all have their private ICU boxes. This box provides more privacy and is sealed with a soundproof door to prevent the patients from hearing other patients cry out or hear other alarms. That is why the boxes in the Erasmus are called Silent ICU boxes. Inside the box, you only hear occasional syringe pumps that run out or empty. You may hear occlusions in intravenous lines and, maybe most striking, the vital sign alarms that get louder and louder as readings deviate from the set parameters to draw staff attention to potential dangers (Park et al., 2014).

At the Erasmus ICU, the nurses take care of one, or sometimes two, patients during their shift. To stay in touch with their patient and hear the alarms at all times, they carry a portable personal monitor (pager) with them.

Most boxes have a window on one side and, on the other, a smaller window for the nurses to watch the patient from behind the desk. The door with a large glass window allows them to see the patient from the corridor.

The ICU box with the IC medicines/machines and many ways to monitor and observe the patients contribute to a very efficient and sterile ICU environment. This focus is accompanied by a dehumanizing technical environment.

A recent appreciation of the effects of comfort and respect for human values in the ICU affirms that moving from a dehumanizing technical environment to a patient-centred environment could improve overall patient well-being during and after admission (Dijkstra, Pieterse and Pruyn, 2006). This could create an opportunity for the Erasmus MC to investigate the effect of the hospital environment on the patient.

2.3 THE ICU PATIENT

As the reason for admission to the ICU varies enormously, there is not one general type of ICU patient. Age, sex, illness severity, mental health, cognitive state and many more factors can be used to differentiate a patient. Also, an ICU admission length differs from a few hours to a few months.

The average age of an ICU patient in the Netherlands is 63 years old and ranges from 18 to 95 (Zimmerman et al., 2013). Three types of patients are admitted to the ICU: reasons differ from patients undergoing elective (planned) surgery, emergency surgery, or patients admitted for medical reasons (e.g. sepsis). In 2020, 57.4% of the admissions were medical, 11% an emergency, and 31.5% planned of the total 62.9% were male (Zimmerman et al., 2013). These groups can further be categorised into high, medium or low-risk admissions. Patients with an associated risk of death of ≥70%, ≥30% - <70%, or <30%.

Many patients do not recall anything about the ICU stay, or only partly. That is because most patients sleep a lot, are on heavy medication and/or suffer from post-intensive-care syndrome (PICS).

2.4 POST INTENSIVE CARE SYNDROME (PICS)

The term PICS captures all complications after ICU admission (Antonius ziekenhuis, 2022), e.g. physical weakness, long-term cognitive impairment, post-traumatic stress disorder (PTSD) and depression in the term PICS (Post Intensive Care Syndrome). ICUs are often described as inherently hostile environments for their occupants. So, it is not surprising that not only the patients but also their family can suffer from PICS (PICS-Family).

Delirium experienced during an ICU stay is a major risk factor for PICS symptoms. Delirium (Figure 2) is a mental state in which you are confused, disoriented, and unable to think or remember clearly. However, it is often temporary and treatable. Many problems can cause delirium, including hospitalization, especially in intensive care (Health Topics, 2022).

Each year up to 80% of patients admitted to ICUs suffer from delirium (Rawal, Yadav and Kumar, 2017). For a designer, it is important to bear in mind not to deteriorate a possible delirium. However, it also creates the possibility that with appropriate intervention, fewer patients may suffer from delirium in the future.

Figure 2: Delirium.

2.5 CONCLUSION

This chapter helped to gain a better understanding of the ICU environment, especially the Erasmus MC ICU. The ICU patient was introduced as well as the Post Intensive Care Syndrome most patients suffer from. Furthermore, it was mentioned that environmental influences in the ICU are seen as important contributors to PICS by affecting the course of delirium (Zaal et al., 2013), important stressors are sleeplessness and exposure to light and noise (Abuatiq, 2015 and Zengin, 2020). Therefore, we will dive further into the patients' experiences in the following chapters to understand this relationship with environmental characteristics.

3.
INTRODUCTION TO SOUND

Like any other person, patients detect the world via their senses. The body perceives five basic senses: hearing, touch, sight, taste, and smell (Sprouse, 2022). Sensations are collected by sensory organs and interpreted in the brain. With the information gathered by our senses, we know where we are, if we are safe, and they allows us to communicate or react to stimuli.

Senses connect patients to their environment. For that reason, the intensity and importance of senses in the ICU differs. In the ICU environment, the sensory modality mainly revolves around sound. Sound is patients' way of being informed about their surroundings and helps to communicate and gather information. As a result, the way they perceive sound is a key element to the perception of the total experience.

In the next chapter, we will discuss the role of sound in the ICU.

3.1 WHY SOUND?

Sound is universal.
Sounds can exert on emotions, mood and, thus, body and psyche.
Sound is a subjective influence on the perception of the patient.

Eyesight is the most important sense for a human being since it provides the most information to the brain per second and the second most information-rich sense is hearing. (Sprouse, 2022). Sound plays a more prominent role in the hospital environment since patients cannot choose to close their ears, unlike their eyes. They involuntarily notice changes in the environment by an increase or decrease in sound, like alarms turning on and off or people going in and out of the room.

Additionally, patients that are too weak to open their eyes or patients whose field of vision is restricted can focus on sound events. For instance, (partially) paralysed ICU patients cannot fully rotate which limits their view of the surroundings. In this case sounds can provide essential information.

Patients can be sedated/comatose, and it is questionable if they experience anything in this state. On the other hand, they can be conscious and experience the ICU environment relatively positive or negative. This depends on their perception. Their perception is mainly based on what they hear.

You can only hear something if you are listening. There are different ways one may listen. The way patients listen is the most common, the most easily influenced and deceptive mode of listening: casual listening (Tuuri and Eerola, 2012). Even when listening without showing much attention, your subconscious is alert.

According to Salandina, Arnold, and Kornadt (2011), hospital staff and patients are exposed to a complex sound environment or soundscape. A soundscape is essentially the auditory version of a visual landscape (Halletal. 2013) and considers what sound means to the individual (Schafer, 1976; Truax, 1984). This acoustic environment's perceptual representation looks at a holistic collection of sounds.

Within healthcare design, the soundscape is often overlooked. But to improve ICU environments, it is important to understand the impact of sound and the feelings that different soundscapes can evoke (Luetz et al., 2019). The perception of sound is subjective by nature and therefore challenging. Still, acoustics can also be an ally offering opportunities, for example, by inducing relaxation in an unfamiliar and/or frightening situation or by providing a quiet, supportive environment for recovery.

Figure 3: Why sound?

3.2 NOISE AND NOISE PERCEPTION OF PATIENTS IN THE ICU

As mentioned earlier, environmental stressors, such as high-noise levels and inappropriate lighting conditions, can cause complications, such as delirium (Abuatiq, 2015).

However, noise levels are only one aspect of the soundscape. Recent studies show new knowledge on noise, specifically that changes in sound level may be more disruptive than continuous sounds. In particular, those arising from lower (versus higher) baseline sound pressure levels (Jaiswal et al., 2017). Furthermore, it is important to note that the absence of sound does not necessarily create a positive environment (Truax, 1984), and it has been shown that there is no clear relationship between reduced sound pressure levels and physiological improvement (Drahota et al., 2012).

Kamdar (2020) also states that to improve the ICU soundscape, one can reduce the absolute noise or attenuate the impact of noise on the patient. The impact of sound on the patient's perception can be, aside from negative (noise), also be neutral or even positive, as it was found that individuals adopted coping methods by accepting and habituating to aspects of the soundscape (Mackrill, 2013).

In addition, according to Park et al. (2019), the staff members produce 57% of the acoustic energy and 92% of the PLPs (Pressure Level Peaks). But, it is questionable how much of this sound is perceived as 'noise' or negative because patients may perceive speech or activity-generated sound events to be more familiar.

So, we will not investigate a percentage of the acoustic energy, but focus on the perception of the sound in the ICU. Because understanding the perception of sound offers a way to improve the effect of sound.

3.3 CONCLUSION

TThis project aims to consider sound in a positive manner in ICU spaces, rather than achieving the absence of sound. This approach contradicts the negative association of sound and noise in the ICU environment because *sound is only noise when it does not fit the patient's state of being.*

4.
UNDERSTANDING THE PATIENT EXPERIENCE

It is important to get a clear overview of the current ICU experience. We want to learn what contributes to the patients' well-being, in other words, the needs of patients and whether these are fulfilled. So we can understand when patients have pleasant or unpleasant experiences or emotions. We will continue to do so in the next chapter.

4.1 THE STATE OF BEING

In his paper "A Theory of Human Motivation" Abraham Maslow introduced the Hierarchy of needs theory (Figure 4). The hierarchy includes five categories, starting with physiological needs at the base, moving up to safety needs, social needs, esteem (or ego) needs, and finally, self-actualization needs (Maslow, 1943). These needs are essential for people and, therefore, patients' well-being. Beyond their crucial role as nutrients for well-being, needs are also a strong direct source of meaning and pleasure (and displeasure), as Sheldon et al. (2001) stated.

Events and situations that fulfil our needs are experienced as meaningful and pleasurable. So, to understand the ICU experience, we need to know what events and activities take place and if these fulfil the patient's needs.

Maslow's theory was used as the basis to develop a typology to provide a practical understanding of psychological needs as a resource for user-centred design practice. Desmet & Fokkinga (2020) developed a complete, design-focused typology of human needs, consisting of 13 fundamental human needs (Desmet & Fokkinga, 2020). The needs included in this typology are the need for *Autonomy, Beauty, Comfort, Community, Competence, Fitness, Impact, Morality, Purpose, Recognition, Relatedness, Security,* and *Stimulation*.

To improve the ICU patient experience. The Thirteen Fundamental Needs for Human-Centered Design typology will be utilized as a source to design a positive, user-centred experience for the ICU environment in later chapters. The needs of the patients must be identified beforehand, as needs play a necessary part in human well-being and positive experiences. This can help to divert the patient's emotions from displeasure to pleasure.

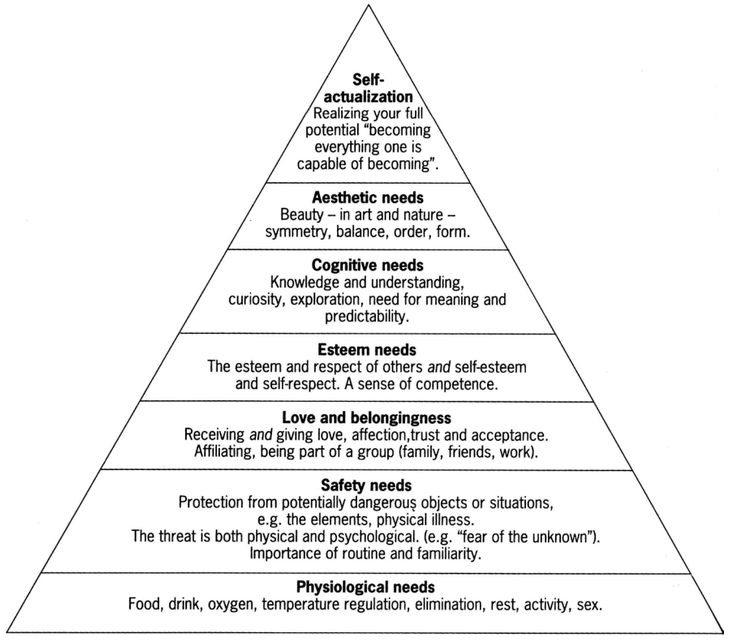


Figure 4: Hierarchy of needs theory, (Maslow, 1943).

4.2 THE PATIENT'S EXPERIENCE OF THE ICU

First, we need to collect information on the events and situations in the ICU and how the patients experience these. In other words, what was the emotional response of the patients (pleasant or unpleasant).

According to the theory of emotions, emotion is elicited by an evaluation (appraisal) of an event or situation as potentially beneficial or harmful (e.g., Arnold 1960; Scherer, Schorr, & Johnstone, 2001; see Desmet, 2002 for an overview). Therefore, we require an understanding of what kind of stimuli there are in the ICU and the patients' concerns. Those combined determine what their appraisal is of the ICU environment.

The researcher observed an ICU nurse for two days at the Erasmus MC adults ICU to collect this data. During shadowing, it became clear that no ICU stay is the same, as no patient is the same. It was expected by the researcher that there would be a chaotic environment where there would be an emergency after emergency. However, the atmosphere was much calmer. There was a more constant state of alertness as the nurses continuously monitored the patients to keep them stable.

To further gain an understanding of the patient experience, semi-structured interviews with eleven former patients were conducted.

Participants

Many patients do not have any memory of their ICU stay. Therefore, it was important that the former patients could recall events or sensations that had happened during their stay. The extent of remembrance depends on the participant.

It is essential to notice that even if patients do not remember what happened afterwards, it does not mean they did not experience anything during their stay. How they experience something at that specific moment is still a vital factor impacting their recovery. An impactful experience, good or bad, can become something they will never forget.
The participants were approached via the personal network of the researcher, and most of them replied to one of the social media posts. Due to the potential vulnerability of the participating group, HREC approval was obtained from the Human Rights Ethics Committee of Delft University of Technnology (Appendix 2).
Among the participants were seven males and four females aged between sixteen and sixty-two during the ICU stay. Some were admitted a few weeks (2022), up to a few years ago (2009). They went to different hospitals: Erasmus MC, Radboud UMC Nijmegen, Beatrixziekenhuis Gorinchem, Reinier de Graaf Delft and even Saint Peter's Hospital in Chertsey, England. Six of them were ventilated by a machine, and all had a different admission: spinal cord injury, car accident, corona or an unexpected open-heart surgery. The length of the stay varied from two and a half days to thirteen weeks.

Procedure

The interviews were mainly held via phone or zoom call. Two of them were performed in real-life. The interview durations differ from 30 up to 60 minutes. Before the interview started, the participants were informed about what would happen and the interview's purpose. After they approved the conditions, they signed the consent form (Appendix 3). The interviews were in Dutch, as this was the preferred communication language of all participants.

Questions

General

When did you stay in the ICU?
How long did you stay in the ICU?
How old were you at the time?
To which hospital were you admitted?
What kind of ICU?
How many people stayed in the room?
How would you describe your experience in the ICU?
Were you ventilated?

Daily routine

Did you have a sense of time? Day/Night?
Do you remember what a day in the ICU looked like approximately? Morning/ afternoon/ evening?
What happened in a day? Can you remember certain events?
What was pleasant? Or unpleasant?
Were you able to have visitors?
Were you able to sleep (well) in the ICU?

Needs

What were your needs?
What exactly did you want or not want?
Did those needs change?

Sounds

Did you remember sensory experiences (smell, taste, touch, hearing, sight)?
Do you remember what you heard in the ICU (environmental sounds, equipment, patients, staff, visitors)?
Which sounds did you dislike (alarms, other people, etc.)?
Which ones did you like (other people, music, visitors)?
Was there music to be heard?
Do you think sounds would have been pleasant?

Concluding

Do you have any tips or tops for a better ICU experience, before and/or after your ICU stay?
Do you have 'material' documentation, a booklet, a diary, or photos?
What would it be if you had to give a metaphor for how you felt in ICU? And why?

Results

The interviews can be found in Appendix 4. All gathered insights were put on statement cards (Appendix 5). These cards were sorted and categorized. Different groups were created that consisted of larger themes related to the patient's experience (Figure 5). The final result will be discussed and explained in the next paragraph.

There are three divisions in the figure 5. 'The patient bubble' in the centre represents the physical and psychological experiences that admission to an ICU entails. The subsequent division surrounding 'the patient bubble' is called 'Isolation'. This division shows factors that isolate/direct a patient inwards or make them more aware of their predicament as a patient. Lastly, the outer layer is the 'environment', which includes all environmental influences that positively or negatively affect the patient's state of being. This figure will be further elaborated in the following paragraphs.

4.2.1 THE PATIENT BUBBLE

The patient bubble (Figure 6) is the inner division c the figure. And it consists of two parts, the physic and psychological experiences of admission to a ICU.

Physical

An ICU stay is tough on the human body. Patient notice this in many ways:

They are in a lot of pain, lose control over their bodies and privacy, and can get thirsty or hungry.

> ***"I was so exhausted and in a lot of pain. I wanted more medication, but I wasn't allowed" — P1***

Their bodies use all their energy, making them exhausted. Logically, they cannot shower. This makes them feel dirty, one of the many reasons they feel uncomfortable.

Mental

Everything is very uncertain, as P9 wondered:

> ***"What is happening to me?" - P9***

Patients can only lie in bed and wait. They do not know if they will survive. Not knowing what they are suffering from or how severe it is. They feel lost. During the ICU stay, patients experience a lot of emotions and feelings. They feel lonely, worried, dirty, embarrassed, panicky, and are anxious they will die. They are confused in many ways. Everything is uncertain, unclear, fuzzy, and they depend on others. Most former participants had trouble remembering all that had happened during their stay. Aside from that, they can have these weird realistic dreams/nightmares, which creates even more confusion. The mental state in which patients are extremely confused, disoriented and unable to think or remember clearly is known as a delirium.

> ***"What is real and what isn't? It is still unclear to me." — P2***

Figure 6: The patient bubble.

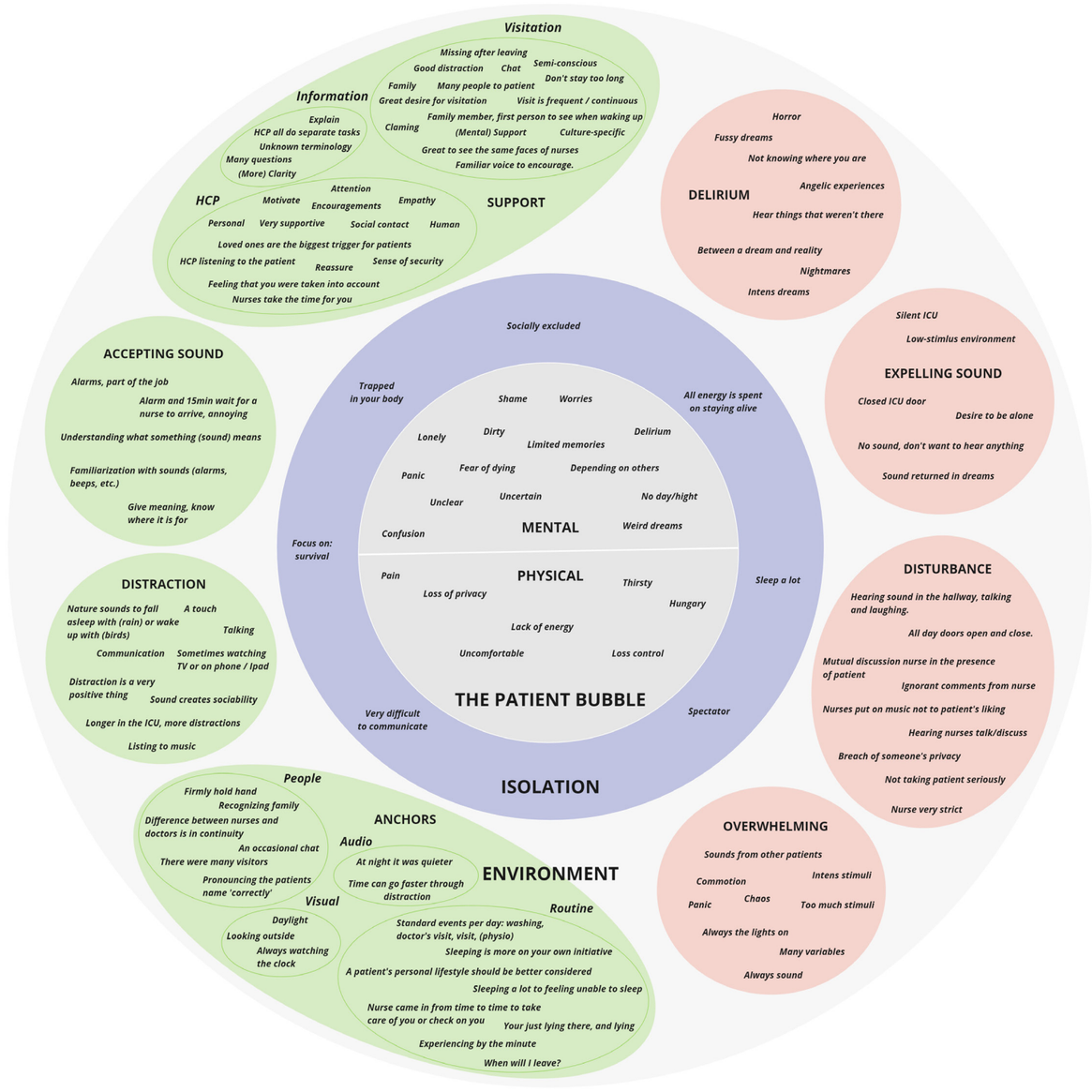


Figure 5: The ICU experience.

4.2.2 ISOLATION

The isolation division relates to factors that isolate the patient, let the patients dwell further into "the patient bubble" towards a more negative mindset, or make them more aware of their predicament as a patient.
A physical factor contributing to an isolated state is that patients are unable to move and too weak to get out of bed. So they lose their mobility and, therefore, a big part of autonomy. They have to rely on the help and care of healthcare professionals. They need all their energy to fight for their lives and their very tiring recovery (P1). The one thing on their mind is surviving (P10). Due to this lack of energy, it is hard to move, and they feel locked up in their bodies (P4).

> *"I did not have the strength to push the emergency button"—P5*

Secondly, six out of twelve of the former patients were intubated, disabling them from talking. Even if they are physically capable of doing so, it takes a lot of energy to talk (P10), making it hard to communicate and causing social exclusion (P4, P5, P9). They feel like spectators (P4), locked inside a metaphorical bubble. Only able to observe the outside world.

4.2.3 THE ENVIRONMENTAL INFLUENCES

The environment plays a big role in the perception of the ICU patient experience, and it does impact not only the appraisal of the experience, but also the course of delirium. Therefore, it is vital to identify and understand the different environmental aspects that negatively or positively affect the patient's state. Some will make the patient feel even more isolated, and others will help to connect and drive them outside their patient bubble. They can be seen as push and pull factors. In green are the pull (out off) factors, and in red are the push (back in) factors.

Expelling

The goal of the silent ICU is to expel all sound from the box for a good reason. Patients enjoy it when it is quiet, and there are fewer stimuli. Less sound appears to help people sleep, which patients do a lot in the ICU. Noise can prevent patients from sleeping (Mackrill, 2013). That is why, for example, the door connecting the ICU box to the corridor is preferred to be closed. The silent ICU seems to be a great solution.

> *"It is nicer when the door is closed". — P1*

> *"The door needed to be closed at all times." — P11*

Some people want to not only expel sounds but all stimuli, including light and people except visitors, but not for too long (P11). P11 talking about the end of a visit:

> *"Relieved because you are so tired. Good that it's done. But it is the most valuable." - P11*

One specific type of patient wants to be alone and only wishes for silence. The Erasmus MC nurse stated that these are, most of the time, patients with a brain injury.

Accepting

But not all sounds can be expelled from the ICU environment; some sounds are inherent in the environment, which makes it easier to accept that they are there. None of the interviewed (former) patients described the continuous alarms as extremely annoying or disturbing, and only some did at night. However, they got used to it, and because they knew the purpose, it could make them feel safer.

> *"Equipment noises. Not great, you get used to it, when you know what it's for." —P1*

> *"I got used to the beeps." — P5*

> *"Beeping machines are part of it. And I just asked what it meant." — P7 and P8*

If they knew what it meant, it could even provide a feeling of security. However, alarms continuously producing sounds until turned off by the nurses could cause anxiety and frustration. P11 said: *"You get nervous from the alarms. A nurse must turn them off."* And P5: *" Alarms were annoying if they lasted 15 minutes."*

The ICU at the Erasmus MC is perceived as very silent. Some patients and nurses even perceive it as too silent. For that reason, one nurse suggested adding sounds during the observation at the Erasmus IC.

Overwhelming

But it is important to always take the status of the patient into account. A few stimuli can easily become overwhelming. For example, P2, P3, and P11 were patients that wanted a low-stimulus environment.
P6, who was admitted to a hospital in the United Kingdom, said:

> *"There was always a commotion. Distress." - P6*

When patients already experience a lot of fuss, any stimuli (sounds, light, or people) may be too much. The (silent) ICU of the Erasmus already attempts to prevent this from happening.

However, even one specific stimulus can have a major impact, such as hearing another patient's call at night, which prevents the patient from sleeping or makes them hyper-sensitive to the next sound.

> *"I heard someone on the other side calling out at night"—P1*

Or the lights being continuously on can drive a patient mad.

> *"Can't sleep, it is too bright." — P6*
> *"There was a sharp green light, all the time".- P9*

Overwhelming stimuli can push patients further inside their bubble into an even more isolated state. This makes it easier for their minds to focus on the negative aspects of their situation.

Distracting

Distraction is another pull factor. When patients are together with others like nurses, doctors or loved ones, this can result in having a positive effect by distracting the patients from their fear, pain, or loneliness. Distractions can be people talking, playing music, or the touch of a hand.
As the length of the stay increases, patients seek more distraction media. For example, P5 (6 weeks):

> *"Distraction: TV by the bed, listening to music, radio, classical music, yes fine, especially in that condition. " - P5*

P8 even tried to improve his sleep:

> *"I played rain sounds to get to sleep. Worked pretty okay." - P8*

The nurse mentioned that distraction is something very beneficial, as the patient's mind is directed to something else, something more positive. For example, P8 always wanted people around to support, comfort, and prevent loneliness. People are the number one favourite distraction of patients.

> *"I needed emotional support. Having someone there all the time. When you think you're going to die, that someone is there." — P8*

But that also means that patients miss their loved ones after they leave.

Disturbance

On the one hand, nurses talking can be comforting and cosy:

> *"It's what you expect. Weirder if it was dead quiet, and sound to me does represent sociability. Two people are having a conversation, confirmation that you are in a normal place. More human. — P4*

But this distraction or sound can also be perceived as more disturbing:

> *"I could hear the nurses in the hallway, talking and laughing. Didn't want to hear it at the time." — P5*

> *"I was close to the consultation room. I heard conferring with a patient. Weird." — P5*

> *"They turn on the radio, but mostly for themselves, 100%NL or something." — P10*

> *"The nurse said to me: " Well, you have already used your deductible for healthcare." I was very angry about that comment." — P11*

The nurses sometimes talk about you like you are not there (P1), make ignorant comments (P5), act very strict (P10), or do not act as if they take you seriously (P11). The disturbance makes patients long for more peace and quiet or positive care, but that remains hard to communicate. HCPs should always consider the impact of their actions on the patients as they could push the patient into a negative mindset.

Delirium

Hospitalization in combination with medication, sleep deprivation, pain etc. (Health Topics, 2022) can cause delirium, which can influence the ICU experience intensively. And this pushes the patient further into the patient bubble.

Patients can even start to experience surreal things. They can hear sounds or see things that are not real. They can even feel like the staff is trying to kill them and have much more nearly realistic experiences.

> *''I had very strange dreams. And though I heard music all day long. German and Dutch mixed together." — P9*

> *''At a later stage, I came up with an entire escape plan." — P5*

> *"I didn't know where I was, I thought in a laboratory" — P10*

> *''I heard sounds that weren't there. Horror. Nothing was there to calm you down. ''—P2*

Most have a very frightening experience, but fortunately, P3 had an almost angelic experience:

> *''Sweet dreams. Delirious, though. On a boat. They were pretty great dreams." — P3*

Anchors

On the contrary, there are anchors, things that help people connect to the real world and push patients out of the bubble. There are some great examples of *anchors*.

Visual

Multiple patients mentioned they would watch the clock the whole time (P3 and P11). They did not necessarily realize what time it was and sometimes were not even able to tell the time. Most patients (9 out of 11 participants) did not understand if it was day or night during their ICU stay.
Patients say :

> *''It is always dark" - P8 and P9*

or

> *''The lights are always on." - P7*

But some do:

> *''At night, the light is disturbing. The pumps and monitors give off light." - P10*

Nevertheless, the clock served as an anchor. It is something to focus on. For others, the window fulfilled the same function. Looking at nature provided comfort and connection to the ''real world" (P10), and the amount of sunlight could indicate the time of the day (P1).

> *"The best thing was that I could see the trees."—P10*

Audio

Interestingly, some would know it was night because it was quieter (audio anchor), and fewer things happened.

> *'' I noticed that it was quieter at night." — P5*

People

> *''I was experiencing it by the minute. Not by the day. I switched my mind off." - P4*

Even though most people did not notice any routine during their stay, they noticed the occasional visits. Nurses could be seen as anchors to help patients understand the real world.

> *''The nurses were very intensely present. Nurses came in from time to time to take care of you or check on you. ''—P10*

Routine

And P11 could recall the standard daily events: washing, doctor's visits, and visitors. For her, the routine did serve as an anchor, something to look forward to.
The nurse explained that if patients' lifestyles were considered better, it could help improve the experience of their (personal) routine and the overall care in many ways. For example, the quality of sleep is higher when patients wake up at their regular time, as they do not have to adjust to the new rhythm of the hospital. Or if during a visit from the speech therapist the patient is learning to swallow again, it would not contribute to the patient's performance if he/she has to eat, for example, porridge when the patient is disgusted by it. Recognizing the patient for the human being he/she is, is crucial.

> *''I felt that my feelings were taken into account." - P4*

Visitation of loved ones can help. Not only to share the patient's preferences but also by being a recognizable face or voice to the patient:

> *''The first thing you saw was your mother. Which I thought was mega valuable." — P4*

Recognition is a big trigger. Aside from loved ones, patients also said:

> *''It was nice to see the same faces of nurses". — P10*

Support

Undeniably, friends and family can contribute the most to supporting the patient. They make patients feel loved, safe, calm, motivated, reassured, informed etc. On the other hand, this creates a big void when they leave.
The presence and care that healthcare professionals provide also cannot be underestimated. Almost all patients feel they were taken excellent care of and recalled things like:

> *''Nurses take the time for you." — P3*

Health care Professionals (HCPs) listen to the patient.

> *''They were so very helpful.' — P10*

The appreciation for the HCPs is enormous.

4.2.4 SUMMARY

Generally, environmental influences causing a **positive** experience:

- Distractions and Anchors
- Support (and Care)
- Expelling or accepting stimuli

And environmental influences causing a **negative** experience:

- Overwhelming stimuli
- Disturbances, like bad communication or not being taken seriously
- Delirium, Physical and Mental agonies

4.3 CONCLUSION: PROBLEM STATEMENT

A lot of insights were derived from the interviews about the events/situations, emotions and needs of an ICU patient and served as great input for the overview that gave a clear impression of the ICU experience.

During their stay, patients lose their sense of control. They cannot control what is happening to them, their bodies, and their surroundings.
Their bodies use all their energy to fight for their lives, leaving no energy for moving or communicating. As a result, the patient can feel like a spectator. This creates a very isolated state for the patients and makes them feel dependent on other people and machines. This is experienced as very dehumanizing by the patients.

The environmental stimuli can have a pull or a pushing effect. Some push the patient towards a more isolated state, like overwhelming or disturbing stimuli. In contrast, others help to push the patients out of it, like distracting stimuli, anchors or patients being able to accept stimuli. But it is hard to strike the right balance between distracting and overwhelming stimuli or the expelling versus accepting stimuli.

Additionally, the overview showed that environmental stressors during a patient's stay could cause a bad ICU experience, primarily when patients can only focus on these bad triggers since they become susceptible to noise, overstimulation, discomfort, and pain.
Therefore, to create a positive experience, a problem statement will be used to form a design goal.

The problem statement:

''ICU patients need a way to be pulled out of their isolated state (patient bubble) or not to be pushed further in because it is hard for them to keep a positive mindset and not to focus on their feelings of frustration, loneliness, discomfort, shame, panic, confusion etc.''

In the following chapters, we will further investigate ICU patients' needs and emotions to understand how we will solve our problem statement.

5.
UNDERSTANDING THE NEEDS OF AN ICU PATIENT

In chapter 3, an overview was created to show the different experiences of an ICU patient. It focuses on the patient-environment relationship, including multiple concerns, stimuli, and appraisal. We gained a better understanding of the ICU experience of a critically ill patient. In this chapter, we will determine the underlying (fundamental) needs which will serve as the basis for the design. The implementation of needs as a basis for design can support a systematic approach to design for positive experiences and subjective well-being (Hassenzahl et al., 2010; Desmet & Hekkert, 2007). Different needs could be identified with the ICU experience overview as a starting point.

5.1 FUNDAMENTAL NEEDS

From there, we could determine the related fundamental needs (Desmet & Fokkinga, 2020) (Figure 7).

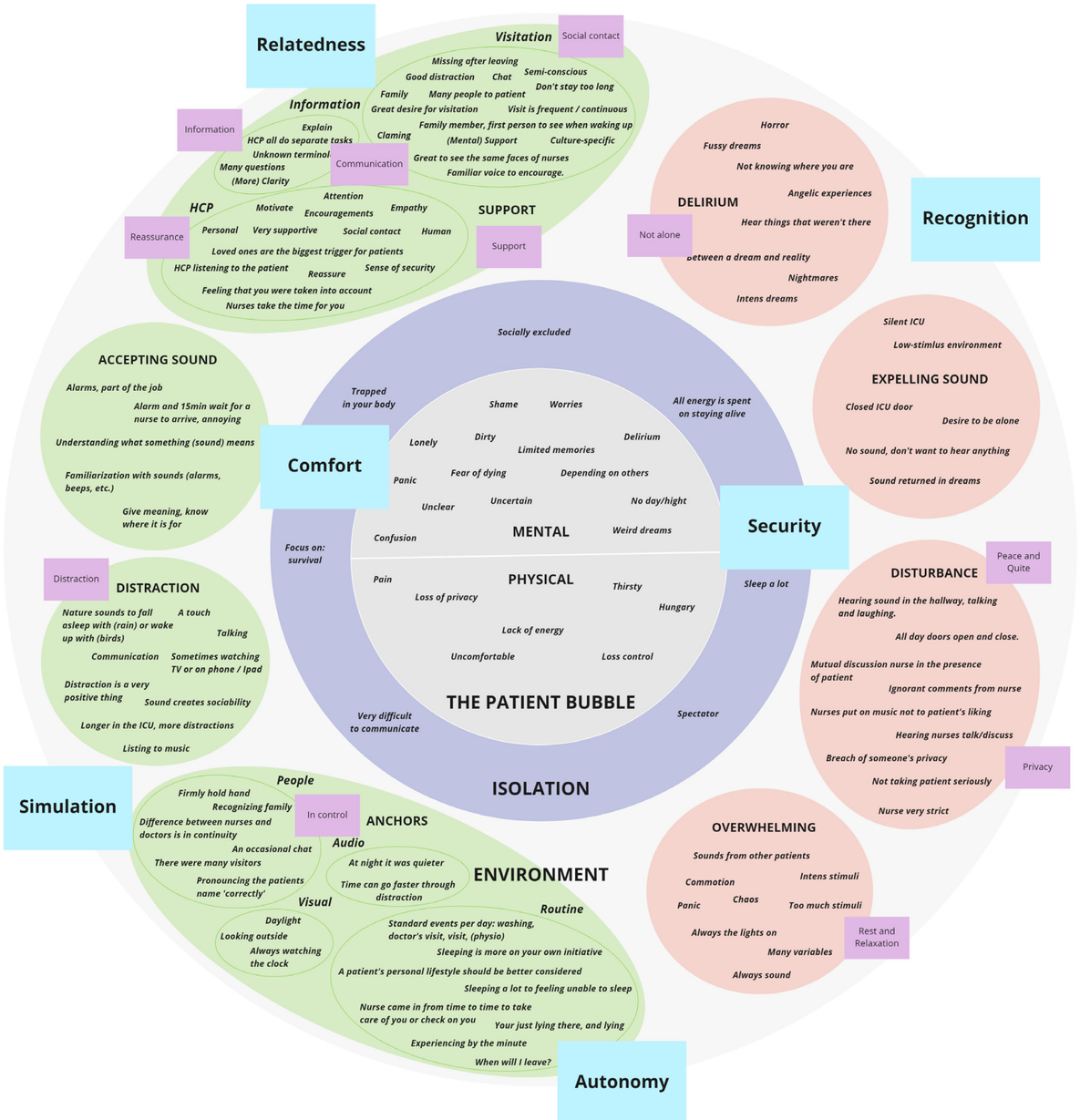


Figure 7: The ICU experience and (fundamental) needs.

The figure shows the close connections between needs and fundamental needs, but needs may be connected to multiple fundamental needs. This table (Table 1) displays only the most obvious once:

Needs	Fundamental Needs
Social contact Not alone Support	**Relatedness** *(Having warm, mutual, trusting relationships with people who care about you)*
Communication Information	**Recognition** *(Getting appreciation for what you do and respect for who you are)*
Distracted	**Stimulation** *(Being mentally and physically stimulated by novel, varied, and relevant impulses and stimuli)*
Peace and Quiet Rest and Relaxation	**Comfort** *(Having an easy, simple, relaxing life)*
Reassurance Privacy	**Security** *(Feeling that your conditions and environment keep you safe from harm and threats)*
In control	**Autonomy** *(Being the cause of your actions and feeling that you can do things your one way)*

Table 1: Needs and Fundamental needs.

The discovered fundamental needs uncovered four main insights:

1. Patients should experience comfort and security as the basis of their experience
2. There is an opportunity to strengthen current needs
3. The interesting balance between Relatedness and Autonomy
4. Possible areas for need fulfilment

5.1.1 COMFORT AND SECURITY

There are three main ways a product can interact with our needs: the product can fulfil needs, introduce new needs, and the product can harm needs. Some products can fulfil a single need. Most products, however, fulfil multiple needs, which can be ranked by order of significance.

In the ICU environment, we have identified six fundamental needs. While the order of significance is yet to be determined, it can be said that the need for security and comfort exists at the core of the experience. Thus, these needs should not be harmed or compromised.
Over the last few years, many products have been developed to improve comfort (alternating air pressure mattresses) and security (removing almost all wires). So, the way the current healthcare system works already includes, understands and tries to fulfil the need for comfort and security. So, patients should experience comfort and security as the basis of their experience.

5.1.2 STRENGTHENING CURRENT NEEDS

Understanding needs fulfilment allows designers to strengthen current needs, introduce new needs, or reduce need harm. Within the ICU environment, there are four key needs that can be reinforced to create a design opportunity.

- **Stimulation** is the best distraction. Simultaneously, it can help the patient to understand what is happening or to focus on something positive to create a more positive mindset and fight boredom.
- Without **recognition**, people feel dehumanized. But when considered and respected, they feel like they are taken into account.
- People lose their feeling of control. Therefore, gaining a sense of **autonomy** can be very valuable.
- Patients want to feel connected to their loved ones and HCPs instead of isolated. **Relatedness** helps them feel safe and taken care of. They feel supported and not alone, and this 'contact' serves to be the best distraction/stimulation.

5.1.3 RELATEDNESS AND AUTONOMY

Sometimes, the fulfilment of one need might detract from the fulfilment of another (Desmet & Fokkinga, 2020). For example, high-heeled shoes are considered elegant footwear in many cultures. Still, they are also a source of impracticality (harming the need for competence) and physical displeasure (harming the need for comfort).

At the ICU, an event or interaction can benefit the need for relatedness while simultaneously harming

the need for autonomy or the other way around. For example, patients love to have their family there (relatedness), but sometimes they just want to sleep and/or have fewer stimuli. Because of their dependency, they cannot do things their way (autonomy).

5.1.4 OPPORTUNITIES FOR NEED FULFILMENT

With this insight, an axis (Autonomy/Relatedness) was created to uncover areas for need fulfilment for both Stimulation and Recognition by placing the patient's needs on this axis. These areas are possible opportunities to strengthen the need fulfilment of ICU patients.

Connect Patients to People

There are two opportunity areas for Stimulation (Figure 8). Stimulation with relatedness creates the opportunity to strengthen the need for social contact, not wanting to be alone and having support. As discovered during the interviews with former patients, visits are the best distraction, and familiarity's impact is enormous.
Therefore, establishing a connection between patients and other people may be an excellent way to stimulate the patient positively. This can be done by creating an impact for loved ones if they're not physically there or by expanding the involvement of loved ones. For example, arranging contact with family members during treatment can help comfort the patient (van Mol et al., 2016).
However, this can result in the patient having too many stimuli, and it can be hard to communicate with the patient (due to lack of energy and being unable to talk). Visits that fit the patients' energy levels could also be an outcome. Nevertheless, it may be hard to set the boundaries for the 'role' of the loved one. Also, all families are very different, so it may not be helpful for everyone. Lastly, the patient's privacy should not be compromised.

Connect Patients to the Environment

Stimulation concerning autonomy is related to the need for distraction and being in control. Connecting the patients to the environment can help patients focus on and understand the here and now. Like a clock, it provides something that gives a sense of 'time', 'to hold on to' or even represents a form of control as mentioned during the interviews.
An opportunity arises to create an anchor. That, for example, introduces a change in the environment and can provide additional information.
A threat may be that anchors can be even more confusing for patients. It is questionable if people understand any distracting anchors because patients, for example, do not have a feeling of time or day/night.
Aside from that, a connection to the environment can also distract the mind while being alone, bored or in pain. You could introduce features to optimize the patient's care like lower/soft voices, sounds for relaxation or music to stimulate movement. But, again, there is the risk of too much stimulation when introducing a distraction.

Conclusion: Connect to distract

The fulfilment of the fundamental needs for stimulation, but also relatedness and autonomy, can be obtained by connecting the patient to distract him/her or helping them redirect their focus toward people or the environment. But it is crucial to stay aware that this distraction is not too much or too intense.

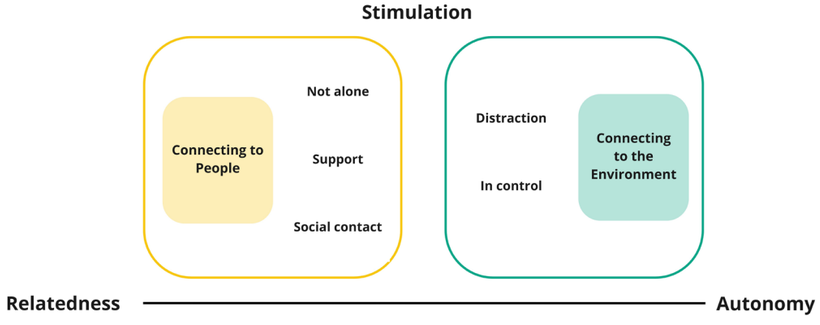


Figure 8: Stimulation.

Personalize by data

We can use the same axis to uncover opportunities for recognition (Figure 9). When placing the remaining needs on the axis in the relatedness/recognition area, there are the needs for communication, information, and reassurance. It reveals an opportunity to better understand the patient, for example to help HCPs monitor the patient.
Usually, aside from checking the monitor, HCPs talk to the patients to see their reactions to better understand how they are doing. They watch the patient's response, but in most cases it is hard to communicate smoothly with the patient. An improvement in how patients are monitored may contribute to understanding the patient. There is the possibility to measure patient response to, e.g. sound(s). Measuring could be done using an EEG or the heart rate. HCPs can then better understand how responsive the patient is and the environment's influence. However, when you measure the heart rate, you can measure a response, not if it is positive or negative. In conclusion, using patient data or measured values as input to personalize care can help to improve the ICU experience.

Personalize by preferences

We can take this matter further, using personal data to assist in better care and personal preferences. On the axis of recognition and autonomy, needs such as privacy, rest/relaxation and peace/quiet can be placed. It is challenging to communicate with the patient and to know what the patient wants and needs. Tailoring care to the patient's needs can help improve care and make it more like patients feel their needs are taken into account. This area shows the opportunity to personalize care by considering personal preferences and help to meet patients' needs such as closing doors, playing music, adjusting the light or serving the right food during swallowing therapy. Unfortunately, it can be complicated to find out preferences like taste in food or music, and it may take too much time.
Secondly, the events and the order in which things happen should be considered to optimize care. All activities should occur when it best suits the patient's needs. For example, HCPs utilize the best moment to disturb or take care of the patient. Patients sleep most of the time, so taking into account the patient's sleep patterns is valuable. HCPs should try to enter the room when the patient is awake and therefore be able to know when the patient is or is not conscious so they do not wake up. So again, monitoring patients may help to reveal personal preferences.

Conclusion: Personalize to humanize

Patients should feel their needs are taken into account and not feel like they have lost their humanity, so it is important to tailor care to their needs. The concept of care should be focused less on a one size fits all solution. Care should be more revolved around the person. Understanding the patients is challenging, yet it is worthwhile to understand their habits, preferences, and state of being. Personalized care will help fulfil the need for recognition and to dehumanize the ICU environment.

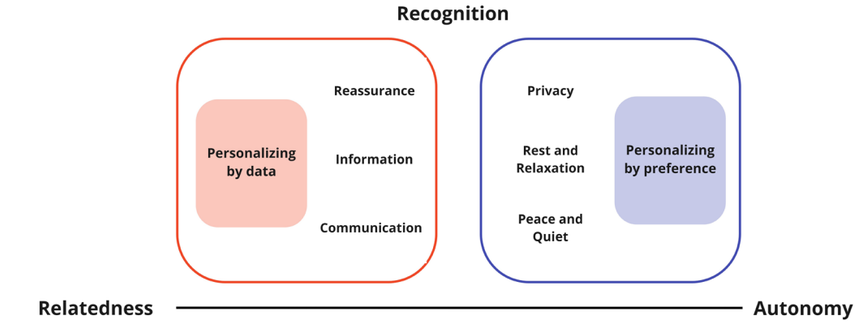


Figure 9: Recognition.

5.2 CONCLUSION: DESIGN GOAL

After thoroughly analysing the needs and the patient experience, we can conclude that the goal is to fulfil one or more of the identified six fundamental needs. This can be done by designing something that connects the patient (the environment and/or people) to distract (redirect their focus). And to think about personalizing the ICU to humanize (by data or preferences).

The problem statement was:

''ICU patients need a way to be pulled out of their isolated state (patient bubble) or not to be pushed further in because it is hard for them to keep a positive mindset and not to focus on their feelings of frustration, loneliness, discomfort, shame, panic, confusion etc.''

This ''***way***'' is the design goal. With the newly gained insights, we can conclude that, therefore, to create a positive experience, the design goal is:

We want **to redirect the focus of the patient** *to pull patients out of their isolated state (patient bubble)* **by connecting the patient to the environment and/or to people**.

We will continue looking into ***how*** to redirect the mind and ***when***. To uncover this, in the next chapter, we will further investigate the needs and emotions of an ICU patient during the day. Personalizing care (by data and preferences) is not yet defined in the design goal, as this can be done in many ways in later iterations of the design intervention.

6. UNDERSTANDING NEED FULLFILMENT TROUGHOUT THE DAY

Until now, we have a thorough overview of the broad experience of an ICU experience. To narrow our focus and continue the diverging phase of the diamond, we will zoom in on the needs throughout the day.

With the insights gathered during the interviews and observations, we could map a patient's daily routine, including all activities, needs, and stressors (sounds). The map will provide insights into when and how to strengthen one or more needs, and design interventions will derive from this.

6.1 THE PERCEPTION OF THE DAILY ROUTINE

All events during the day were put on a timeline (Figure 10), and because sound plays a big part in the perception of the ICU environment, the related sounds were also mentioned. The next step was to include the related needs derived from the former patient interviews and shadowing of the nurse. These needs would either be fulfilled or unfulfilled.

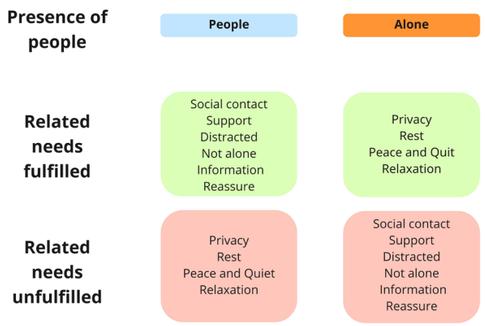


Figure 11: Environmental states and needs

Two different environmental states with the related needs could be identified (Figure 11).

The needs that are fulfilled when patients are in the room with people or when they are alone:

With **people**: *Social contact, Support, Distracted, Not alone, Information, Reassure, Communication (Relatedness Recognition Stimulation)*

Alone: *Privacy, Peace and Quiet, Relaxation & Rest, In control (Comfort Security Autonomy)*

So, patients' need fulfilment changes according to what is happening inside the room, figure 12.

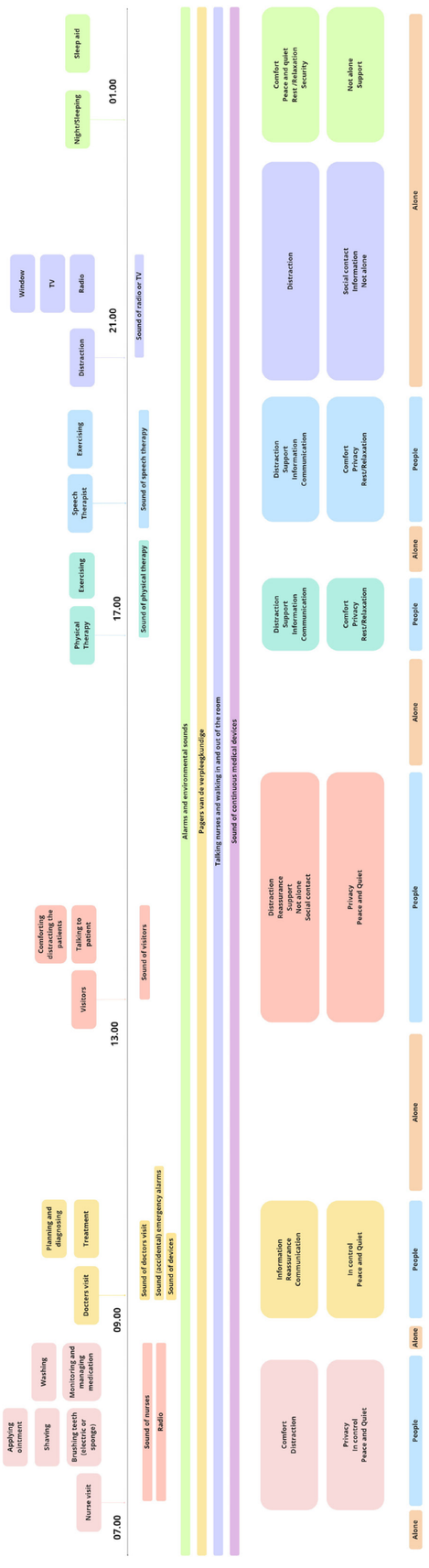


Figure 10: Daily routine, Timeline.

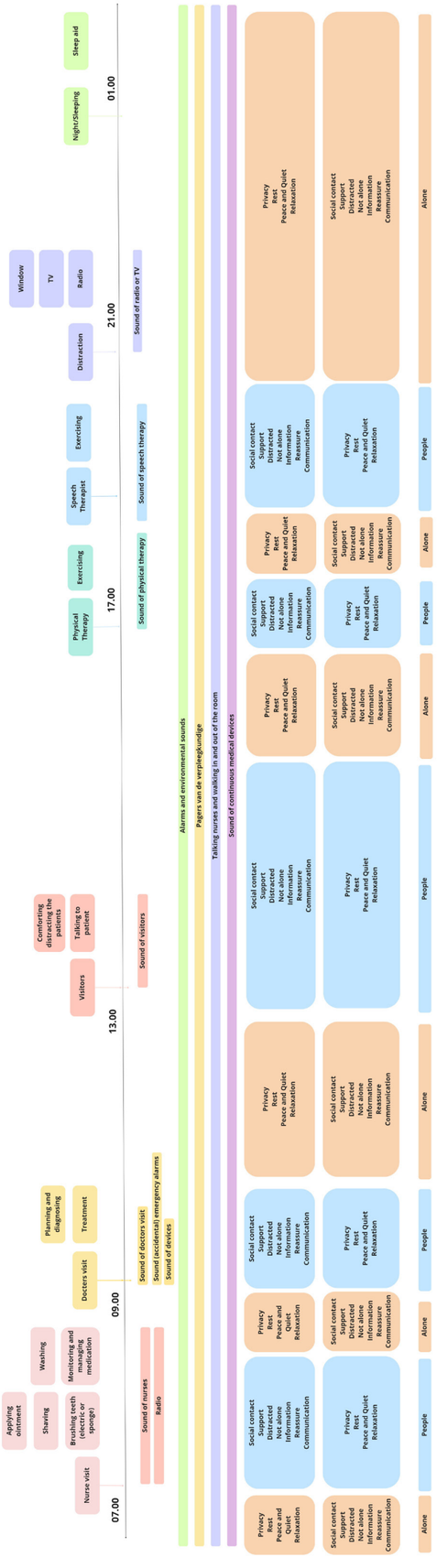


Figure 12: Daily routine, Changing needs.

The interviews and observations confirmed that most patients do not detect a routine throughout their day. Rather, an event- or non-eventful moment which stems from the absence or presence of people. In this case, the absence or presence of people is equivalent to the absence or presence of stimuli.

The absence or presence of people is in ICU soundscapes associated with the absence or presence of sound. As concluded in the soundscape analyses of Park et al., 2019, the biggest change in the soundscape occurs when nurses, doctors and/or visitors enter/leave the room (92% of the LPL is produced by staff (Park et al., 2019)).
We can draw the conclusion that the most significant difference in the patient's perception of the experience is **event-based.** So, the need fulfilment of patients changes according to the eventfulness in the ICU.

6.2 THE EFFECT OF EVENTFULNESS

Eventfulness is for now defined as eventful with people and uneventful as without people. The patients' need fulfilment changes according to the eventfulness. If you put it that way, their perception of the environment also depends on the influence of eventfulness on their needs (Figure 13).

When the room is eventful, needs like relatedness (social contact), recognition (reassurance, support) and stimulation (distraction, information) are fulfilled, but when people leave (uneventful), patients may experience a feeling of loneliness or fear of dying, there is no distraction (boredom), and it is harder to communicate.

On the other hand, needs such as comfort (the need for peace and quiet, rest and relaxation), autonomy (privacy), and security are fulfilled when the environment is uneventful. Then the change in the ICU environment by the entrance of people (eventfulness) can be perceived more negatively. The patients can get confused and distracted, feel less respected, and the environment can be too loud (chaotic).

So, environmental changes related to people entering or leaving the room can be modified to benefit the patients' experience. These *transition moments* need to be further investigated.

6.3 THE PERCEPTION OF EVENTFULNESS

To further investigate the transition moments, it is crucial to understand which needs are impacted more by the changes in (un)eventfulness: Stimulation, Recognition and Relatedness or Security, Comfort and Autonomy.
To determine this, we need to know the patient's emotional response when people enter, are inside the room, leave, or are outside the room. We will use a patient journey (Simonse, Albayrak and Starre, 2019) to map the emotion of the patients over time.

To collect data to formulate the patient journey, twelve former patients filled in the questionnaire (Appendix 6).

Goal

The main research goal was:

- How do patients perceive (un)eventfulness?

Sub-questions were:

- What are their needs in an eventful or uneventful environment?
- What is the impact of an event?
- How do they experience the transition moments?

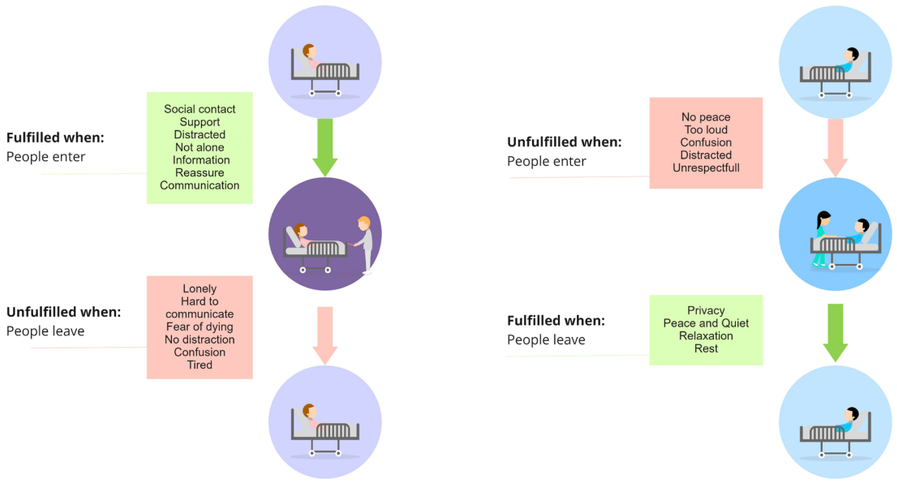


Figure 13: The effect of Eventfulness.

Participants

Again all participants were recruited via the personal network of the researcher. Nine participants of the previously executed interviews also assisted in this part of the research. Three participants were aged below 25, five were between 25 and 50 years old, and four were older than 50. They stayed in the ICU between 2009 and 2022 from 1 day up to 6 weeks.

Questions

General:

What year were you in ICU?
How long were you in ICU?
At what age were you in ICU?

Part 1 (Mapping emotions)

Doctors (intensivists, physical therapists, etc.) often come in to provide medical care, for example, or to discuss the daily action plan.

How did you feel when doctors came in?
How did you feel when doctors were in the room?
How did you feel when the doctors left?
How did you feel when the doctors were gone?

Nurses often come in to provide medical care, administer medications or monitor the patient, for example.

How did you feel when nurses came in?
How did you feel when nurses were in the room?
How did you feel when the nurses left?
How did you feel when the nurses were gone?

During visiting hours, family and friends visit or, for example, when the patient wakes up for the first time in the ICU.

How did you feel when loved ones came in?
How did you feel when loved ones were in the room?
How did you feel when loved ones left?
How did you feel when loved ones were gone?

Because of the lack of memory and the fuzziness around most ICU stays, the decision was made to characterize the events according to the person in the room: loved-ones, nurses or doctors (other staff members or hospital personnel were excluded from this research).

This made it easy for the participants to differentiate their experiences and allowed the researcher to compare/combine them afterwards.

Part 2 (Alone vs. Together):

Patients were also asked to select the needs that they experienced when they were ALONE and when they were TOGETHER with people out a list of needs that had been identified earlier.

Did you experience a need for:

- *Having social contact*
- *Having distraction*
- *Not being alone*
- *Getting information*
- *Being reassured*
- *Being able to communicate*
- *Having privacy*
- *Having support*
- *Having peace*
- *Having quiet/silence*
- *Having rest and relaxation*
- *Being in control*

Results

Mapping Emotions (part 1)

A patient journey format will be used to explore the emotions and pain points patients encounter when people enter, are inside the room, leave, or are outside the room.

All participants' answers to the questionnaire part 1 were combined to create three overviews of the former patient's emotional response to the changes in the environment in the presence or absence of loved ones (Figure 14), nurses (Figure 15) and doctors (Figure 16).When people entered the room, all former patients felt mostly positive emotions:

Loved ones: *Happy, Excited, Relieved and Joyful*
Nurses: *Happy, Safe, Distracted and Reassured*
Doctors: *Happy, Curious and Tense*

When a HCP/doctor entered the room, negative emotions like stress and anxiety could also be experienced. That was due to the fact that the doctor's presence might mean bad news could be delivered.

> ***"Updates from doctors… especially in the beginning when it wasn't clear if it was going to be okay" – P3***

During their stay, they continued to have positive and some negative emotions:

Loved ones: *Happy, Cosy, Peaceful, Joyful and Trouble communicating*
Nurses: *Happy, Safe, Cosy, Good/Fine and Trouble communicating*
Doctors: *Happy, Relaxed, Anxious, Frustrated, Angry and Confusion*

The biggest negative influence on the experience appeared to be when the HCP was unprofessional, e.g., talking loudly or joking at the patient's expense while in the room. This has been discussed in detail in the previous study into the patient's experience. The emotions are mapped inside the figure of the doctors, but this applies to both nurses and doctors. Nevertheless, most people reflected on 'unpleasant treatment' very positively, even though, at the time, it was uncomfortable. This proves the trust and confidence patients have in the HCPs.

> ***"Everyone was tremendously professional, so I had complete confidence in everyone who helped me and their skills and experience. I was happy with the care received." — P7***

When people left, patient emotions changed:

Loved ones: *Bummer, Disappointed, Sad, Unpleasant, Everything is too much and Tired*
Nurses: *Anxious, Stressed, Nothing special, Good/Fine, and Trouble communicating*
Doctors: *Awaiting, Safe, or remaining negative emotions*

When 'everything is too much" it is pleasant when loved ones leave so there are fewer stimuli. There is also less need for communication, which costs a lot of effort. So, when people leave, patients can be relieved, especially when someone is extremely loud.
But most of the time, the transition from an eventful to an uneventful environment is perceived largely negatively, as their needs get harmed by the absence of people. This shows a great contrast between the absence and presence of people in a patient's emotional state.

The patient emotions when people were gone:

Loved ones: *Loss, Disappointed, Sad, Lonely, Fear, Everything is too much, Tired*
Nurses: *Deserted, Lonely, Tired, Good/Fine*
Doctors: *Relaxed, Bored, At ease, Tired*

The absence of people and the absence of distraction make room for more negative feelings like loneliness and boredom. And at the same time, no new needs get introduced or fulfilled.

The biggest difference between the emotion maps for the different individuals is the impact size. The impact of the family on the patient is enormous. Patients experience the entrance of loved ones as most exciting and comforting. But the downside is that when they leave, the patient experiences the worst emotions like loss, disappointment, sadness, loneliness, fear, tiredness and as if everything is too much.

The interaction with the nurses and doctors is experienced as less intense. But, patients' emotions do follow the same trajectory. This means that most have a positive experience while HCPs enter or are inside the room and experience more negative emotions when they leave or are gone.

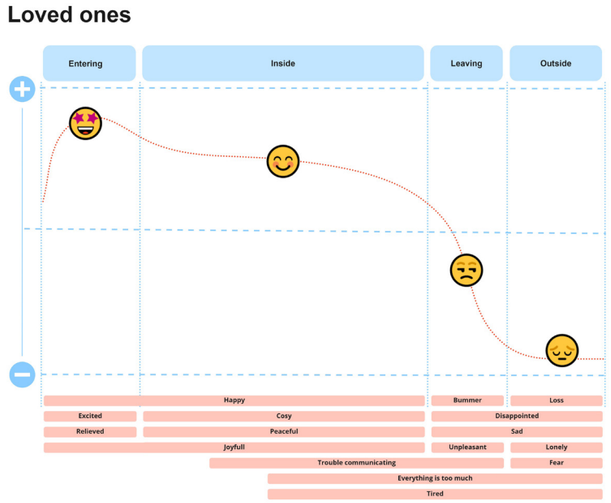


Figure 14: Loved ones.

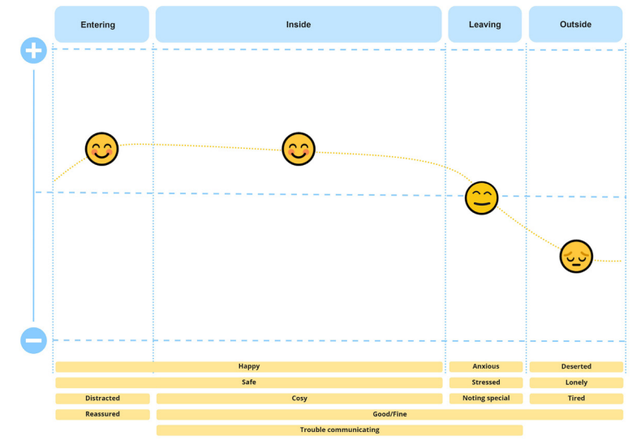


Figure 15: Nurses.

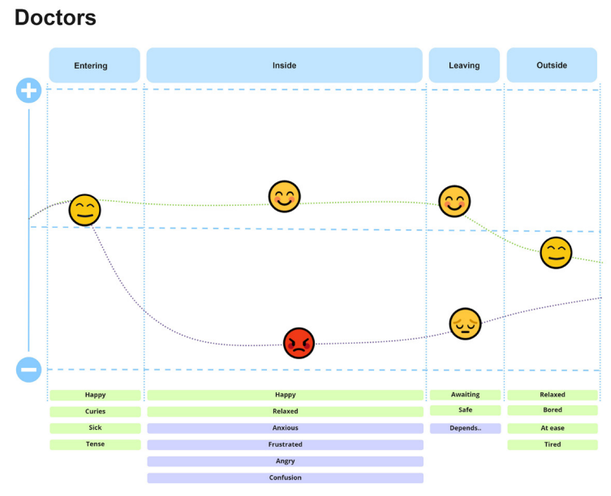


Figure 16: Doctors.

Alone vs. Together (part two)

These were the results of part 2 of the questionnaire (Figure 17 and 18).

Comparing both figures gave the following insides:

1. All needs are present to some degree. Thus, the identified needs of an ICU patient are endorsed.

2. Silence is rated relatively low in both cases, suggesting that patients may not benefit as much if one focuses on eliminating more sounds and creating an even quieter ICU.

3. A notable need when participants were alone was distraction, rated highly by 10 participants. This confirms the proposed design intervention to redirect the mind's focus away from negative thoughts, physical agonies, and boredom. However, this must be done correctly since eight former patients desired a peaceful environment.

4. This figure shows that distraction is more desirable than silence when patients are alone.

5. When former patients were together with other people inside the room, they wanted to have social contact (9/12), information (7/12), support (7/12), communication (8/12) etc. Needs such as peace (3/12), silence (2/12), relaxation (3/12), and control (3/12) were less appreciated. The presence of people helps to fulfil these prominent needs like social contact or support, and the other needs like peace or silence may be harmed, but this figure shows that they are also less valued in this situation. This shows that the presence of people is much appreciated.

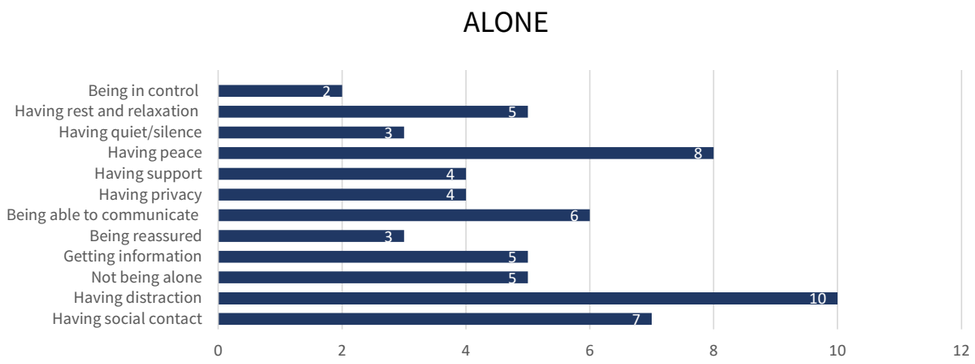


Figure 17: Needs when patients are ALONE.

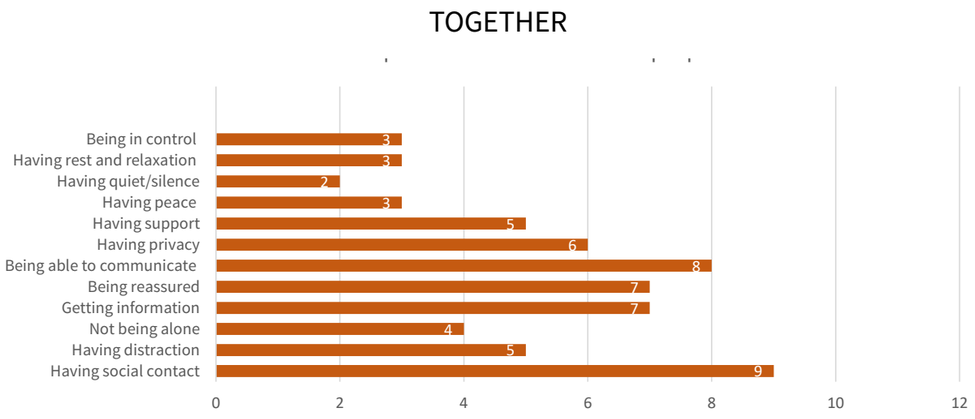


Figure 18: Needs when patients are TOGETHER with people.

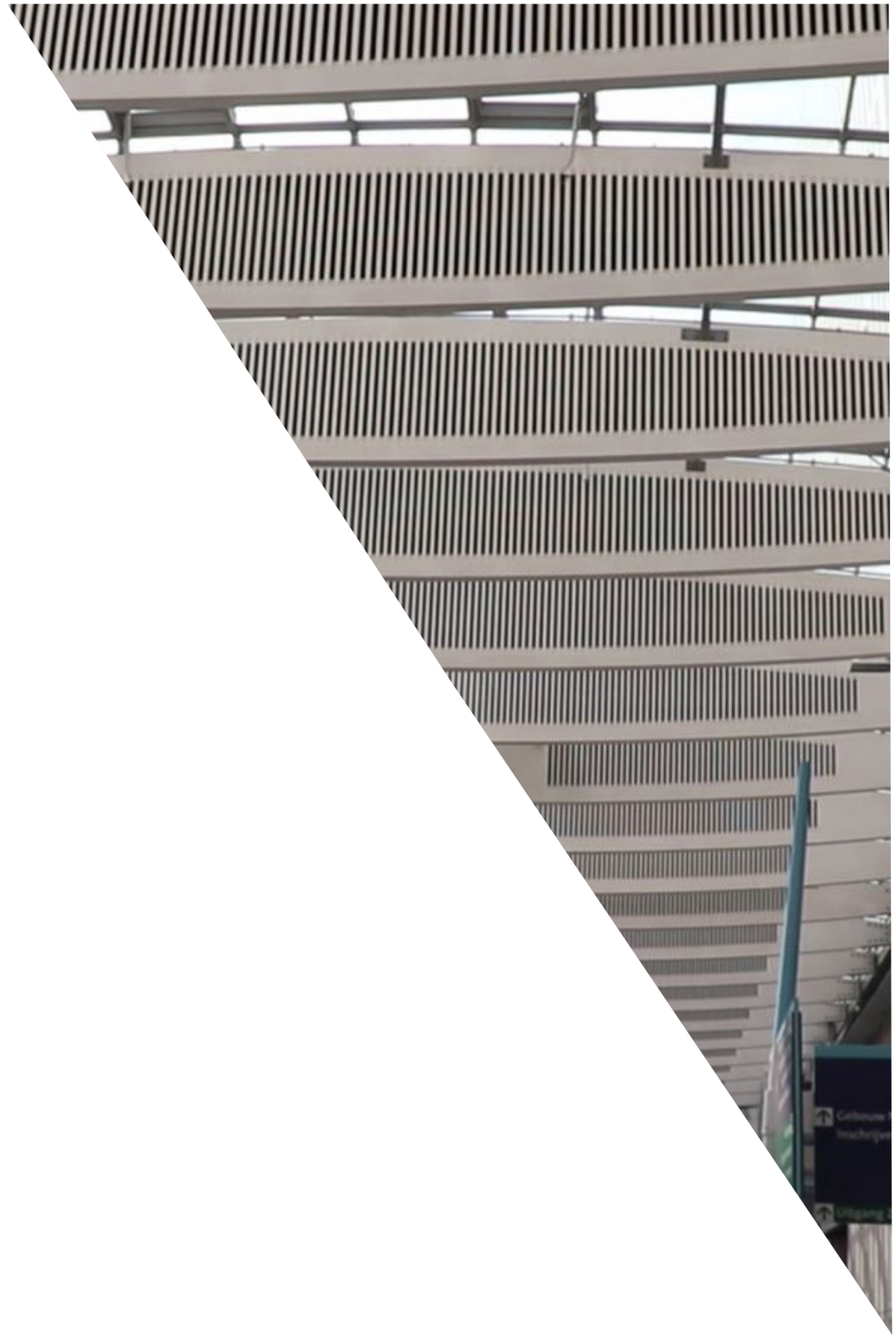
6.4 CONCLUSION

We investigated the patient's emotional response when people enter, are inside the room, leave, or are outside the room.
Both the results of parts one and two suggested that the hypothesis that patients would not react positively to the entrance of people when their needs included Comfort, Autonomy, and Security was partly false. These patients were very sensitive to stimuli, but their primary needs changed when people (nurses, doctors, and family) entered the room. Thus their emotional reaction was still mostly positive (results part 1).
As needs change and patients value Stimulation, Recognition, and Relatedness over Security, Comfort and Autonomy in the presence of people (results part 2).
The results show that it can be concluded that the transition to a more eventful environment is more appreciated than to an uneventful environment.

Because an uneventful environment means an absence of people, we continue to focus on connecting patients to the environment, not specifically people.

7.
DESIGN DIRECTION

In the next chapter, we will decide on the design direction. A design vision will serve as inspiration for several design directions. Finally, one of the design directions will be chosen.



7.1 DESIGN VISION

WHY?

ICU patients need a way to be pulled out of their isolated state (patient bubble) or not to be pushed further in because it is hard for them to keep a positive mindset and not to focus on their feelings of frustration, loneliness, discomfort, shame, panic, confusion etc.
This ‘’way” is to create a positive experience by r*edirecting the focus of the patient*. Based on the identified six fundamental needs of the ICU patient’s experience, we learned that this could be done by designing something that connects the patient to the environment and/or other people. Additionally, there is the possibility of humanizing the ICU with personalization (data or preferences).

WHEN?

It can be concluded that the transition to a more eventful environment is more appreciated than an uneventful one, as needs change and patients value Stimulation, Recognition, and Relatedness over Security, Comfort and Autonomy in the presence of people.
Therefore, the impact of a transition towards uneventfulness is perceived more negatively. Because of this, it is also very credible that the patient’s journey showed that the absence of people right after they leave causes the most harm to the patient. Thus, the decision was made to focus on this *transition moment*.

HOW?

As their needs change accordingly, the difference in the patient’s perception of the experience is *event-based*. During transition moments, the number of people inside the room shift, as does the number of sounds and the sound pressure levels.
Patients notice events mainly because of a change in the acoustic environment. So, if you measure sound pressure levels (dB) in the ICU environment, you measure eventfulness (Figure 19). And therefore detect the transition moment from an eventful (high sound pressure levels) to an uneventful (low sound pressure levels) environment.

WHAT?

The addition of visual stimuli like light (Smonig et al., 2019) or a clock (Arbabi et al, 2018) and/or auditory stimuli such as an audio recording (Byun et al., 2018) or music (Arbabi et al, 2018; Cheong et al., 2016;) can be used to the benefit of patients’ recovery instead.
Possible benefits of these additions could be content for time orientation, anxiety/pain reduction, and attention training (ESICM LIVES, 2018).
So, instead of only removing acoustic and visual influences in the ICU environment, the design interventions could introduce *new environmental stimuli* to redirect the focus of the patient. The introduction of new stimuli can also be underlined by the patient experience study and the emotion mapping study, which showed that distraction is more desirable than silence when patients are alone.

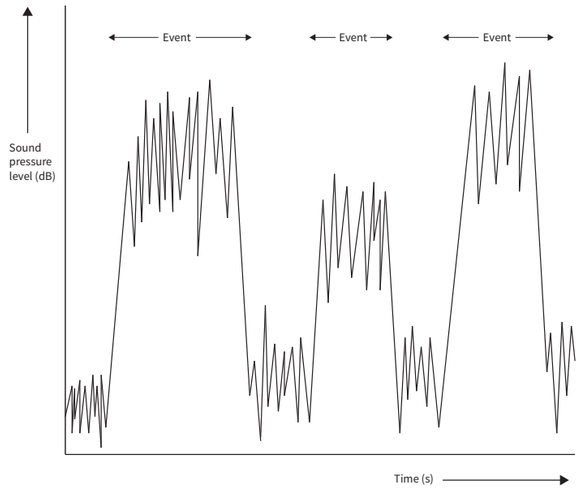


Figure 19: Measuring eventfulness.

7.2 DESIGN DIRECTIONS

First, the possible directions needed to be explored to select a new stimulus. Appendix 7 gives an overview of exploration during this ideation phase. The prior framework derived from the identified fundamental needs was used to inspire.

There were four stimuli design directions selected that could have the greatest positive effect on the patients’ experience. These included adding: *event stimuli, transition stimuli, background stimuli* or *signal stimuli.*

EVENT STIMULI

.
An event stimulus (Figure 20) could be added to the ICU environment (by nurses or loved ones). It could be used during treatment to distract the patient (eventful environment). Or, for example, if there is an uneventful environment. A stimulus could then be provided if the patient would appreciate this, for example when he or she experiences a social gap. Event stimuli create the opportunity to connect the patient to people or the environment.
For example, enabling family or friends to share a message with the patient can be used to explore the possibilities of the involvement of loved ones, even if they’re not (physically) there. However, timing the event stimuli without the involvement of a nurse can be tricky.

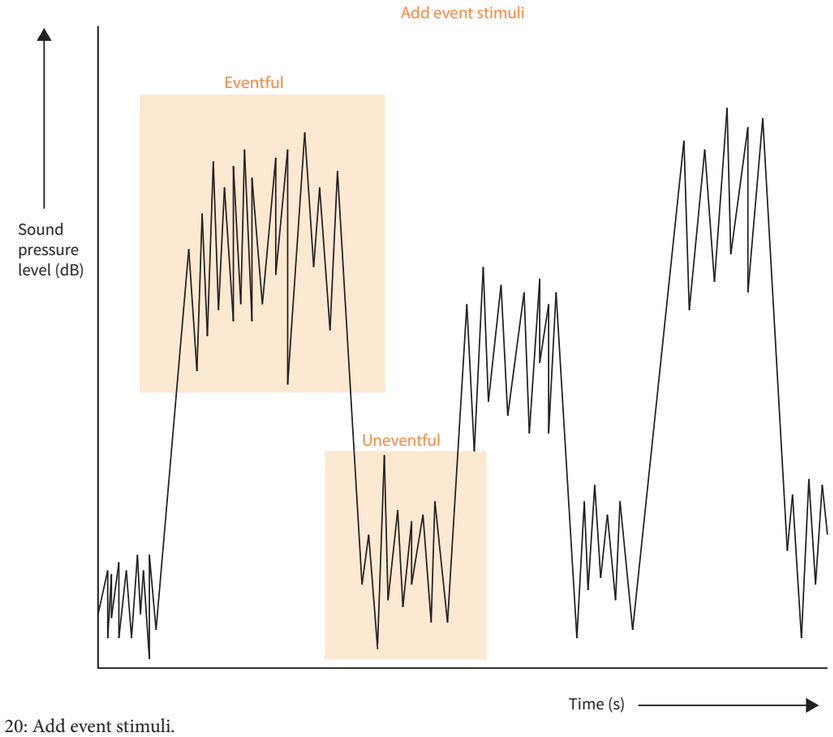


Figure 20: Add event stimuli.

TRANSITION STIMULI

A transition stimulus (Figure 21) can distract the mind from unpleasant emotions after treatment or after a visit when loved ones leave, and feelings of sadness, despair etc., rise to the surface.
The stimulus can, for example, help guide the patient into the new soundscape. After events, which are usually very energy-consuming, most patients need to sleep. Sleep quality may benefit when the patients fall asleep more comfortable and at ease. The stimulus can be based on the recorded sound pressure level principle or personal preferences.
Challenges would be to find the right transition stimulus, possibly sound and/or visual stimulants, which should not be intrusive.

BACKGROUND STIMULI

Examples of a background stimulus (Figure 22) may be a background sound or a (new) clock (design). A visual stimulus, like a clock, can provide something that gives a sense of ‘time’ or ‘to hold on to’ or to focus on at all times.
The goal of background sound is to decrease the difference between higher and lower sound levels. Sound level changes may be more disruptive than continuous sounds (Jaiswal et al., 2017), particularly those arising from lower (vs higher) baseline sound pressure levels. This background

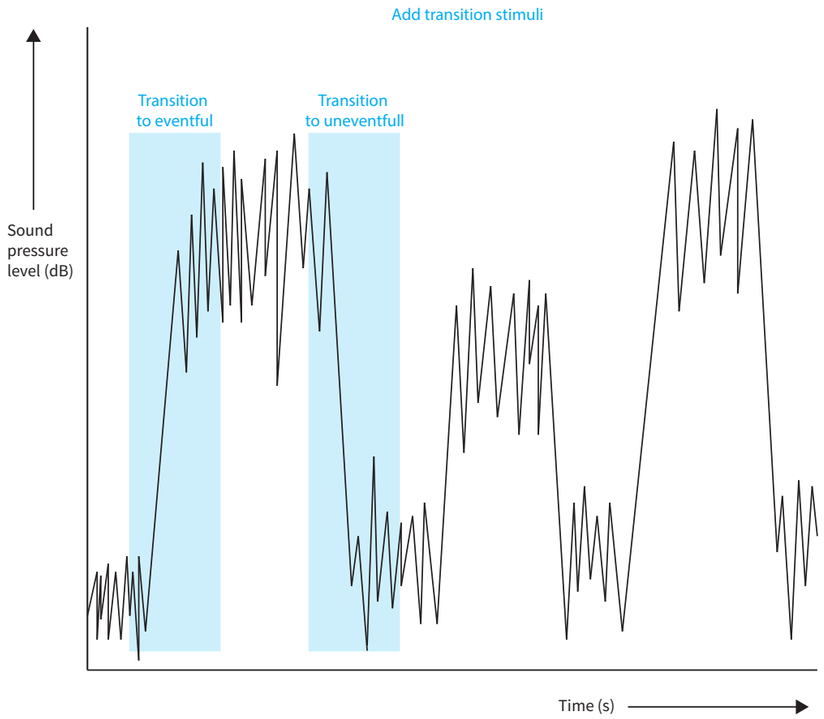


Figure 21: Add transition stimuli.

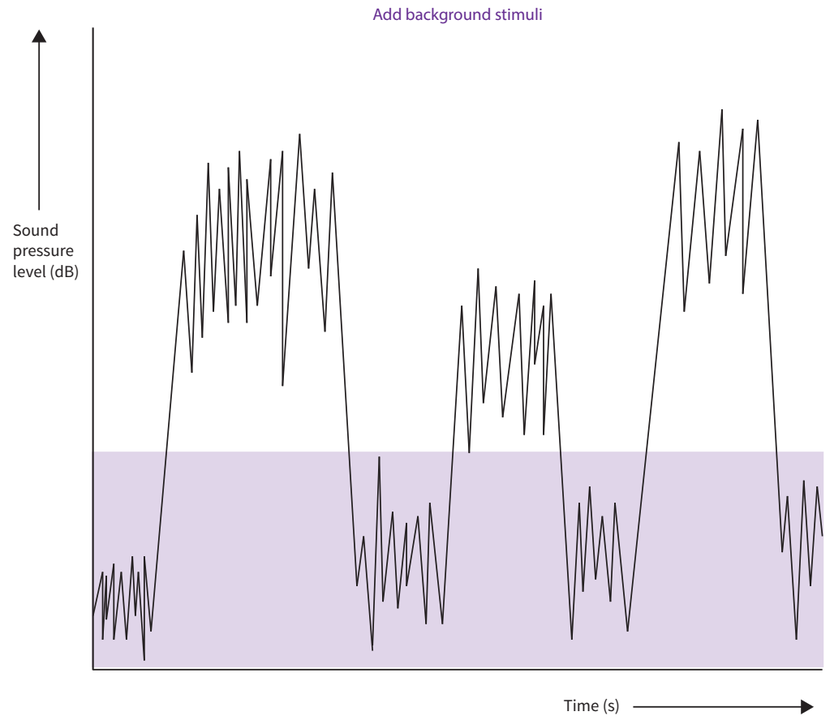


Figure 22: Add background stimuli.

sound could be background noise or, for example, background music. However, as this opens up the opportunity for a personal touch, the presence of any sound can conflict with the (momentarily) preferences and needs of the patient. During the interviews, patients had different points of view on the 'background music' topic. Some were too overwhelmed by the sound of familiar music (P10 in the patient experience study). In contrast, others loved it and indicated it made them feel more human (P5 in the patient experience study). This illustrates the complexity of the context.

SIGNAL STIMULI

The signal stimulus (Figure 23) for people entering and leaving serves as a cue, providing information that something is (or even what is) going to happen or that it is finished. The signal can also stimulate the patient to be more active or indicate that the patient can relax now. Lastly, signals can also alert the nurses that the patient is responsive, so they do not forget to give some personal attention. The signal can be, for example, visual (flashing light) or auditory (doorbell). However, the cues/signals could be even more confusing or frustrating. There is certainly the risk of too much stimulation.

7.3 CONCLUSION: THE SELECTION OF THE DESIGN DIRECTION

The chosen design intervention to explore is the *transition stimuli* because:

1. The focus is on the transition (eventful to uneventful), which causes the most harm.
2. It is the opportunity to redirect the focus, keeping the patients away from (more) negativity.
3. There is a clear transition point due to the use of the sound pressure level principle.
4. It is the opportunity to add new stimuli.
5. It is the opportunity to personalize care.

However, qualities of other stimuli can be integrated into the final design intervention.

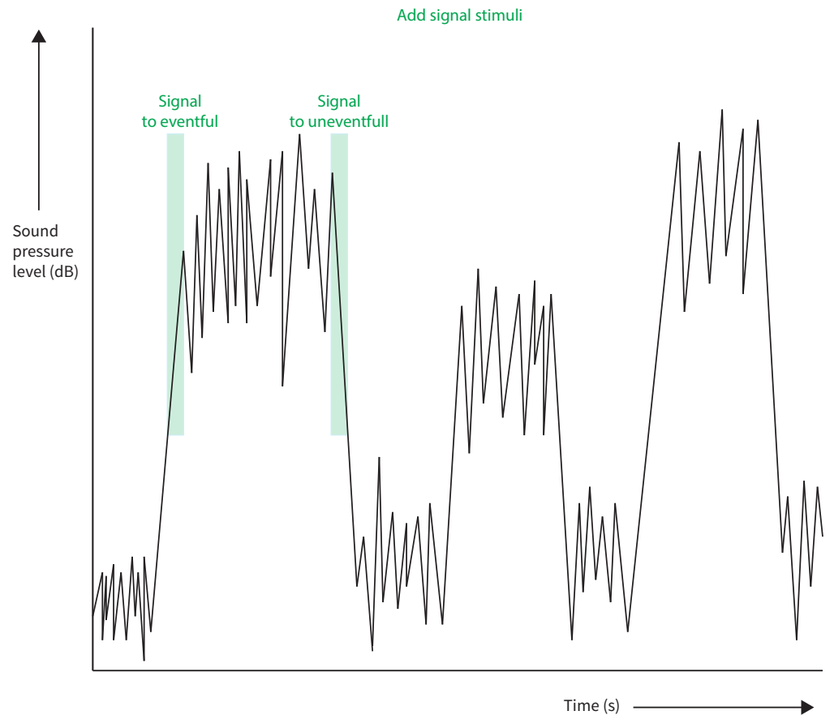
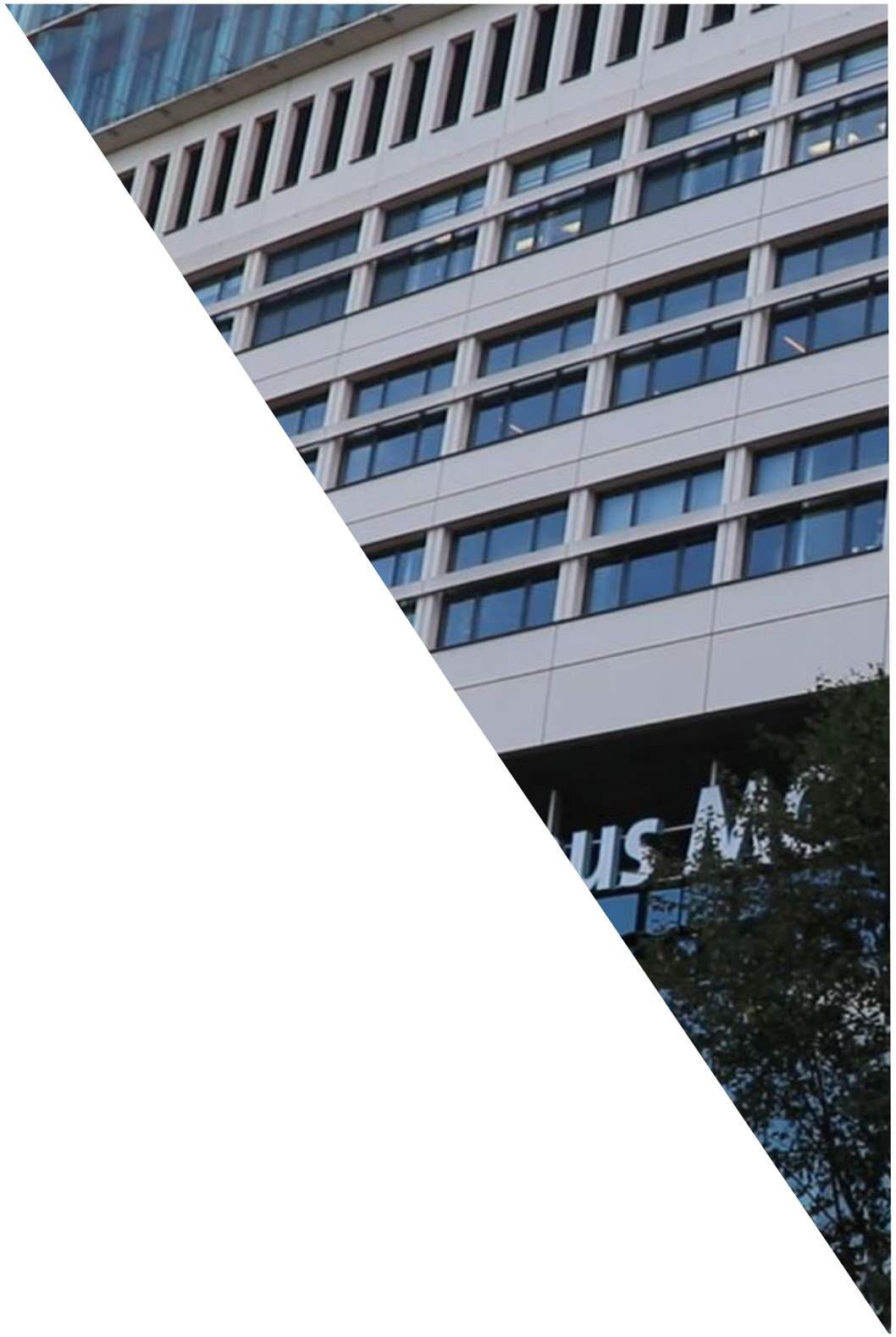


Figure 23: Add signal stimuli.

8.
INITIATION TO DESIGN

Now, it is finally time to start designing the intervention. In the previous chapters, we made the decision to add new transition stimuli to the environment. In the next chapter, we will investigate the characteristics and types of stimuli.



8.1 CHARACTERISTICS OF THE STIMULI

To begin, an analogy was used to give some characteristics to the new stimuli. Currently, the transition is sudden and very binary (sound/no sound, people/no people). The characteristics of the transition stimuli can be found in the analogy of a sunrise (Figure 24).

A sunrise…

... is beautiful to look at (pleasant).
... is not intrusive.
... is nature (strong connection to nature).
... introduces a new phase (day).
... is multisensory (more light, more warmth, more sounds of animals).
... is influenced by different factors (of the day e.g. cloudy or not).
... is never the same, keeps being interesting.

8.2 THE APPROPRIATE STIMULI

Products should be designed to please our senses (aesthetic experience). So, what will the appropriate stimuli be to please the senses of an ICU patient? The very fact that stimuli are (or are not) pleasant, combined with the meaning patients attach to them, results in a variety of emotional responses (Hekkert, 2006, p. 160). If this emotional response is pleasant, a positive product experience is established. Possible stimuli include sound, vision, taste, smell, and touch.

Sound

At the aesthetic level, we consider a product's capacity to delight one or more of our sensory modalities. In the ICU environment, this sensory modality mainly revolves around sound. Sound is the patients' way of understanding the world around them, communicating and gathering information. As a result, the way patients perceive sound is a key element to the perception of the total experience and, therefore, a promising stimulus.

Vision

Hearing is our most sensitive sense (due to the range of 'loudness' over which hearing operates). Our dominant sense is sight (The senses working together, 2022). Patients do not only sense the world with their ears, but also with their eyes. To know the time, for example, the patients can notice that it is quieter during the night, or they notice (the absence of) daylight or watch the clock. It is, therefore, not surprising that it is important to provide the patient with a fair amount of visual, hearing, and speech mobility to save him/her from disconnection from the surrounding environment (Ghaeli, 2018), as this disconnection can cause confusion and delirium in the patient. Moreover, the advantage of multi-stimuli could be that a visual context can be given to the sound so that it is less alienating. Like patients know alarms come from machines, it has to be there for a reason to make the patient understand where the sound comes from.

Touch, Taste, and Smell

Although the other senses, touch, smell and taste, have been less studied, are less mentioned in the literature (Ghaeli, 2018), and their impact may be smaller, they should not be forgotten. For example: using pleasant scents and air fresheners can help make the environment pleasurable for the patient. But for now, they are considered out of scope. In addition, touch is left out of scope because of the regulations required to introduce a product that comes into contact with a patient.

For these reasons, the design intervention will consist of auditory and visual stimuli

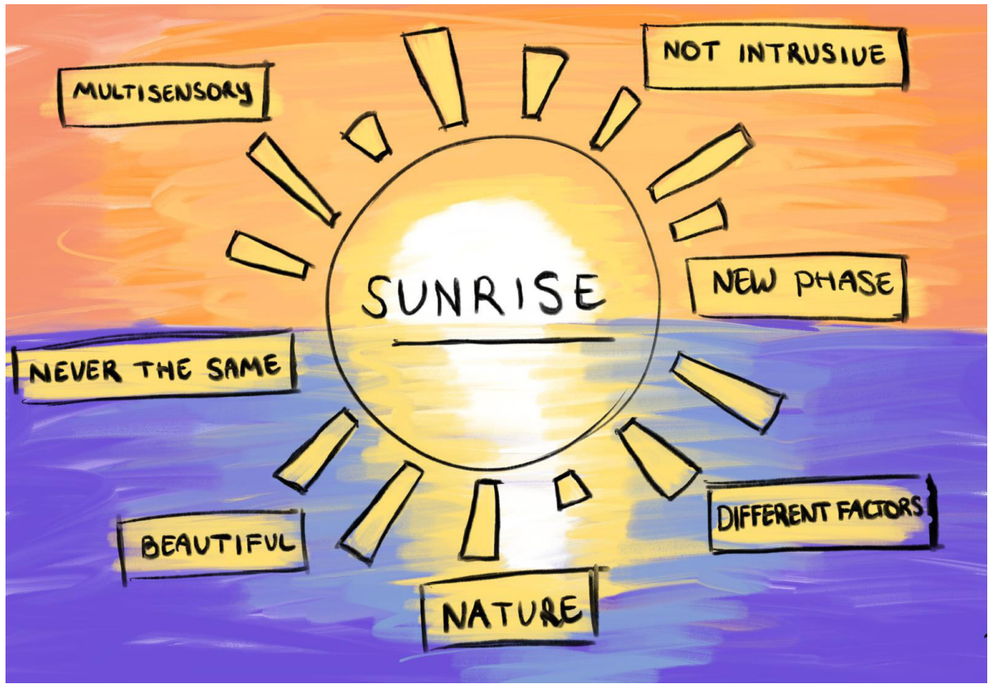


Figure 24: Sunrise analogy.

8.3 CONCLUSION

The design transition stimuli will consist of an auditory and a visual stimulus with the characteristics of a sunrise. In the next chapter, we will start to diverge more and start the ideation for possible design solutions that fit the sunrise characteristics, the use case and the requirements of the ICU environment.

9.
IDEATION

The goal is to design a transition between an eventful and uneventful environment so that the sharp changes are perceived as less disruptive by the patients of an ICU. The audio/visual stimuli aim to mask this contrast and shift the focus of the patient. The next chapter will focus on creating a new concept idea.

9.1 CO-CREATION

Brainstorm

The next step in the process started with a co-creation session (Figure 25) about possible stimuli with ten nurses. After the midterm presentation, the nurse, who continued to help me gain as many insights and information as possible, invited me to present at a 'Klinische les' (a clinical class). This is a weekly moment of one hour on Thursday afternoon where the ICU nurses can voluntarily attend a relevant presentation or workshop.

During my clinical class, I gave a presentation similar to the one I had given in my midterm presentation. When the presentation finished, we held a co-creation session where the nurses had to brainstorm possible stimuli.

Results

Nurses said that patients can sometimes listen to the radio, often with very annoying advertisements. So radio is not a very suitable stimulus. The advertising consists of the same sound clips every single time. They emphasized that in no case repetition should be used.

They suggested that there are, e.g., baby boxes that stimulate the babies with sounds, not necessarily music. So the stimulus does not have to be music to be comforting.

Additionally, they confirmed what was already discovered in the literature and interviews with former patients: too many stimuli can cause anxiety (delirium).

One nurse mentioned that there once was something like a beamer tried in one of the ICU boxes. She thought it was a device that could project things on the ceiling. It was recommended to ask Koos more about this device. That is why Koos van der Ree Doolaard (team manager ICU) will be later consulted to elaborate on this projector.

Additionally, snooze spaces that help comfort the patient were mentioned. These are especially for people with dementia or mental disabilities and will be further investigated in the following chapter.

When suggested, nurses confirmed that colours could be typically pleasant and projecting colours throughout the whole room would be great. As discovered earlier, nurses said, it is essential to sustain the day/night rhythm (so lighter during the day than at night).

Figure 25: Co-creation session.

One of the nurses proposed a photo frame with family pictures that could provide comfort. But whatever the design intervention is, the nurses strongly advised that they must always be able to look at the patient to assess their situation.

One exciting thing was concluded by one of the nurses:

> ***''We as nurses must be mindful of the sounds we produce and the support staff when they come to refill something. Through your presentation, we realize this much more."***
> ***- Erasmus MC nurse***

Conclusion

All things considered, the nurses saw the potential of adding stimuli to the environment. They made some great suggestions for audio stimuli (radio without advertisements, stimulating sounds and non-repetitive sounds) and visual stimuli (colours, projections, and family pictures). Nevertheless, they emphasized that it should not make patients anxious and that they should be able to assess the status of the patients by being able to hear and see the patient.
This session proved the potential of visual/auditory stimuli and served as the source of inspiration.

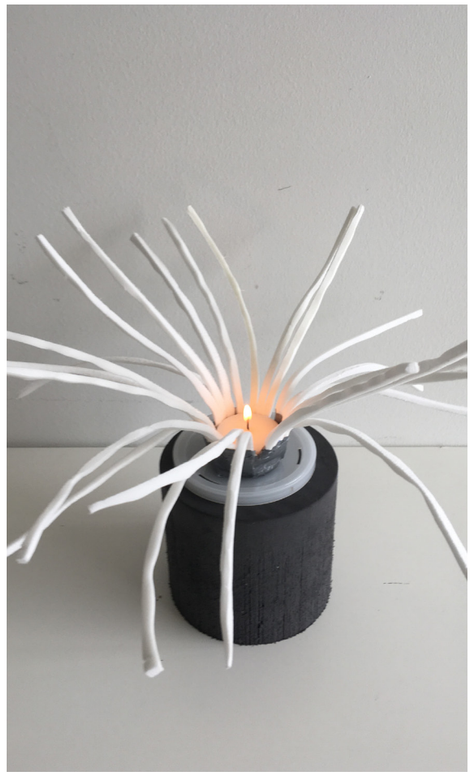


Figure 26: Object with candle.

9.2 IDEAS

So, with all this inspiration for design intervention, it was time to come up with some ideas myself. The analogy was used as a starting point to create ''How could you". This first ideation step can be found in appendix 8.

Another exploration started. As drawing only allows a two-dimensional creation space, it felt limiting. That is why, for the next iteration step, (three-dimensional) physical objects were built (Appendix 9).

From the object exploration/ideation, there were three interesting ideas.

1. The ritual of a candle (Figure 26)

2. Using the power of the elements (Figure 27)

3. Motion by sound (Figure 29)

9.2.1 THE RITUAL OF A CANDLE

Like the ritual of lighting a candle for an ill or dead loved one, the family can do 'something' for the patient to feel less powerless. When loved ones can do something, it gives them a sense of power and connection.
They can leave something behind, like warmth, light, or sound. At the same time, patients can enjoy the effort and derive hope from and/or be distracted by it.

Even though it would be a very nice use case, the focus is more on the loved one than the patient's experience. For that reason, we are not further developing this idea.

9.2.2 USING THE RESTORATIVE POWER OF NATURE

Just observing the objects with some natural Just observing the objects with some natural elements (Figure 27) gave a pleasant feeling and served as an incentive to further research the power of nature for restorative healing.

Figure 27: Object with natural elements.

The restorative values of seemingly untouched wilderness have been long acknowledged in the literature (Knopf, 1987). The interviewed former patients mentioned the comfort they found while looking through the window.
The literature tends to affirm the value of contact with nature in these hospital environments. In practice, the power of nature is widely used to help people better cope with pain and stress caused by their illness, treatment, or the hostile ICU environment. It provides a positive distraction (Von Lindern, 2017). This allows patients to endure pain and stress better, recover faster and reduce their stress levels. Moreover, Hartig & Cooper Marcus (2006) affirm that not only those who receive care but also the HCPs, the family members and friends of the patients can benefit from the restorative power of nature in health care environments.

In the hospital environment, there are many examples of such devices. The Erasmus MC ICU, for instance, has a large window in most rooms and in the rooms that do not, there are screens showing nature imagery.

Based on this, it was decided that the visual and the auditory stimuli should be inspired by nature.

Real nature is not a very feasible option in the ICU. But the power of nature is not limited to nature experienced outside. The use of natural elements (water, fire, earth and air) or (abstract) digital simulations can establish similar benefits (Figure 28).

We want to introduce, aside from a visual stimulus, also an auditory stimulus. Not only are the appealing qualities of sounds of nature convincing, but this also creates the possibility of preventing repetition. Although music and music therapy have been extensively researched and contributed to the patient's experience (Drahota, 2012 and Martin-Saavedra, 2018), music is also very personal. Like patients (P10 and P11 of the patient experience interviews) said:

> *"They turn on the radio, but mostly for themselves, 100%NL or something." — P10*

> *"Music I could not handle at all, it was very emotional." — P11*

Besides, it is already possible to play music (or radio), so in conclusion: natural sounds are more promising than music.

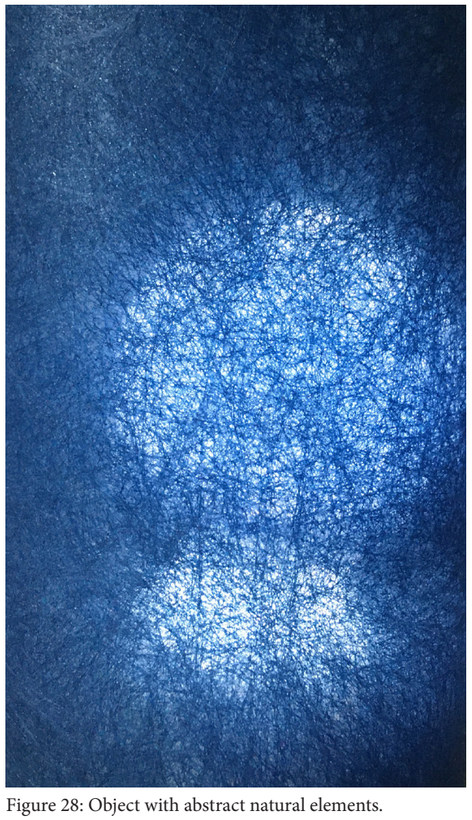


Figure 28: Object with abstract natural elements.

Figure 29: Experimenting with water.

9.2.3 MOTION BY SOUND

The core of the idea is that sound vibration can cause waves to form in water. Motion is life, variation, and interaction which could get patients more engaged in the environment.

Sound pressure levels in the ICU room can be used as input for changing the visual stimulus to make it more interesting to watch. You will be able to see what you hear. This can help the patient by distracting him/her or be an anchor for a transition.

Experimenting with water (Figure 29) and creating waves in water by playing sounds made it clear that sound is a very intuitive incentive for motion. However, using actual water would have a massive impact on the environment: maintenance, cleaning and, more importantly: how will the patient be able to see this without it obstructing the HCPs?
Also, exact sound frequencies needed to be played at a specific volume level.

Figure 30: Digital projection of water (Photo by MegaGadgets).

A virtual/digital visual (University of Twente, 2022) could be a good option because it is better to display, takes less space and maintenance, is easy to update and adapt, and it is not in the way of healthcare professionals (Figure 30).

Sound can be input to change sound. Sound pressure levels in the ICU room can be an incentive to change the visual and/or the soundscape to make them more interesting to listen to or see, which also can announce or introduce a transition.

9.3 CONCLUSION: THE CONCEPT IDEA

The chosen concept consists of nature sounds combined with a nature-based projection, as this best fits the context of an ICU and combines the best parts of all ideas. The audio and the visual change according to the SPL in the room.

Transition stimuli:
As the audio and visual react to the SPL, they help guide the patient into the new environment.

Signal stimuli:
It is a subtle way to notify the patient that something is happening. Something that anchors the patient to the environment.

Event stimuli:
Distract the patient (when bored or during treatment). You can not only hear a change in the acoustic environment, but you can also see it.

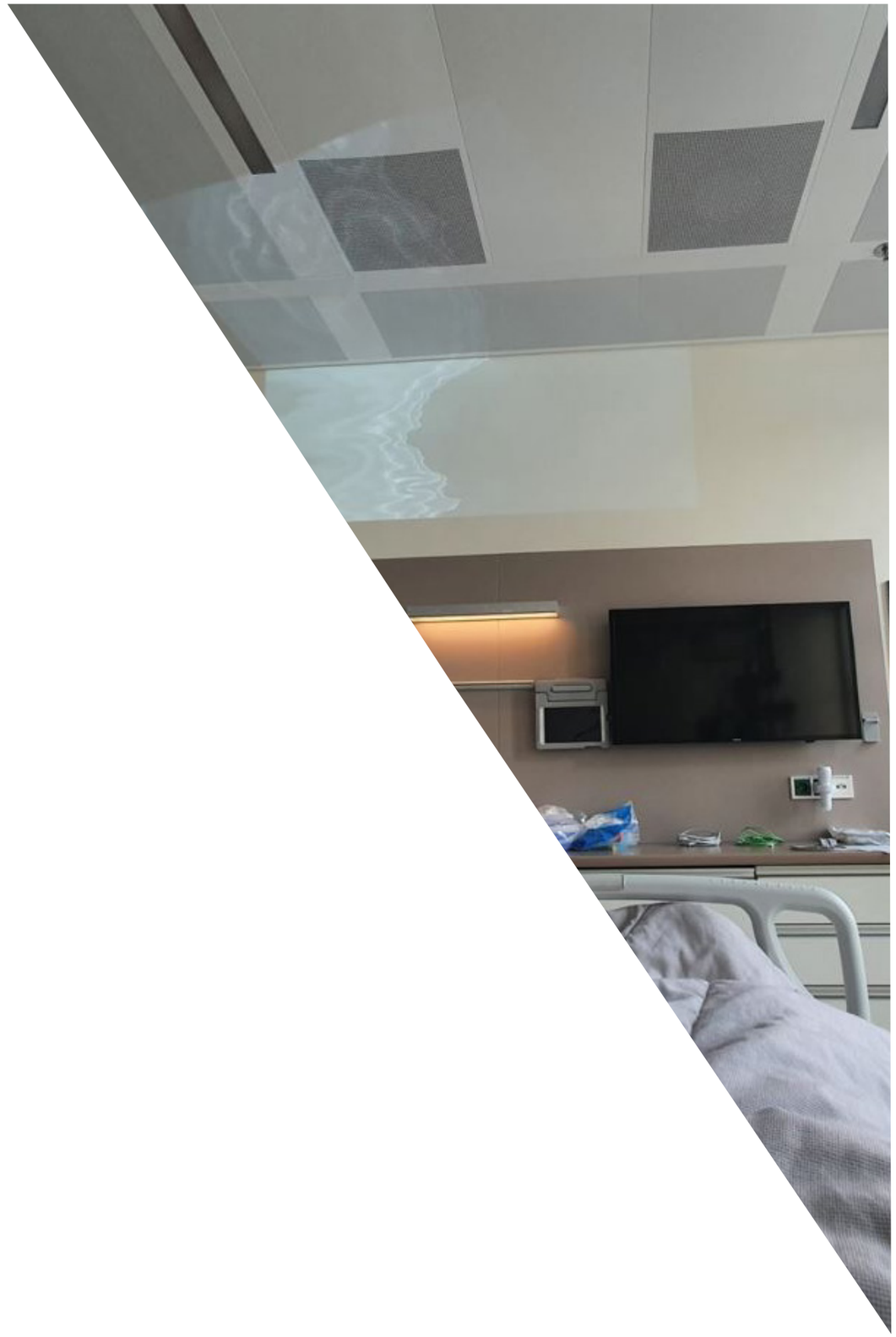
Background stimuli:
A stimulus that is always there to decrease the difference between higher and lower sound pressure levels.

Thus, the aim of the concept is to make the eventful, the non-eventful and the transition moments clear but also more pleasurable.

10. CONCEPT DEVELOPMENT

In the next chapter, the concept idea will be developed into a concept. The same approach is used for both the audio and visual parts of the intervention. First, the current stimuli will be discussed to know what you hear or see in the ICU environment now. Secondly, we will research the current interventions and what is already out there. And thirdly, use these insights to learn how to improve what exists and create a new visual and audio intervention.

First, we start with the development of the auditory stimulus and proceed with the visual stimulus. Both elements of the design intervention must complement each other and behave according to the same principle when adapting to the SPL changes in the room.



10.1.1 CURRENT AUDIO STIMULI

What do you hear now?

Together with the nurse, I went back to the ICU box to understand the current ICU's soundscape and make some audio recordings (Figure 31). Knowing the sounds and knowing the perception of these sounds offers a way to improve the soundscape.

Figure 31: QR-code recorded ICU sound.

The ICU is called a silent ICU and is indeed very quiet, but there are sounds. When nothing is happening, you hear:

- The air-conditioning (you do not really notice, but if it stops you would feel "relieved")
- Your own breathing and movement
- The mattress filled with air going in and out to prevent decubitus (patients find this extremely annoying)
- The heart rate monitor only during treatment or when the set boundaries are exceeded
- The door opening and closing
- People in the hallway if the door is open
- The door
- Sound of nearby rooms, the door is soundproof, but the walls are not, so patients are still able to hear alarms or other louder sounds from the adjacent rooms.
- The sound of a suction tube (to remove slime out the throat of a patient)causes an immediate stress reaction in patients
- A breathing support machine (ventilator) can be annoying, but the consistency of the sound gives a feeling of security
- Other sounds of the machines, most of the time, mean nothing but the patients do not know this when coughing or exceeding certain limits etc.

To summarize, what we know about the positive and negative sound perception as of now is:

Sound is perceived as **negative** when:

It is annoying
It is repetitive
Sound is shameful (the human body can produce (unintended) sounds)
Sound reveals your privacy
You hear other patients' sounds
You hear people talk about you

Sound is perceived as **positive** when:

It gives structure (anchors)
It is happy/comforting (e.g. music)
You just get used to it
It explains what is happening
It directs the attention
You do not want it to be silent
The doctors and nurses are talking reassuringly
Natural sounds are played
There is less sound (quiet)

During prior research into the patient experience and daily routine, we gained a great understanding of the sound in the ICU environment. We have also already discussed the importance of sounds in the ICU. The next chapter will delve deeper into the current sound interventions.

10.1.2 CURRENT INTERVENTIONS

What is out there?

Currently, the added sounds that are non-related to human activity are radio and music. The patients can actively listen to this, or it can play in the background. Interestingly, the majority of interventions focus on the reduction of sound instead of the introduction of sound.
There are many measures to eliminate sound (Luetz et al., 2019):

1. Optimizing the architectural design: private rooms or installing automatically closing doors.
2. Establishing behavioural changes of staff and visitors by improving awareness
3. Improved material choices: using sound absorbing materials and avoiding sound reflective surfaces.
4. Implementing alerting systems. For example, sound measuring systems can enable staff to recognize harmful SPL immediately and, if possible, delay non-essential interventions to prolong restorative periods of quiet.
5. Implementing noise-cancelling technology to protect the patient from noise exposure: e.g. headphones with anti-noise or music and earplugs.

Removing sound perceived as noise is a straightforward way to aid the patient as noise is a commonly mentioned issue by survivors of critical illness. But not all sounds can, in the end, be removed from the environment while prohibiting fully isolating a patient from the surrounding.

All these efforts to eliminate noise can disconnect the patient, especially earplugs and headphones may cause this isolation. In reports, tolerability is a significant issue, as non-sedated patients often frequent dislocation, discomfort, and feelings of isolation when wearing earplugs (Demoule, 2017 and Richardson, 2007).
The new intervention will therefore be delivered to the patients via speakers instead of ear/headphones.

As mentioned earlier, there have been studies in which relaxing music was introduced into the ICU environment (Gheali, 2018). Through hearing, patients are still attached to the environment. Therefore, using soft music without lyrics could help lower patient anxiety and reduce confusion and delirium in patients (Wong, 2001).

This project attempts to look beyond music and aims to introduce nature sound into the ICU environment because the sound of nature seems to benefit more patients as it is more universal and has a restorative effect. But there have not been any significant studies on this subject yet.

10.1.3 NEW INTERVENTION

There are many ways we could introduce natural sound to the ICU environment.

One option considered giving the loved ones the control and letting them select sounds before leaving. By allowing loved ones to select sounds just before they leave, they can introduce that they are going away. The advantage is that they can choose something with the highest chance of being to the patient's liking.
However, the stimulus would then need to be actively controlled (as the recorded sound pressure level principle is not used). Therefore, it could easily be forgotten, feel uncomfortable, and if the selected sound is finished, the patient would again be in the quiet ICU room. This direction was rejected because it was more desirable to have the stimulus play in the background.

There lies a great opportunity in introducing a background sound. The goal of background sound is to decrease the difference between higher and lower sound pressure levels by raising the lower sound pressure levels. As a result, sound level changes may be experienced less disruptive (Jaiswal et al., 2017), making the transition moment less extreme or intense.
Therefore, if comfortable for the patient, the audio stimulus will generally be on for long periods.

If something is playing for a long time or multiple times, you do not want it to be repetitive. To prevent repetitiveness, it is desired to use a continuously and randomly generated audio file instead of a standard audio file.

Aside from this, we want the audio to react to the recorded sound pressure levels. This can be accomplished in two ways:

1. Changing the volume

When using a standard audio file or a randomly generated audio file (calm nature sound or white noise), you can let the audio volume correspond to the recorded sound pressure levels in the room.

2. Changing the audio

You can also create reactive audio that changes the audio according to the room's sound pressure level (SPL). This would mean that the audio would become more interesting or increase richness when the room's sound pressure level rises.

When the sound pressure level would be at its minimum (1 or 5), only the background base sound would be playing (this would preferably be a randomly generated audio file). As SPL in the room rises, the audio becomes increasingly more diverse (2), and as SPL decreases, the audio becomes step by step more ordinary again (4) (Figure 32). All sound levels play when the highest SPL threshold is reached (3).

While the patient would still be able to hear the visitors, as the audio volume level stays the same, the transition can become much more appealing. Therefore, it was decided to continue developing the reactive audio direction.

We have already decided to use speakers instead of earbuds/headphones. We do not want to confuse the patients or direct their attention in a specific direction. Therefore, two speakers will be placed close to the patient's head. This way, they will have the best audio experience without turning up the speaker extremely loud. A directional speaker can be an exciting option to prevent the HCPs from hearing the audio. However, it may

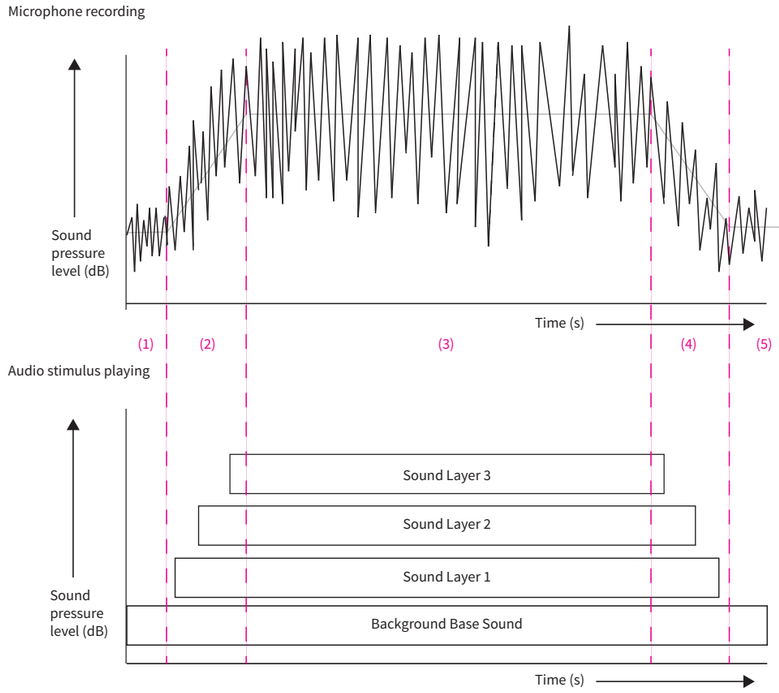


Figure 32: Changing the audio.

also be interesting to investigate the effect of the intervention on nurses or loved ones, as they also experience a hostile environment. Maybe they also want to hear it because it makes them feel comfortable. Therefore, for now, we choose the regular speakers.

10.1.4 CONSULTING AN EXPERT

Anıl Çamcı PhD is, an Assistant Professor of Performing Arts Technology at the School of Music, Theatre & Dance (University of Michigan), consulted on this idea. The questions can be found in Appendix 10.

His thoughts on the background sound and transition in sound were as stated below:

The background sound:

- When creating audio in this context, avoid loops
- The idea of white noise in the form of natural sounds like wind through trees is good
- An algorithm approach seems appropriate for the background sound. It could generate a new audio stimulus every time. And another advantage may be that it could be written in a way that it could learn personal preferences and become better at creating personalized, comfortable transitions in the soundscape.

The transition in sound:

> ***"An evolutionary trait of our hearing is an acute attentiveness to subtle changes in quiet sounds, which can be easily exploited to draw the patient's attention" – Anıl Çamcı***

- Introduce a 'sharp' sound or sharp change, so the patient really notices the change or the transition in eventfulness.
- These "sharp" changes can be implemented in the sound itself, but the location the sounds come from or the direction the speaker is pointed towards can also be changed.
- The idea of using layers of sound samples seems to be a good Minimal Viable Product (MVP).
- For later on, think of ways to make it even more interesting to listen to by changing the specific sound samples according to other parameters aside from volume levels.
- For now, using sound samples is recommended, but also think of synthesizing natural sounds. This creates even more possibilities for changes like changing the pitch, frequency, etc.
- Aside from adding and removing layers, in the future, investigate changing the background sound from natural sounds to rhythmic or even music (you would need the previously mentioned synthesized sounds as a basis for that).
- Do not make it too complicated the first time you are going to test this principle.

After discussing the idea with Anıl Çamcı it was confirmed to focus on reactive audio direction. The audio would be based on pre recorded natural sound samples instead of synthesis. The transition will be created by adding and removing sound samples according to the measured sound pressure levels in the room. The goal is to create a non-intrusive 'sharp' change in the soundscape because subtle changes in quiet sounds can be easily exploited to draw the patient's attention.

10.1.5 PROTOTYPING

So the idea is clear. Now we need to develop the idea into a working design. This will serve as a high-fidelity prototype to test this idea and prove the feasibility.

The requirements of the audio stimulus are:

- Must be interesting, not repetitive
- Must be based on nature
- The patient should still be able to hear HCP and vice versa
- Must not be intrusive
- Must not be annoying

As explained, the audio will be created using sound samples. A selection of different natural audio samples was made with the use of Envato Elements website. The sound samples had to be of different lengths to establish the fading-out idea.

A lot of nature sounds were heard and evaluated, taking into account if they would quickly become annoying. Hearing the same bird wings clap 20 times will drive you crazy. After around ten sounds were selected, they were mixed in Adobe Audition (Figure 33) to hear what a combination of the sounds would sound like, an example can be found on the SoundCloud page by scanning the QR code (Figure 34). Based on the researchers' opinion, a selection of sounds that fit together was made.

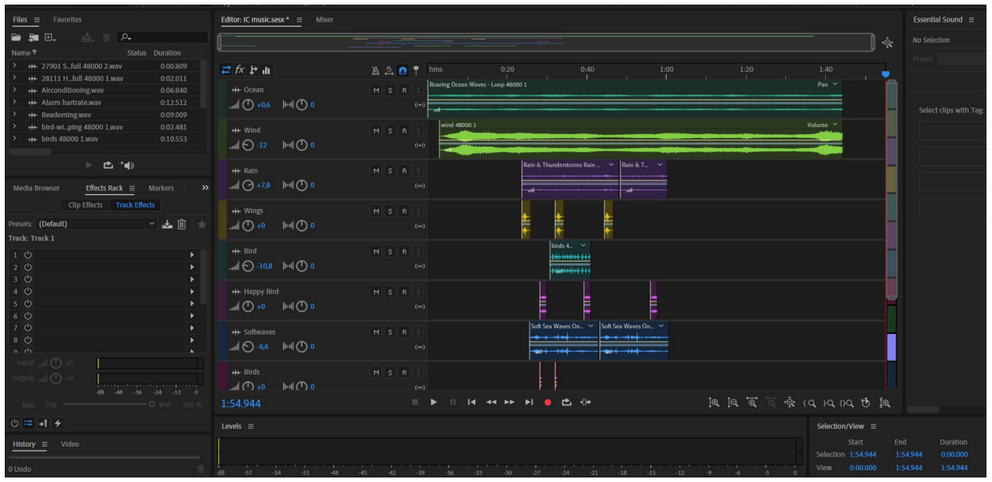


Figure 33: Adobe Audition prototype.

Figure 34: QR-code example Adobe Audition prototype.

Then the code was written in P5.js (Appendix 11). In the future, making the audio stimulus in a software program called MAX can also be interesting. This software allows you to do many cool things like synthesizing sounds. However, because it was desired and advised to start with a basic setup, the decision was made to do this in P5.js as this is a very suitable program for doing all kinds of prototyping.

The basic idea of the code is that if a volume level is reached, a sound sample with a dedicated threshold will start to play. For the final code, six sound samples are used: ocean (base sound), rain, birds, sea, wind howl and fruits (sound like creaking twigs).

If the samples are playing, they will only be replayed after the total sample finishes playing and if the threshold volume level is measured again. This is a continuing process for all sound samples. So sometimes, more and sometimes fewer samples are playing, and the soundscape is created randomly

based on the measured SPL in the ICU Box.
Until it is too quiet in the room and only the base background "white noise ocean" sound is playing. Additionally, if the measured SPL is immediately very high, more sound will start to play at once. But due to the length variety, a fading-out effect is created.

To illustrate and understand the working of the code, visit the link to the P5.JS code:
https://editor.p5js.org/Evavh/sketches/uZHI52jMM

After tweaking the volume levels and the threshold when samples would start to play, the prototype was finished and ready to use for the evaluation experiment.

10.2 DEVELOPMENT OF THE VISUAL STIMULUS

From here, we shift our focus and continue developing the visual stimulus. Again, we follow the same steps to create a new intervention.

10.2.1 CURRENT VISUAL STIMULI

What do you see in the ICU?

In the ICU, patients can see the room if their eyes are open (Figure 35). They can see the wall, ceiling, door, clock, cabinets, a chair, and a TV screen. Through the window of the door (Figure 36), they can watch the corridor. And most rooms have a window through which they can look outside.

Most of the time, the blinds of the window are halfway down (Figure 37). Nurses do this because too much light can be too bright (patients squeeze their eyes) and can be annoying or cause sleep deprivation. But to have some daylight is good to give the patient a sense of day and nighttime. Most lights are turned off at nighttime, and only the one above the cabinets is on (Figure 38).

For entertainment or to distract the patient, the TV can be turned on, or the patient can use his/her phone. However, most patients look outside through the windows or just look around in the room to see the furniture and maybe look at some pictures/cards of family and friends hanging on the wall.

Patients must look at (the pattern of tiles on) the ceiling (Figure 39), the lights are constantly on, and excessive light (Krampe, 2021) can all be environmental stressors. Thus, we can conclude that the environment can be stimulating and informative to look at on the one hand but can also be boring, overwhelming, or annoying.

10.2.2 CURRENT INTERVENTIONS

What is out there?

Aside from the TV and a phone, other interventions could benefit ICU patients. In this paragraph, we will discuss three different types of interventions that have some overlap with the proposed visual stimulus concept. These products are the *Qwiek.up* (a projector), *Snoezelen* (a Multi-Sensory Environment) and the *Philips VitalSky* (a light therapy system).

Figure 36: The door.

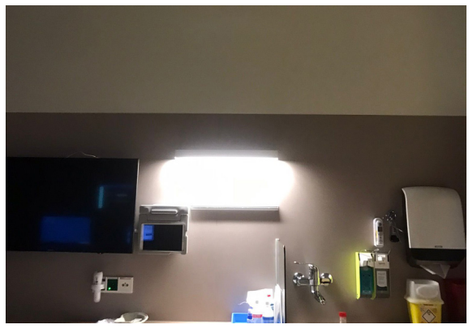


Figure 38: Light above the cabinets.

Figure 39: Ceiling.

Figure 35: Patient view.

Figure 37: Blinds of window halfway down.

Qwiek.up

According to the nurses, there had been a projector in the ICU environment. After asking Koos van der Ree Doolaard (team manager ICU), it became clear that the nurse talked about the Qwiek.up (Qwiek, 2022). The Qwiek.up (Figure 40 and 41) provides an audiovisual experience during care moments. The goal of the Qwiek.up is to make restless care moments in elder care more enjoyable, reduce stress during treatment in the hospital and stimulate, in the case of over- and under-stimulation in the care for the disabled.
Explicitly reducing stress during treatment in the hospital appears to be a good fit for the ICU context. Only one feature was suitable for the context: projecting peaceful visuals with audio.
Koos van der Ree Doolaard could provide some insight why the Qwiek.up was not fit for the ICU (they tried it once). This was mainly because it was designed for a different target group. Patients in the ICU are too ill and not adequate, so there was no added value. Koos van der Ree Doolaard suggested that it may be a better fit for a peripheral hospital because patients leave the ICU there in better conditions.
In his opinion, moving such a device into the room every time you wanted to distract the patient would not be worth it. He was afraid the visuals of coral etc., would be too intense, and he believed that it could benefit the patient by distracting him or her, but it could also be annoying.
Koos was a big advocate for reducing the sounds in the ICU first and then maybe focusing on adding stimuli. He said: ''***The sound of the door can already be too much noise".***
However, in the end, you will not be able to control all sounds. You can not eliminate all, there will always be sounds, but with the design intervention, you may control the perception. It just has to be designed with the right target group in mind.

Snoezelen Multi-Sensory Environments

Snoezelen Multi-Sensory Environments (Figure 42) are relaxing spaces that help reduce agitation and anxiety, but they can also engage and delight the user, stimulate reactions and encourage communication (Snoezelen Multi-Sensory Environments | Sensory Rooms and Therapy Explained, 2022). Snooze rooms were also mentioned by participants and nurses. Some elements of these rooms can indeed distract or comfort ICU patients. However, a snooze room is not fit to perform care in or to conduct sufficient patient observations.

Figure 40: Qwiek.up (Photo by Qwiek.up).

Figure 41: Qwiek.up (Photo by Qwiek.up).

Figure 42: Snoezelen Multi-Sensory Environments (Photo by Snoezelen).

Figure 43: Philips VitalSky (Photo by Philips).

Philips VitalSky

VitalSky (Figure 43) is a personalized light therapy system, designed for clinical use in the ICU. The VitalSky light therapy system provides a circadian-effective program to support the sleep-wake rhythm of patients. This program simulates the natural progression of daylight. The light conditions can be personalized to the needs of the individual patient. Advanced features include the additional option of playing calming nature scenes in full-colour, soft-focus video, and the future enablement of cognitive training is also planned. (Philips introduces VitalMinds, new non-pharmacological approach for preventing delirium in the ICU, 2022). But the device is not able to adjust to the environment itself (SPL) like the proposed design intervention, but only to the time of day. Nevertheless, it shows a global leader in health technology is also advocating for displaying nature visuals in the ICU environment (Research | Digital Nature—Enhancing Patient Experience in ICU | Department of Design Production & Management, 2022).

10.2.3 NEW INTERVENTION

How to improve?

We want to introduce a nature-based visual stimulus, similar to the suggested calming nature scenes of the VitalSky. However, our visual has to react to the measured sound pressure levels (like the audio stimulus) and become more interesting to look at, so it is more distracting or appealing. When the SPL decreases, the extra distraction feature slowly fades out and vice versa, similar to a windmill or wind spinner toy (Figure 44). It enables the patient to see the changes in the soundscape. Like the windmill example, the ''motion' will not stop, meaning that the patient is still visually stimulated even with very low sound pressure levels.

A screen is very defined and bright. I want to use a projection (Qwiek.up) instead of a screen (VitalSky) because it is less bright and more inherent with the environment as it can project on both the walls and ceiling. Creating a more engaging environment, like a snooze room.

There would be some distortion of the visual because it will be partly projected on the ceiling. For the visual design itself, this would mean that it must display something within the spectrum of a real versus abstract.
It should be recognizable or feel familiar to the patient. Realistic in the sense that it does not become too trippy. So, it needs to be abstract, but it should remain a representation of nature or have a strong connection to nature.
As the SPL rises or lowers, the visual should become more or less distracting. This can be created by increasing or decreasing the visual's motion and changing the visual's relative real versus abstract level.

Figure 44: Wind spinner (Photo by AliExpress).

Figure 45: Biophilic lighting design (Photo by Beersnielsen).

10.2.4 CONSULTING AN EXPERT

Sylvia Pont, professor of Perceptuel Intelligence at the Faculty of Industrial Design Engineering, was consulted on this idea. Her main interests are lighting design, visual communication of light, material, form and space, the measurement and tuning of appearance, and art. Questions asked can be found in Appendix 11. She gave some great tips:

- The discussed choice for beamer versus screen, she agreed on beamer for the reasons.
- Beamers can make a lot of noise. Look for a quiet beamer. And think of the correct specifications (covert area, brightness etc.)
- She liked the link with the nature element and mentioned the benefits of restorative environments
- In lighting design, there is Biophilic lighting (beersnielsen.nl). Lighting design inspired by nature. This can be used for inspiration.
- Think about what changes need to be made to make the product ICU proof
- Avoid 'glare'. Direct glare would be staring into the bright light of the beamer projection. You could also have indirect glare, where you stare into the high brightness reflection of the beamer light on a shiny surface. Prevent this both from happening.
- The light should always adjust to the (natural) lighting of the room. So the brightness, contrast etc. should be fit, set and changed according to the state of the environment.
- Tovertafel would be a great project for you to get inspired by (Tovertafel will be discussed later on).
- Do not test the audio and visual components separately (it is about the total experience)
- For the idea of the changing visual, make sure to make the basis, the background lighting pleasurable and lighting changes subtle yet distracting.

Inspired by biophilic lighting design, the aim is to create a nature-inspired visual stimulus projected on the wall and ceiling that, in the first place, is pleasurable to watch. Then, when sound pressure levels rise in the ICU box, the visual reacts and behaves more distracting yet pleasurable. This fades out again when SPL drops. How much the visual reacts depends on the height of the volume level.

10.2.5 PROTOTYPING

The last step in the development of the visual stimulus was the creation of a functional design. This illustrates the working, and during the evaluation test this high fidelity prototype was used.

Requirements of the visual stimulus were:

- Must represent of reference nature
- Must be pleasurable to watch
- Must have interesting changes
- Must not too be intrusive
- Must not be repetitive or annoying

Waves became the inspiration for the audio stimulus (Figure 46) that had to change motion and level of realness versus abstraction.
Utilizing waves is very suitable since it fits the analogy of the sunrise and nature perfectly. Due to the relaxing effect and repetitive property of waves, and because of the inseparable connection between sound and waves.

The visual was created in Touchdesigner (and played via assisting software called Touchplayer). Touchdesigner is a software program to create real-time moving visuals. It is used by (performance) artists. It allows you to assign behaviour to pixels, for example, to move in a constantly changing motion. And most importantly, it can use measured SPL. This data can serve as an input to make changes in the behaviour of the pixels (output).

A lot of experimenting was done to get the pixels to move like waves and to create the real versus abstract spectrum difference when SPL would rise and fade out again. Eventually, the visual looked like figure 47 and 48.
The visual reacts to the changes in the volume in

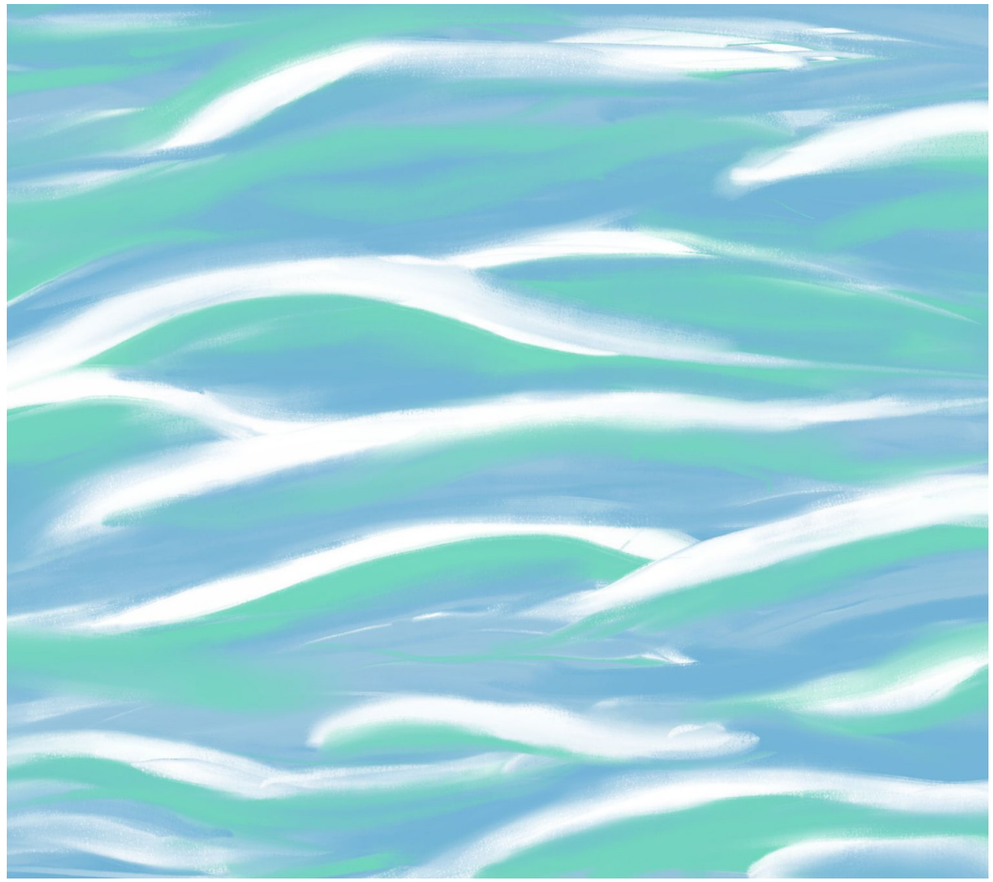


Figure 46: Drawing of waves.

the room. Figure 47 is when it is quiet and figure 48 is when there is increased volume. When SPL rises increasingly, the visual will start to react/change more. Figure 49 and 50 show the projection of the visual stimulus.

There are a lot of parameters that could be tweaked to change the visual and the behaviour of the visual. It would even be possible to give some control (like changing colours or speed) to e.g. the family members in the future.

According to the researcher's preference, the high-fidelity was finished and ready to use in a test simulation to evaluate the design intervention.

10.3 CONCLUSION

The design intervention has an auditory and visual component. Both are playing continuously in the background and reacting to the SPL changes in the ICU environment.

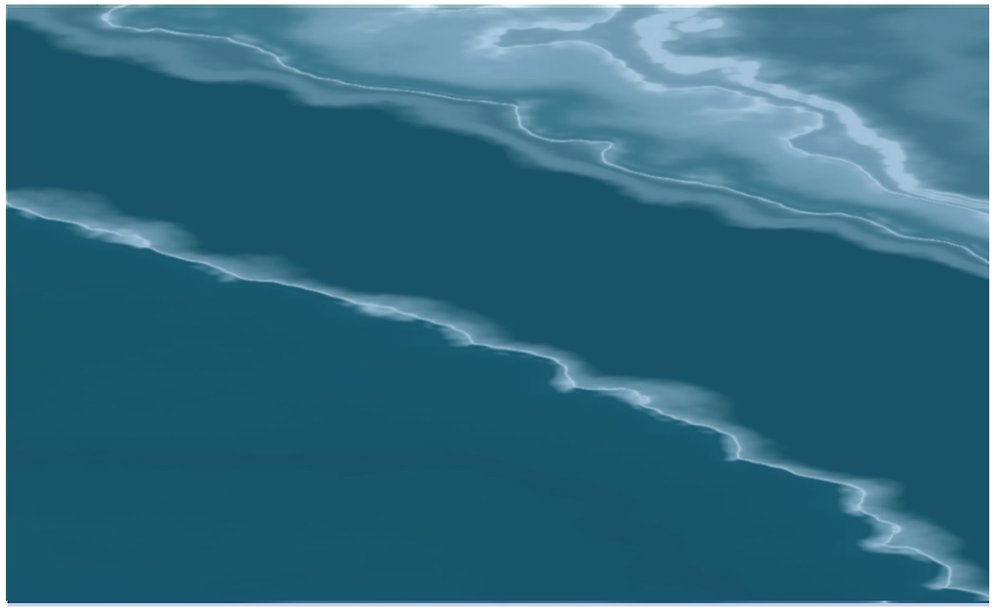


Figure 47: Visual (Quiet).

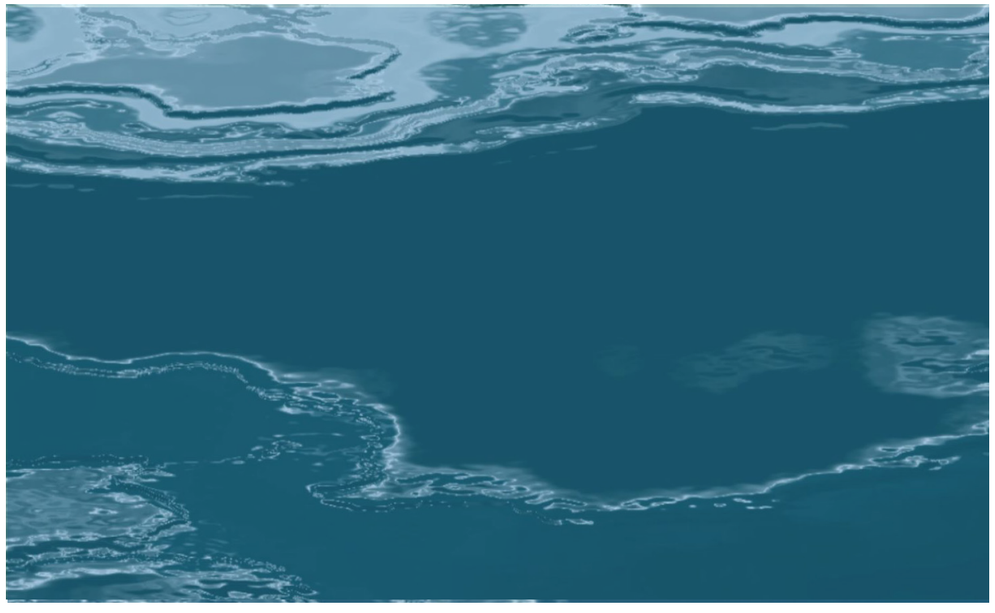


Figure 48: Visual (Increased SPL).

The audio is based on pre-recorded natural sound samples, played through speakers on both sides of the patient's head. The visual stimulus is an animation of changing waves in a spectrum of real versus abstract, projected on the wall and ceiling. It aims to support the patient during the transition between event- and uneventful moments and provides more comfort and stimulation.

The visual and auditory stimulus have been developed and prototyped. The developed stimuli will be test in a simulated ICU environment to see what the possible effect is on the ICU experience. In the next chapter, the design intervention will be embodied and integrated into the ICU environment.

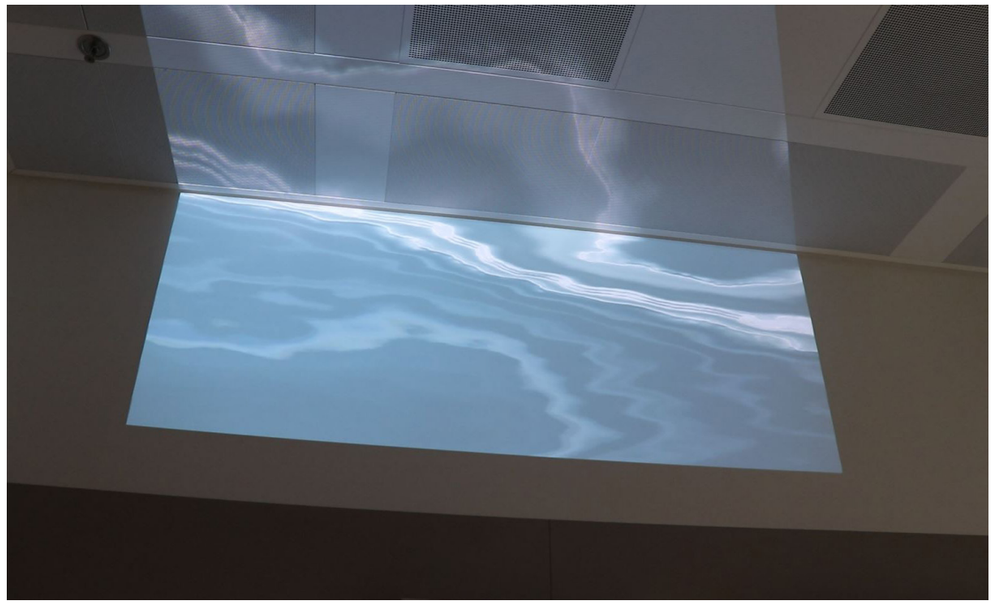


Figure 49: Projection (Quiet).

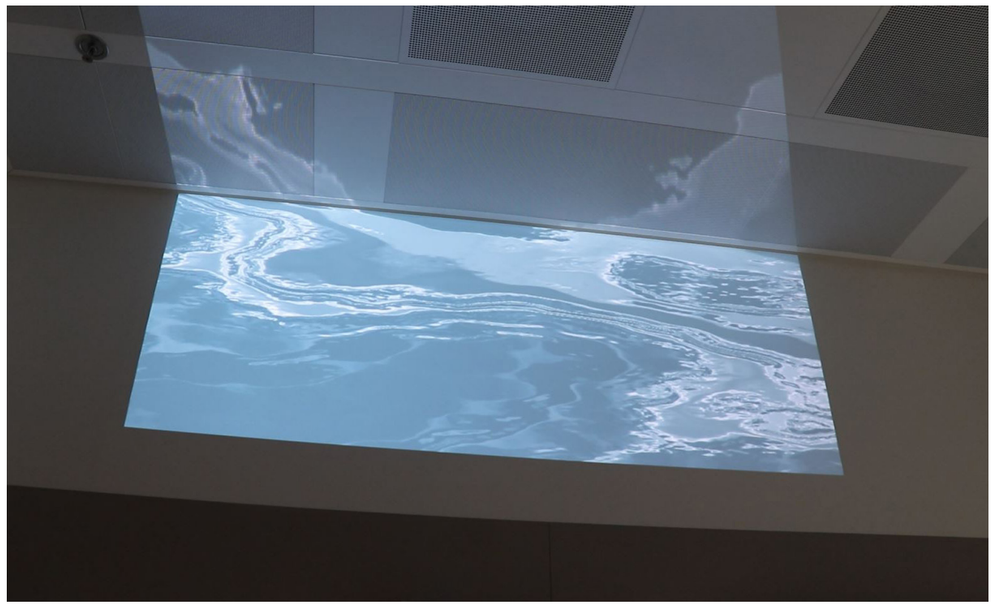


Figure 50: Projection (Increased SPL).

11.
EMBODIMENT

In the next chapter, we will embody the design and illustrate how the concept will look in the ICU environment. We will examine the integration into the ICU environment and select the hardware and software needed to produce the audio/visual stimulus.

11.1 THE ICU INTEGRATION

In order to be able to design and implement, the requirements of the context need to be known, therefore, the possibilities and limitations must be explored.

11.1.1 GENERAL REQUIREMENTS

It is important to understand that, when designing an ICU device, you must keep some basic requirements in mind. According to Koos van der Ree Doolaard, Team manager ICU, those are:

1. Easy to clean/removable
2. Easy for the caregivers to use
3. Nothing sharp / not hurting
4. Not in the way / not disturbing the care staff
5. Ergonomic design
6. Easy to store
7. No batteries
8. Fits within the existing environment

11.1.2 PLACEMENT OF THE DESIGN INTERVENTION

This last requirement, which insists on ensuring that the intervention you are introducing is placed well in the existing environment, needs further explanation.

With Sebastian Wagenar (nurse), and Koos Jabaaij (technical office), I went to the ICU to investigate product placement. I learned that if you want to design something for the ICU, you should ensure you can attach it to the DIN rail of The Dräger ceiling care system (Figure 51 and 52).

This is the best option considering that otherwise the product can be in the way of care, and many other products are already attached to it. Besides, you are not allowed to attach something to the ceiling.

In addition, power outlets are required. All power outlets in the ICU room can be used for medical and non-medical devices. Multiple are available at the back of the two Dräger arms (Figure 53) and one above the cabinets (the other is used for powering a flashlight), Figure 54.
It is the only spot where you can place the design intervention (if it requires more than one power outlet).

You can attach devices or objects to the Dräger system using DIN rail (Figure 55). DIN rail is a simple, standardized rail (Rails accessories, 2022). The width and height are 1 × 2 cm and the rail is available in various lengths. It is very commonly used in hospitals. Also, these beams can be found everywhere on the Dräger Ponta (Figure 56), the Ceiling Care System used in the ICU (Ponta Beam Supply System, 2022). DIN rail can carry a minimum of 15 kg, and the maxima differs. As it is not expected that the designed intervention will exceed this weight, it is safe to attach it to any of the rails.

Figure 51: The Dräger ceiling care system (Photo by Dräger).

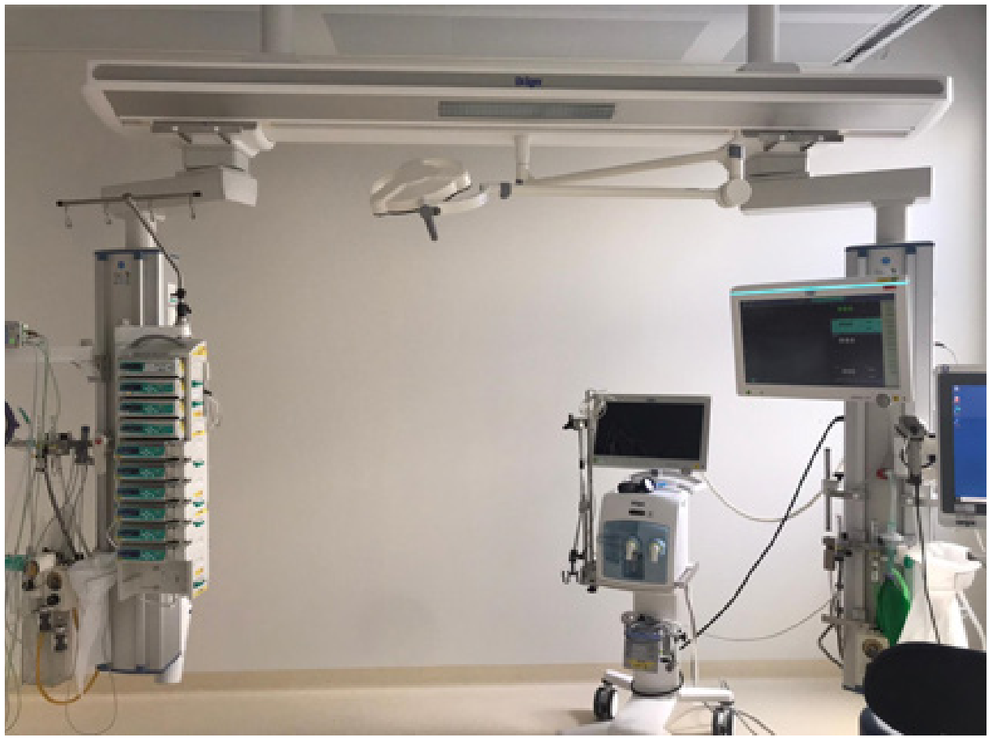


Figure 52: The Dräger ceiling care system (Ponta) at the Erasmus MC.

Figure 53: Power outlets arm.

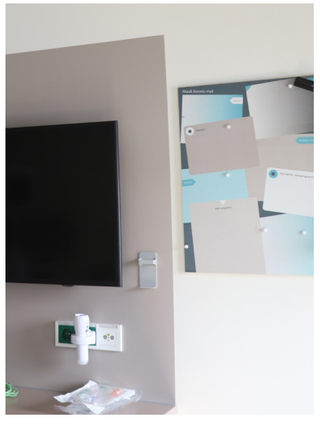


Figure 54: Power outlets above cabinets.

Figure 55: DIN rail with attachment pieces.

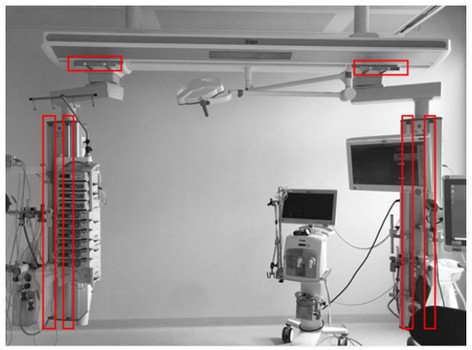


Figure 56: Marking DIN rail.

There are all types of attachment pieces on the market, for example see figure 55.

So instead of designing an attaching system yourself, it is easier and safer to choose from the existing ones (really, they have any type, shape or form).

For example, the one you can see in figure 57. It shows (1) the jacking bolt, (2) the attachment piece and (3) the DIN rail.

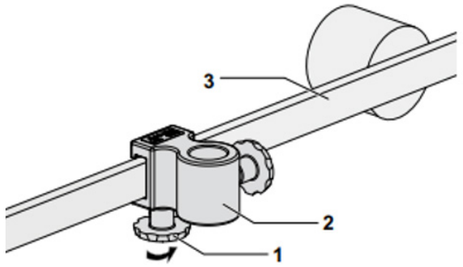


Figure 57: Example attachment piece (Photo by Dräger).

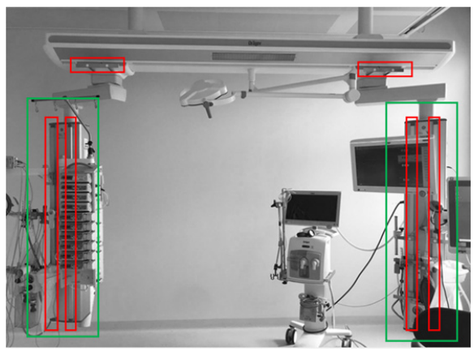


Figure 58: Suitable location on DIN rail.

Audio

We now know that we want to attach the design intervention onto the DIN rails of the Dräger ceiling care system. We will attach the speakers on both the DIN rails, one on each arm of the Dräger Care System. Two power outlets are used, one per arm. And the maximum height for the speakers was determined. There is enough room if the speaker is not higher than 21 cm.

The speakers should be attached with the selected attachment pieces (Figure 59 and 60) to the DIN rails somewhere in the green area (Figure 58), preferably high, so they can be directed towards the patient's head and be as much out of the way as possible.

Figure 59: Selected attachment piece on DIN rail.

Figure 60: Selected attachment piece.

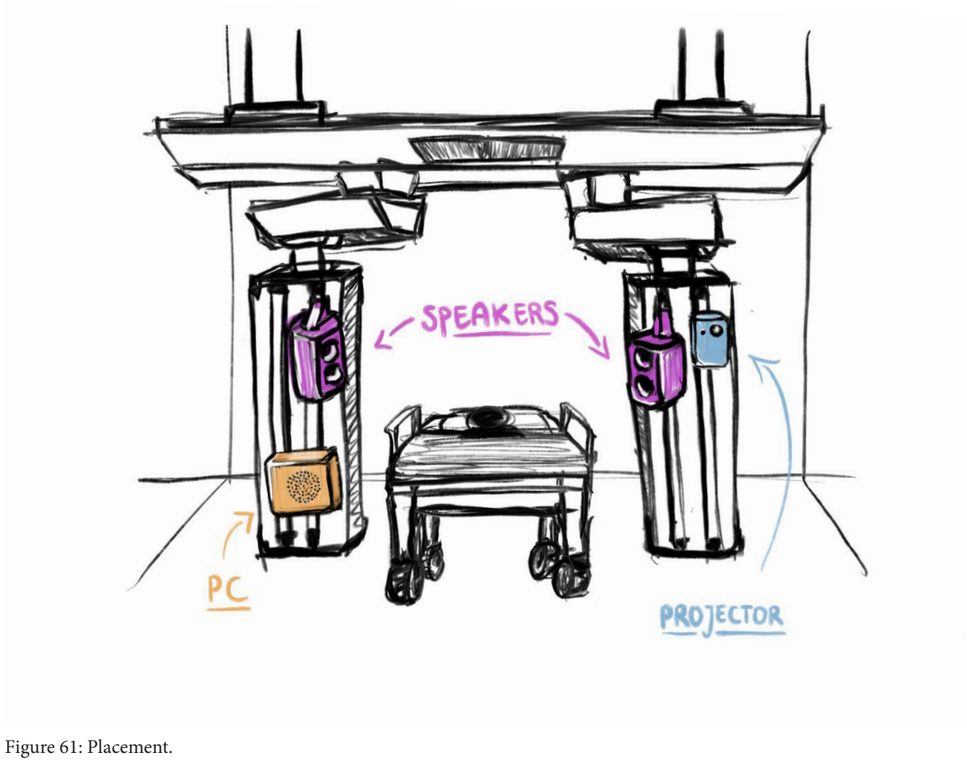


Figure 61: Placement.

Visual

For the visual stimulus, we will need a beamer/ projector. For the placement of this projector, we will need one power outlet. We will need to prevent glare, and it should not be in the way of the HCPs. The projector should be directed at the wall across the bed. It can be attached similarly to the speakers on the DIN rails on one of the Dräger arms (Figure 58). If the beamer needs to be placed closer to the wall above the cabinets, the other power outlet must be used (Figure 62).

Also, the computer and microphone need to be powered and placed in the room (requires one power outlet). Most importantly, it should not be in the way but easily accessible because the power button will be on this component. Possible places are shown in the figure (Figure 61).
It will probably be preferred to have the casing with the microphone and computer attached to the Dräger system. As other devices are already located there, it is close to the nurses that turn it on/off, and the DIN rail fixation would make it possible to remove or move the device easily.

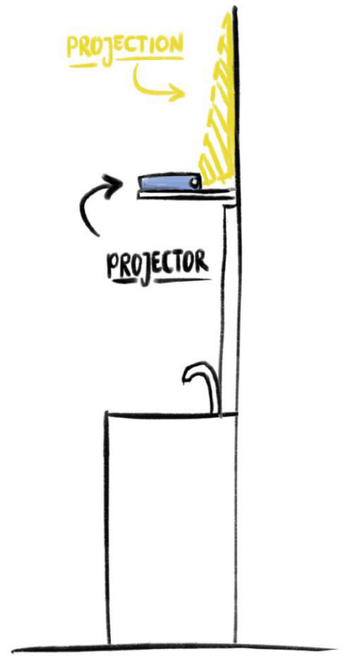


Figure 62: Placement beamer close to wall.

11.2 THE EMBODIMENT OF THE DESIGN INTERVENTION

We know the probable placement of the design intervention in the ICU. This is important as it influences the choice for selecting the necessary hardware. The design intervention is a combination of software and hardware. The software is already selected, Touchdesigner/player en P5.js and possible MAX in the future. But what about the hardware? And how much will this cost?

11.2.1 THE SYSTEM

The idea of the system is not overly complicated.

A microphone measures the SPL, which is the input. These data are processed by a computer that outputs a visual and auditory stimulus through speakers and a projector (Figure 63).

To create a stand-alone device in the ICU environment the following will be needed:

Hardware products

- Microphone
- Speakers
- Projector
  (+Attachment projector)
- Computer
  (+ Casing for mini PC and Microphone)

For wireless communication between all components, you need Wi-Fi and an additional router if there is no good/reliable Wi-Fi. The choice for Wi-Fi over Bluetooth was made because Wi-Fi is more secure, and Wi-Fi allows more devices and users to communicate at the same time.

With regard to power supply, four power outlets are needed for two speakers, one computer and one for the beamer.

The computer should be running on Windows, and the software programs installed must be a web browser for P5.js or MAX, Touchdesigner and Touchplayer.

The interface is just one power button on the computer and a volume button on the speakers. The beamer has a remote. Personal preferences can later be introduced with an app. Until then, you can upload new versions on the PC to try different types of interventions.

And lastly, maintenance is kept as little as possible, just periodic cleaning and changing of the lens of the beamer after its lifespan has been exceeded.

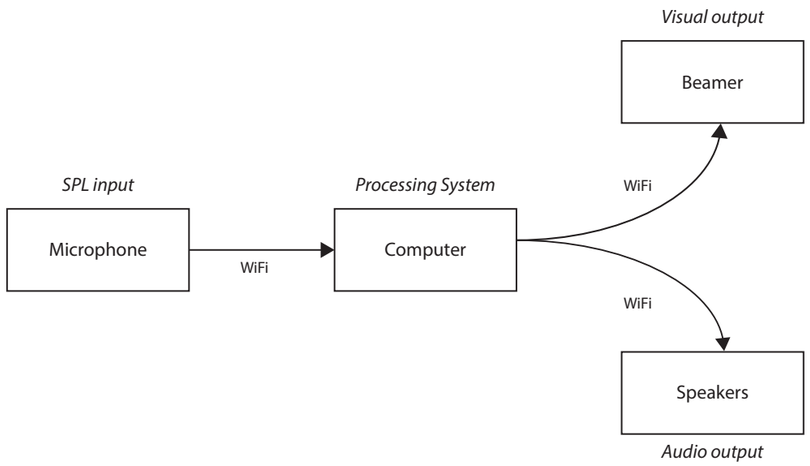


Figure 63: The system.

11.2.2 SELECTION OF THE HARDWARE PRODUCTS

Aside from the general requirements, the components of the intervention system all have their requirements. Based on these, *hardware* products were selected. The selection of the products is explained in the next paragraph.

Microphone

There are two main types of microphones: omnidirectional and directional. Because we want to measure sounds from all directions and moving objects, the decision was made to select an omnidirectional microphone (Nymand, 2022). An omnidirectional microphone will, in principle, pick up sound equally from all directions.
Connecting this to a computer is the easiest by USB, this way, you can communicate (send data) and power the device (microphone) simultaneously.

The Jabra Speak 510 MS (Figure 64) would be a good choice to use in the product and during the experiment because its specifications include USB and omnidirectional.

Figure 64: The Jabra Speak 510 MS (Photo by Coolblue).

Speakers

The requirements for the speakers include that they do not have batteries and should be powered by sockets. The speakers can have a wireless connection via Wi-Fi or Bluetooth, which can be achieved with a hanging system. In this way, the speakers can be easily attached to the DIN rail.

The selected speakers were the Sonos One SL Duo Pack White (2x) because this speaker can connect over Wi-Fi (Bluetooth possible two), is powered by a socket, and there is a hanging system available on the market (Figure 65 and 66).

Figure 65: Sonos One SL Duo Pack White (2x) (Photo by Sonos).

Figure 66: Sonos One SL Duo Pack White (2x) hanging system (Photo by Sonos).

Beamer

The beamer has specific requirements due to the room it needs to perform in.

The brightness (ANSI-lumen) of the beamer should be high as the room will be partly covered in daylight, but half of the windows are covered most of the time to prevent patients from squeezing their eyes and being uncomfortable. So, the room will be partly dark, which comes in very handy.

Patients usually lay with their heads 30 degrees tilted when awake, sometimes 20 degrees (less active patients). This means that their vision normally consists of the upper part of the wall and partly the ceiling, as shown in the figure (67). The best place for the design intervention is above the cabinets so that the patient can see it easily, and it is not in the way of anything.

Figure 67: Patient vision.

Additionally, there is room to have a projection of 90 × 310 mm on the wall, and the distance is 3.5 m from a lighting beam (of the Dräger Care System) to the wall.

Tover

To understand the beamer's requirements, I talked with Lindsey Vermeer of Tover, a company that sells the Tovertafel. The questions asked can be found in Appendix 11. The Tovertafel projects interactive games and vibrant images onto a surface such as a table or a floor. The goal is to create a more caring and inclusive world for people with cognitive challenges (seniors with dementia or adults with intellectual disabilities).

Lindsey explained that the Tovertafel has a computer and speaker built into the projector. This makes the Tovertafel a stand-alone product, but also heavy. Therefore, combining all components in one product would not be an excellent idea for the design intervention. Besides, it is preferred to have a separate speaker, so the audio is equally directed at the patient from the right and left side. Additionally, to create a one-piece integrated system, a customized system is needed. Tover buys hardware systems in Poland, for example. Tover's business is the software that runs on it. Existing hardware will be used for the design intervention, but this could be investigated in the future.

Lindsey Vermeer also said that projecting on a white table works best. On a wooden table, the projection is less visible. Therefore, a projection on a white wall in the ICU is most suitable. The Tovertafel is remotely controlled. The staff in elderly homes, etc., are in charge of this remote. The hospital staff should also be in control of turning the design intervention on and off by a remote because they are in charge of the care and can best judge the patient's desires.

Calibration of the Tovertafel only has to be done once and is easy, but it takes some steps first. Lindsey recommended using one of the newest techniques in the beamer industry called autofocus. With autofocus, the lens focuses automatically, with no need for calibration. Furthermore, if the focus of the lens shifts, it will automatically correct.

One last note of Lindsey was that there is a recent development in the branch: the LED beamers. Tovertafel has a traditional lens, but the LED lens lasts much longer, heats up less quickly, is brighter, and the beamers are smaller (more compact). Aside, the newest beamers all have built-in Wi-Fi and Bluetooth connections, making it easy to connect to phones and also to the design intervention.

She gave a few tips on what to look for when picking out a projector: lifespan of the lens, lens type, brightness (ANSI lumen), resolution, image ratio, weight, autofocus, distance, remote control or by hand, colour, factory settings (cold or warm), power supply and power consumption (how many watts). Last but not least, testing is always crucial.

Autofocus vs short throw

The projector could only be placed on the rotating arms. Otherwise, the power cable could get loose due to the arm's movements, or they can obstruct the movement of the arm. Placing the beamer on the moving arms would mean that the beamer would have to calibrate every time the arm is moved. It is not an option to do this manually. There are two possibilities to solve this, by using an autofocus lens or a short throw beamer.

A short throw beamer could be placed above the cabinets. This will not be in the way of anyone, and no one can walk in front of the screen. The autofocus lens beamer can be placed similar to the speaker on one of the arms of the Dräger care system. The autofocus lens could calibrate automatically every time it moves (this can be done up to 45 degrees).

Selecting

So, there are two options, a short throw and an autofocus beamer. After searching for many types of beamers, there were two beamers selected. The Xiaomi Mijia - 4K - Laserbeamer - Ultra Short Throw and XGIMI Halo+ Plus - Android TV Smart Beamer - 1080P Full HD - Portable Beamer (figure FIXME). This selection was based on reading reviews and watching (comparison) videos on YouTube while keeping in mind the requirements of the ICU and the tips of Tover. Both solutions are likely to work, but they both have advantages (Table 2).

	Xiaomi Mijia - 4K - Laserbeamer - Ultra Short Trow	XGIMI Halo+ Plus - Android TV Smart Beamer - 1080P Full HD - Portable Beamer
Type	Short throw	Autofocus
Price	1869,99 euro	849 euro
Contrast ratio	3000:1	1000:1
ANSI-lumen	2400	900
Wi-Fi	Yes	Yes
Lifespan	25.000 hours	30.000 hours
Resolution	3840 x 2160	1920 x 1080
Kg	10 g	1.6 kg
Distance	15 - 50 cm	100 - 350 cm

Table 2: Comparing beamers.

The benefits of an autofocus beamer would be: cheaper, easy (no calibration), LED lens, a longer life span of the lens, lighter and smaller. Compared to competitors, the projector has a bigger amount of ANSI lumen, 900 instead of the average 500 for this type of beamer. There is no need for an extremely dark room to see the projection. It is therefore suitable in lighter surroundings like an ICU.
The benefits of the short throw would be the higher

Figure 68: Xiaomi Mijia
(Photo by Bol.com).

Figure 69: XGIMI Halo+ Plus
(Photo by Bol.com).

resolution, more ANSI lumen, and no glare.
Both can connect via Bluetooth and Wi-Fi, so there is no need for an additional Chromecast. And because both are smart devices, it is also very easy to access Netflix or other entertaining platforms. So, the TV would not be that necessary anymore.
Beamers are evolving at a fast pace, but there is no perfect projector yet. You have to make concessions and test what works best in the end. For now, the decision was made to use the Autofocus projector. During research, it was uncovered that the short throw beamer (and beamers in general) produce a lot of sounds. The ventilator blows very loud when cooling the (advanced) system.
The autofocus beamer has a LED lens, meaning better quality and more future-proof. Also, the installation and control are effortless. It is also smaller and lighter, so it takes up less space and is easier to integrate into the ICU box. Additionally, the projector can project over the required distance of 3.5 m. And you may lose some ANSI lumen, but the LED lens is brighter, and the projection also does not have to be crystal clear. Too bright can soon be too much of a stimulus for a patient.
It is unclear how well they perform for both solutions if you want to project on both the wall and ceiling. So, no validated argument can be made on this. For this reason, but also because it is always very recommended to always do so, you should still test it.
Projectors are evolving and innovating fast, perhaps in a few months or years, there will be a beamer that may even be better suitable for our purpose.
Furthermore, the selected beamer also has an excellent built-in speaker. So, if the speakers do not work, the beamer's speaker could take over. Or, if you do not value the acoustic environment that much, those speakers could be redundant.

Future beamer

The best, but not a feasible solution for now, would be to integrate the beamer into the Dräger ceiling care system (Figure 70). A different type of projector can then be selected. Thus, it will be possible to have a more classical type of static projector. It would only need calibration once and will never need to be adjusted because it cannot move, plus the powering system will be hidden in the body of the care system.

Placement beamer

To attach the beamer to the DIN rails, we require (an) attachment piece(s) and an extra hanging system to be able to rotate the projector. For when the projector is installed or is moved out of focus too much. Such a hanging system could be similar to this one, a Mini Beamer Suspension System (Figure 71) to the bottom of the beamer (Figure 72).

Figure 72: Bottom of the beamer (Photo by Bol.com).

Figure 71: Mini Beamer Suspension System (Photo by Bol.com).

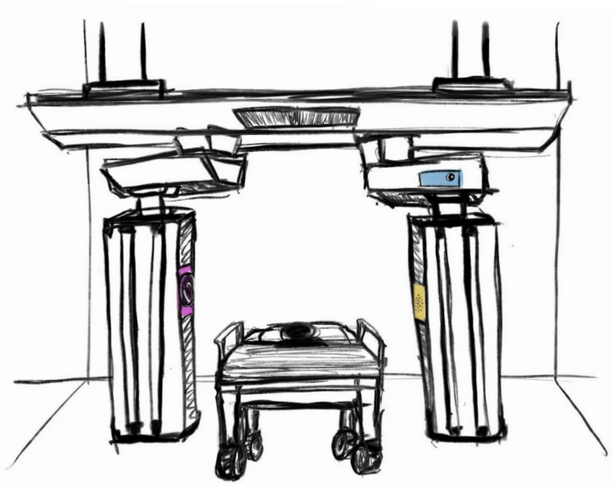


Figure 70: Integration in the Dräger ceiling care system.

Computer

Casper Krijgsman, Teacher's Assistant for the course "Visual Communication Design", knows much about p5.JS and software. He was consulted on the creation of the stand-alone device.
As expected, it is not possible to do this on a Raspberry Pi (single board computer) or Arduino (microcontroller motherboard), primarily because they do not possess (a good enough) graphics card to run Touchdesigner. For our system to run, we need:

1. Motherboard
2. CPU
3. Graphics card
4. Memory
5. Storage
6. Case
7. Power supply

This system must be optimized to fit the purpose of our design, but the main requirements are that it should:

- Have the right graphics card (GPU) to run all updates of Touchdesigner, a Nvidia driver newer than the K1100M. TouchDesigner runs on Nvidia Geforce and Quadro GPUs or AMD Radeon and FirePro GPUs. Recent Intel integrated graphics are supported, but will have limitations due to the graphics requirements of TouchDesigner.
- Have a Wi-Fi module (and a Wi-Fi connection to run P5.js)
- Have an USB connection
- Run on Windows 10 (or higher)

The SKIKK Gigabyte Plus was selected after an extensive search. It meets all the requirements and is a mini PC and therefore very small.

I talked to Casper, and he advised me on the system selection but also mentioned that you need to write a script that, when the pc is turned on, will start to run the created Touchdesigner file, opens the webpage of the p5.js file and connects to the speaker and beamer automatically. So, you would need an interface.

Figure 73: SKIKK Gigabyte Plus (Photo by SKIKK).

Casing

To create a sleek and clean appearance, the microphone and PC could be placed into one casing that can be attached to the DIN rail system (2 attachment pieces). The limited number of products that will be produced could be 3D printed. The design should be simple and easy to clean. Also, it must be ensured that there are holes for ventilation, the power outlet and the microphone. It is also possible to use an existing casing like the "Cooler Master MasterBox NR200 Mini ITX Computerbehuizing- Compact SGCC" then you can drill some extra holes in one of the walls and attach the DIN rail attachment pieces.

Figure 74: Cooler Master MasterBox NR200 Mini ITX Computerbehuizing- Compact SGCC (Photo by Amazon).

11.2.3 PRICE TAG

With the hardware (and software) selected, it was possible to estimate the price of what the intervention will cost (Appendix 12). Keep in mind that there will likely be additional hourly wages for making the case, writing the script/software, the assembly, and the installation. Add to that the cost of powering the intervention and DIN attachment pieces, which the hospital will probably pay.
The design intervention is estimated to cost around 2278.17 euros. If it is desirable to have the most professional software of Touchdesigner and Touchplayer add almost another thousand euros and end up with a price tag of 3148,21 euros.

11.3 CONCLUSION

The name of the design intervention is: REFOCUS (Figure 75 and 76). This name was selected because our ultimate goal is to "refocus":
Refocus on the human in the ICU environment.
Refocus the mind of ICU patients away from negative emotions like anxiety, loneliness, and boredom.
Refocus on the restorative power of nature-based stimuli.

Figure 75: Showcase 1.

Figure 76: Showcase 2.

12.
EVALUATION OF THE CONCEPT

In this chapter, we will evaluate the design concept in a simulated ICU environment at the IDE faculty. Using the developed visual/audio prototype, we want to gain an understanding of the impact the design intervention can have on ICU patients.

The experiment's focus expanded wider than solely on the transition from an eventful to an uneventful environment. Because ultimately, the intervention should be suitable for all transfer moments.

The decision was made to simulate the interaction between a patient and a HCP. Even though the impact of family leaving may be more impactful in an ICU environment. In a simulation, it is probably less engaging or experienced less realistic. The presence of a doctor is more effective in creating an ICU feeling compared to the presence of family members. It would also require much more preparation and participation, as families would need to take part in the evaluation test.

Besides, as confirmed during the emotion mapping, patients experience the same emotional trajectory but less intensely. So, the findings will be (less extreme but still) valid.

12.1 GOAL

The main goal of the experiment is to evaluate the developed concept using the visual/audio prototype. Therefore, one by one, participants (within subjects) will first be introduced to a simulation of the ICU environment (the control scenario). Then in the second scenario, the design intervention will be introduced into that same simulation. Finally, both scenarios will be evaluated to gain a better understanding of both experiences and to answer the following questions:

- What is the impact of the design intervention? And how is this different from the control scenario?
- What type of emotions does the scenario with audio/visual stimuli provoke compared to the control scenario?
- How is the design intervention perceived? Both visual and audio? How well do the visual and auditory elements work together?
- How is the transition from an eventful to a non-eventful moment (and vice versa) perceived in both scenarios?
- What kind of impact can the design intervention have on the need fulfilment of participants?

To answer these questions, the participants will answer questions, so the measured data will be qualitative and compared among participants.

12.2 PARTICIPANTS

The selected participants were invited randomly, as opposed to the focus on former ICU patients in prior research. In a further study, it would be a great step to test with actual ICU patients. However, for the purpose of this concept evaluation, it was not desirable to put any vulnerable participant group at risk. The participants were asked to sign a consent form (Appendix 13).
In addition to the pilot session, twelve participants aged 22-27, five males and seven females, took part in the study. Ten participants were students at the TU Delft. The study background of the participants differed widely. Among the participants were students of Microelectronics, Chemical Engineering, Engineering Policy Analysis and Industrial Ecology and four IDE students. All participants had Dutch nationality.

12.3 MATERIAL AND SET-UP

12.3.1 MATERIAL

List of all materials present:

- *Hospital bed + Blanket + Mattress*
- Other *hospital materials*:
Doctor: gloves, surgical mask, clothing.
Patient: Blue pyjama, ECG sticker, fixation material, blood pressure band and pulse oximeter oxygen.

Figure 77: Hospital materials.

- *Camera:* a camera was used to record the sessions. The camera position was not fixed.

The ICU audio was created using pre-recorded sounds of the ICU in Adobe Audition (Figure 81). The researcher could, in real-time, turn sounds on and off like, e.g. the alarm. The materials needed to play the ICU audio included one laptop and one speaker (JBL), as shown in Figure 82.

Figure 81: QR-code of the ICU audio

Figure 78: Hospital bed with participant.

Figure 79: Hospital bed with participant.

Figure 80: Hospital bed with participant.

- *Speaker* (JBL): to play the ICU audio (Adobe Audition) placed in front of the beamer.
- *Laptop 1*: connect to the speaker (JBL) playing the ICU audio.

The prototype (design intervention) consisted of two laptops, two microphones, one beamer, and two speakers as Figure 82 shows.

- *Speakers (2X)*: to play design intervention audio (p5.js) placed in the top left and right corners of the hospital bed.
- *Beamer*: to play design intervention visual (Touchdesigner) placed behind the hospital bed, projected both on the ceiling and the wall
- *Omnidirectional Microphones (2x)*
- *Laptop 2*: connected to the microphone and beamer playing the visual stimulus
- *Laptop 3*: connected to the microphone and the speakers playing the audio stimulus

The design intervention

Via a projection on the wall and ceiling, the participants were shown a visual stimulus of abstract waves slowly rippling. When sound pressure levels would rise in the room by, for example, the alarm or the doctor's voice, the waves would ripple and move a bit more.
Next to the introduction of the projection, there was an audio source playing. This was the audio stimulus part of the design intervention. Initially, this sound would be a white noise/ocean background sound. The audio also reacted to the volume changes in the environment. When SPL went up, the soundscape would not get louder, but after reaching SPL, the assigned additional sound samples would start to play. Both audio and visual stimuli reacted to voice as well as the sound of the monitor, for example.

12.3.2 SET-UP

The experiment took place at the IDE facility of the TU Delft. Two studios were used in the basement. One of the studios could be turned into an ICU environment by dividing the room using cabinets. A hospital bed was placed in the middle of the second room, facing a white wall. Outside the room, there were signs asking by-passers to silently walk on. Figure 83 shows the layout of the space.

In room 1, the lights were turned on, and in room 2, the lights were turned off, meaning that light entered the room via the glass windows, artificial light from room two and natural light from the other side. In the ICU room, the sunblinds are most of the time partly/halfway down, so it gave a good impression of the ICU lighting.

12.4 PROCEDURE

Playing the part

To create an immersive environment that resembles the Erasmus ICU, it was crucial that the room(s) would resemble an ICU room. The people inside this room also need to behave like they are in an ICU environment. Therefore, there was a distinction between rooms 1 and 2. When you enter room 2, the participant and the two facilitators (a healthcare professional and the researcher) all play their roles to create a close-to-real ICU experience.

The role of the participant

The research and the research goal are explained at the beginning. In addition, the participant was told that they were an ICU patient in this research. This meant that the participant could not move or speak during the test. This was done to provide an isolated perception.

The role of the healthcare professional

Dr. Moritz MD (a registered doctor) executed an in advance prepared 'scene' where she talked to the patients to attract their attention, told them what was happening and then turned off the alarm and left. Note: The researcher behind the scene turned off the alarm manually.

The role of the researcher

Behind the scenes, the researcher was timing the duration of every step of the stimulation. Besides, the researcher was also in charge of the ICU audio that was playing. The background noise was always playing, but the alarm and door sound needed to be activated at the right moment. In addition, the researcher was responsible for starting the design intervention.

Scenarios

The experiment took place in twelve sessions of two parts, one scenario with and one without the design intervention.
Outside the rooms, the participants were welcomed at a table. The researcher informed the participant, gave the necessary instructions, and after the consent form was signed, the experiment could start.

Figure 82: The set-up.

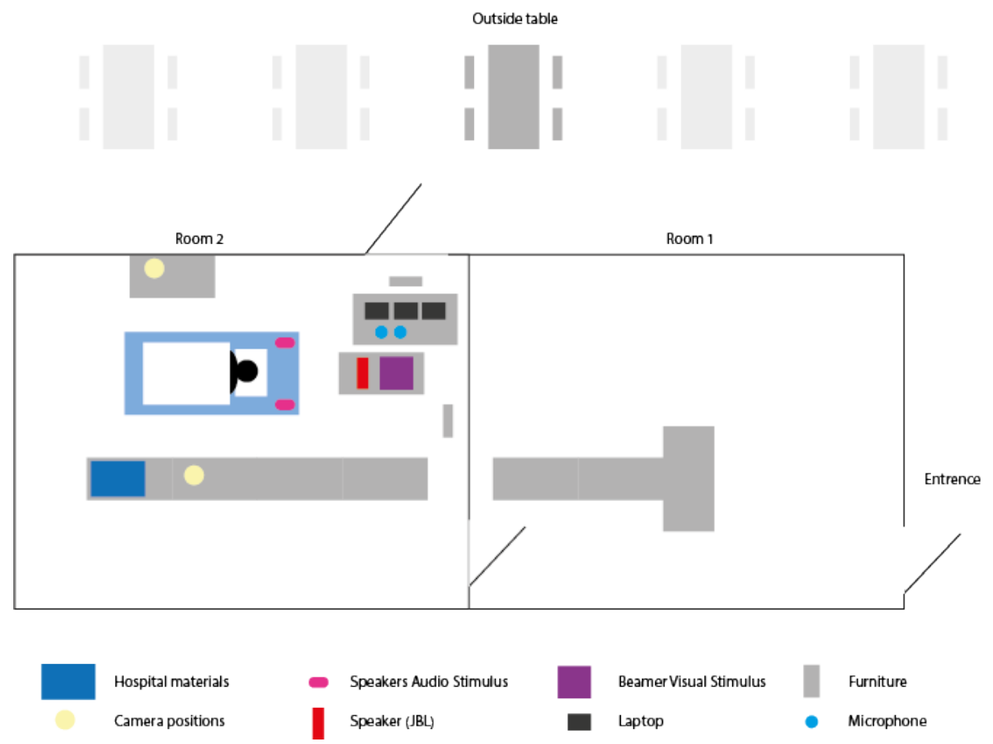


Figure 83: The layout.

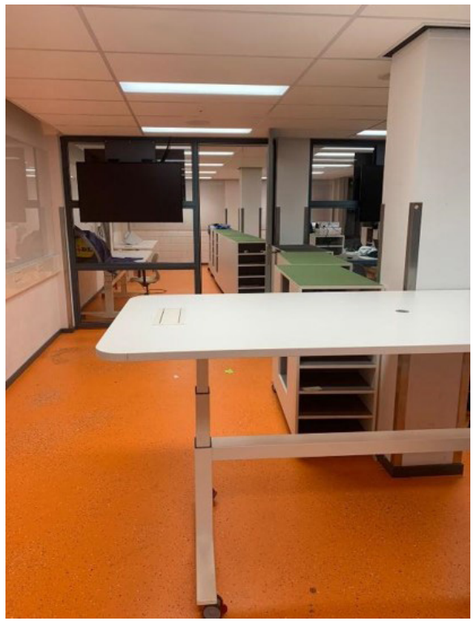


Figure 84: Room 1 (changing).

Figure 85: Room 2 (simulation).

The participant went into the first room (Figure 84), where he or she changed into the hospital pyjamas and was introduced to the doctor. In the second room (Figure 85), the simulation took place.
The participant would lie in the hospital bed, and the doctor would attach all hospital materials, including fixation materials on the wrists. Once again, they got reminded that he or she was unable to move or talk, and the experiment started. From there, the simulation started and took a little over 15 minutes.

Scenario 1

The participant was lying in the hospital bed alone for a few minutes. The ICU audio played (consisting of air-conditioning and machine noises).
At a particular moment, the alarm went off (meaning the patient's heart rate oversteps the set boundaries). The HCP would enter the room to assess the patient. Then she did a quick check (she was now wearing the gloves and surgical mask) and turned the alarm off. Then she left the room again. The patient was lying alone in the bed for a few more minutes.

The schedule looked like this:

3 min:	Patient lying in silence, only ICU audio recording playing
20 sec:	Alarm was added to the ICU soundscape
2 sec:	The sound of the door opening was added to the ICU soundscape
1 or 2 min:	The doctor was inside the room and turned off the alarm
3 min:	Patient lying in silence, only ICU audio recording playing

Scenario 2

Everything happened similar to scenario one, only the design intervention was playing too. The schedule is for one scenario, executed two times per experiment.

Only after the second 3 minutes in silence, when scenario one finishes, was the intervention turned on. Then the 3 minutes of lying in silence with only the ICU audio recording become 3 minutes of lying with the intervention and ICU audio recording playing. Then, the whole schedule is repeated with the audio and visual stimuli.
When the experiment was finished, the researcher gave a clear sign. The participant was freed out of bed, and after he or she had put their clothes back on, the interview would take place at the same location as the welcoming did.

12.5 QUESTIONS

After the simulation, the participants were asked to sit at a table next to the rooms where the simulation took place. There, the researcher asked several questions, which can be found in the next paragraph. The aim was for the interview to take 25 to 30 minutes. Some participants slightly went beyond this time. During the interview, the researcher recorded the audio and the time while writing down some notes in a notebook. The interviews were held in Dutch because all participants were Dutch (as was the researcher). This made it easier for the participants to put their thoughts into words. The (Dutch) interview results can be found in (Appendix 14). The choice was made to gather data via interviews because this would allow the participants to better voice their experiences and tap into their latent knowledge levels.

General

Gender?
Age?
Nationality?
Profession?
Have you ever been hospitalized in the ICU?

Experience scenario 1 and 2 (2x)

Can you describe what the environment was like? And what changed?
What did you feel when you were alone? Why?
What did you feel when there was someone in the room? Why?
What did you feel after someone left? Why?
Can you describe what the transition was like from alone to together to alone?
What did you like about what happened? What did you dislike? Why?
Did you miss anything? What?
What grade between 1 and 10 would you give the experience? And why?

The design intervention

What was the difference between scenarios 1 and 2 for you? What caused this?
Did you experience different feelings? Which ones? By what?
Was the intervention distracting? Why? Was this pleasant or unpleasant?

Audio/Visual

Does the audio work with the visual? Why yes/no?
What would you improve about it?
Did the projection contribute to the experience? Why did/did not it?
Did the auditory contribute to the experience? ? Why did/did not it?

Perception of the environment

Did time go faster or slower in scenario 1 than 2? Why?
Could you imagine what it might be like as a patient? Why?

Future

Would you envision this in an ICU? Why?

Needs

Which of these needs do you think the design intervention could contribute to you as a patient (use table 3)? Why?

Needs	Fundamental Needs
Social contact Distracted Not alone Information Reassurance Communication Privacy Support Peace and quiet Relaxation and Rest In control	**Relatedness** *(having warm, mutual, trusting relationships with people who care about you)* **Recognition** *(getting appreciation for what you do and respect for who you are)* **Stimulation** *(being mentally and physically stimulated by new, varied, and relevant impulses and stimuli)* **Comfort** *(having an easy, simple, relaxing life)* **Safety** *(feeling that your circumstances and environment keep you safe from harm and threats)* **Autonomy** *(being the cause of your actions and feeling that you can do things your own way)*

Table 3: Overview needs during questions.

12.6 RESULTS

After the interviews were documented per participant, statements cards (in English) were made and categorized per topic. This gave a clear overview, which can be found in Appendix 15. The following results were derived from combining all the different perspectives of the 12 participants on these different aspects of the design intervention:

12.6.1 THE FOCUS OF THE PATIENT

Many participants were impressed by the immersiveness of the simulation. As a result, the participants experienced similar feelings as patients in an ICU. Some were wondering what was going to happen (P9). Some were excited when something did happen (P10). However, some also felt stressed (P1), oppressed (P5), uncertain (P5), alone (P9) and/or not in control (P4).

The resemblance between a participant's experience and that of an ICU patient demonstrates the utility of the insights that emerged from this research study.

It was clear that participants were bored (P5, P10, P11, P12), waiting for something to happen (P12) and searching for some form of distraction (P2). As P5 put it:

> *"You are living from alarm to alarm". - P5*

And the participants were waiting to understand what was happening (P6).

Concluding, the participant's focus was mainly on negative thoughts like boredom (what to do?), confusion (what was going to happen?), loneliness (how long till someone comes?) and anxiety (am I okay?).
Same as for the ICU patients, a lot of participants mentioned:

> *"Here I am, alone again" – P5*
>
> *"What is going to happen?" – P6 & P1*
>
> *"Am I okay now?" — P1*
>
> *"And now? How am I going to keep myself busy?" — P9*

Furthermore, participants like patients really appreciated the entrance of the doctor. Not only because the doctor could provide care, an explanation, and comfort (P1, P5, P7, P8, P11, P12).

> *"It was nice that there was something happening" – P10.*

Also, the change in eventfulness would break the silence and shift their focus. P11 even talked about the difference in eventfulness:

> *"Environment 1, you could really divide into two pieces when something was happening which is fine, and when nothing happened which is boring." — P11*

This stems from the appreciation of eventfulness, also found during interviews with former patients, and the importance of a pleasant distraction.

12.6.2 REDIRECTING THE FOCUS OF THE PATIENT

When participants describe the experience of the first environment, it shows a need for a distraction aside from a doctor's visit to help participants focus on something (else). Therefore, in the second scenario, the design intervention was introduced.
Generally, all participants appreciated the design intervention, mainly because they were distracted from boredom, stress/anxiety, negative thoughts or discomfort. It made the experience a bit more comfortable or relaxed.

For example, P1 experienced the same stress when the monitor went off.

> *"I did have the same stress immediately, but now with the distraction, I was all Zen." - P1*

This illustrates the calming effect of the design intervention.
P2 mentioned that she was less stuck in her head. So, she got pulled out of her isolated state. Or, as P11 stated:

> *"There's something that distracts you, that takes up brain capacity. You just start watching and listening more to something because it's constantly changing. So you do think less." - P11*

And the intervention could just provide an overall more positive experience like P10 said:

> *"A little less of the feeling of 'gosh, I'm lying here." - P10*

12.6.3 TRANSITION

The design interaction does not only distract the participants, it also changes their perception of the transition from an eventful moment to a non-eventful moment and vice versa. It made the transition less abrupt, intense and/or noticeable.
P6 and P8 said, for example:

> *"The arrival of the doctor was a little less noticeable." — P6*
>
> *"When the doctor entered and left, it felt a little less intense." — P8*

Other participants were also trying to give an explanation for these phenomena:

> *"It was a little less abrupt when the doctor came in because you're also a bit preoccupied with the projection. Less sudden." — P4*
>
> *"If something happens while you are not doing anything, then someone comes in, and it is suddenly very abrupt, but the bird sounds etc. make it perhaps a little softer or something." — P3*
>
> *"The transition was a little less big when the doctor came in. You just felt a little more comfortable. In the second environment, you're already a little bit engaged in something. When the doctor leaves, that transition is also a little less big because you're kind of in that beach world." — P7*
>
> *"In the first scenario the silence is really broken, in the second scenario it comes with additional sounds, so I can imagine that you are less surprised then. It's less of an overwhelming experience." — P11*

But the participants said the intervention did not only have an effect on a doctor's visit. The reaction to the alarm changed similarly.

> *"The difference whether or not the alarm goes off is a little smaller, the sound is less loud and less scary. You're a little calmer anyway because you're distracted. "– P11*
>
> *"Beeps were less present/ annoying." — P4*
>
> *"In environment two, you're a little less focused on the beeps." — P7*
>
> *"Sound could really help, you hear those beeps a little less." — P6*
>
> *"Especially if the sound is also a little soothing, when beeps go off, for example. Then the patient's reaction can be tempered a little bit." — P10*
>
> *"I did notice a difference in my perception of the sound from the monitor. I was less concerned with it. Waiting was less annoying." — P5*
>
> *"When the beeps came, the waves became a little more intense. You were kind of carried away from the beeps to the doctor coming in." — P7*

12.6.4 COMPARING BOTH ENVIRONMENTS

The patients were asked to rate their application of the total experience on a scale of 1 to 10,
with 1 meaning extremely unpleasant and 10 extremely pleasant.

Every participant rated the second environment with the design intervention higher. The grade itself is based on the participant's personal interpretation. So the averages of 5,4 (scenario 1) and 7 (scenario 2) show indeed the rise in appreciation. The participants grade pleasantness differently, as they use different ranges of the full spectrum. It should not be seen as an increase of 1,6 points because a rating difference from a 3 to a 3,5 (P3) may represent the same impact as one from a 3 to 7 (P2).

The results are shown in figure 86. There are a few reasons why participants argued scenario 2 deserves a higher rating.

In the first place, it distracts.

> *"Novelty" – P5.*
>
> *"You can do something." — P7*
>
> *"Felt more like a level-up version. It felt more useful. Entertainment without Cliniclowns." — P8*
>
> *"In the second environment, you were kept a little busier." — P9*
>
> *"Slightly less scary. You have something to do." — P11*

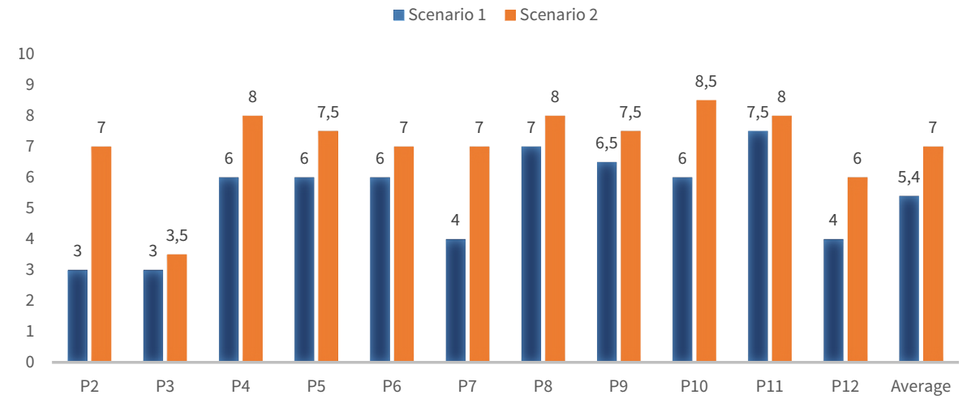


Figure 86: Results grading scenario 1 and 2.

Secondly, it is relaxing.

> *"It was a little more relaxed." — P1 & P6*

> *"Much more calming and felt like I wasn't doing nothing" – P12*

Thirdly, the environment is more engaging and less alienating.

> *"You're better connected to the environment" – P5*

> *"It is less invasive because your environment "changes along"."—P3*

> *"A very empty space also causes alienation." — P3*

> *"The room feels less empty."- P2*

> *"Because you are more at ease, and you also feel safer than in such a sterile room." — P7*

12.6.5 AUDIO/VISUAL FOCUS

Because you have something to listen to or see, it is easier to redirect your mind. Some participants focused more on the visual (P1, P2, P4, P5, P7, P9, P12), others were mainly focused on the audio (P6), and some were really focussed on both (P3, P8, P10, P11). .
Only one patient mainly focussed on the audio. This is probably because our (healthy people) sight is our most sensitive sense.

> *"Audio was the nicest. The type of visual didn't matter for me, but that it was both there was nice." — P6*

But focussing on one stimulus more than the other did not make the other stimulus redundant.
Many participants mentioned the great balance between the two and stated that both should be implemented as they complement each other (P1, P3, P7, P8).

> *"Did complement each other. Combination was good." - P1*

> *"They reinforced each other." - P3*

Also, the connection to the environment via multiple senses makes it easier to associate with and, therefore, recognise.

> *"The sound gave me a beach feeling. Maybe it was because of the image that accompanied it." — P6*

> *"The sound blended more into the image. It kind of melded together. Almost felt like I was imagining the sea sound itself." — P2*

Audio

P7 said something very interesting: '

> *'Complete silence is also a bit crazy, so I thought it added something.". - P7*

But what did the participants think of the audio stimulus? For most, it was calming and relaxing.

> *"Very nice, very calming. Even when you weren't looking, you could hear the sound and imagine you were on the beach." — P4*

> *"The sound created the setting which was chill." — P9*

> *"The beach, a more familiar feeling than sterility. More reassuring than silence." — P7*

The audio stimulus drowned out the unwanted noise of the machines and air-conditioning or even the alarms.

> *"Heard the noise of the air conditioner a little less." — P2*

> *"In the first scenario, the silence is really broken. The second scenario comes with a sound, so I can imagine that you are less alarmed." — P11*

Not everyone appreciated every sound. They worried that if it would get repetitive, it could become very annoying. Some sounds were a little too much, like the wind for P3 and the bird sounds for P5.

> *"White noise, in general, is chill. But it shouldn't become repetitive. Found the wind a little "too much". The water sound was more chill." — P3*

> *"The bird sounds might be distracting when the doctor is talking. Especially if you don't see him or her." — P5*

Visual

As stated previously, participants liked the distraction and 7/12 were, in fact, mainly focused on the visual. P10:

> *"Visual was especially good to distract you.". - P10*

This is understandable because, in a room with only white walls, a projection draws attention. The participants said they liked the choice for the projection:

> *"Projection, a good choice because not so bright and screen-like." — P1*

They also liked the projection on both the ceiling and wall:

> *"The ceiling and wall was nice. You look a little less at a white wall. And the sea was also nice.' - P2*

> *"Ceiling and wall chill, it's like really being surrounded by it." — P3*

> *"Partial ceiling and wall helped, to put you completely in a different environment." — P5*

Participants liked the slow but constant movement of the visual:

> *"It was nice that it was steady." — P2*

> *"More focused on the visual. Nice that it kept moving" – P4 & P5*

> *"You believe it more if it also moves. Because otherwise, it's just a beamer with an image. And now it doesn't necessarily fade into the background, but stays interesting. Distraction while something is happening." — P10*

> *"I also liked the fact that when nothing was actually happening, the wave action was still there so that not nothing was happening. That you still hear something." — P10*

> *"Also nice that it moves not only when it reacts to the environment." — P3*

> *"The projection remained constant. It gave peace. If you don't look, it still remains." — P4*

> *"You see time passing, that's more reassuring." Somewhat like the famous philosophical phrase, except then: "I am because I see something happening." — P12*

They could not notice any repetition, which was possible due to the way the visual was designed. The fact that some participants actually tried to notice a pattern, already in such a small amount of time, confirms how our minds work.

> *"No repetition. Good. You couldn't get the hang of it. Good." — P8*

> *"There was no pattern." — P10*

12.6.6 CHANGES

No change

Of the participants, 8 out of 12 noticed visual and 7 out of 12 noticed audio changes, four noticed both and one noticed nothing (Figure 87). When they could not notice a change, this did not negatively influence their experience of the transition.

"In the audio, it was hard to hear what you changed about it. Not necessarily anything bad. It was still nice."" - P12

As P6 said that if you did not notice, it must have felt natural.

"Didn't really hear the audio change. Didn't really notice it. It just felt natural." — P6

Otherwise, you would expect a participant to have mentioned something weird/random/unexpected happening.

Changes in audio stimuli

However, when participants noticed changes, the transition was experienced more smoothly. As the noticed changes helped redirect the focus and to better connect to the environment.

Interestingly, participants did not notice the sound layers. They did mention an increase in volume, for example, P10:

"The audio gets slightly louder. Also creates a new dimension to your experience and proof that something is happening." — P10.

However, this was not the intended difference because the volume level did not rise. It could be that due to the more interesting soundscape, perception of the loudness levels increases.

Or they did notice some change but did not assign any meaning to it, like P4:

"I noticed that the sound changed a little, but I don't know. I heard, e.g., more sea sound at some point." — P4

When asking participants, they sometimes just thought a "random" audio track was playing, so they did not expect something to change along with the environment. And taking into account that most participants were more focussed on the visual stimulus, it is unclear if the changes in the soundscape are essential in creating a smooth transition. However, the idea of different sounds (or sound samples) reacting to the environment seems to be a great solution to prevent repetition and give the patient some audio cues and a connection to the environment.

Changes in visual stimuli

Compared to the changes in the audio, participants noticed differences in the visual stimulus better when SPL increased. Again, this could be because healthy people are focused on visual stimuli more and patients on auditory.
They did not only notice it, but they also felt more connected to their environment.

"I liked the change in the visual when the alarms went off, that your surroundings subtly moved with it. Waiting became watching." — P3

"Changing the image worked though. Keeps you busy." — P6

But one participant (P10) had an interesting interpretation:

"When the beep went off, the water would sort of vibrate. Moving based on the sound. I thought that was kind of cool. Nice that something is happening. It was cool that if you couldn't see the doctor because she was behind you, you could sort of 'see' her because the waves were moving. You were able to see in a different way." — P10

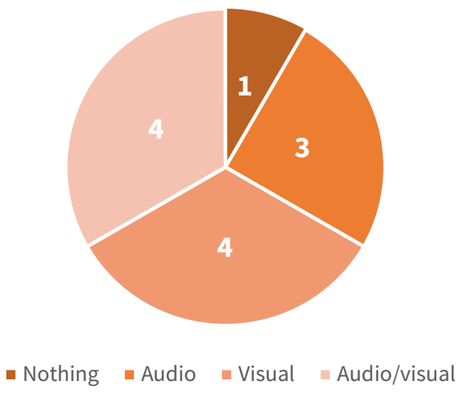


Figure 87: Participants noticing change in the audio and/or visual.

And she further explains:

"You can't see anything else when you can't turn your head. But now I can see because the visual shows sound and therefore movement in the room. In a way, more sensory freedom. What you hear also happens on the screen, it is kind of a second confirmation." — P10

She implies that because of the audio/visual design intervention, the patient can see a sound and therefore see something is happening. Making a patient less dependent solely on their hearing, creates an opportunity to connect and understand better what is happening in the environment.

Not only can you use the visual changes as confirmation that something is happening according to P10, but this also works the same for the audio stimulus:

"Audio I think did get a little louder when the doctor came in. Again, I think that can give a kind of new dimension to what is happening and a kind of confirmation." — P10

To establish such an interaction (or interpretation of the design intervention), the patient should be aware of the meaning of the changes in the visual and auditory stimuli.

During this research, most participants were unaware of this, maybe because they were only exposed to the design intervention for a limited time.

In the ICU environment, a patient would need to be lucid to notice and understand the meaning of these auditory and visual stimuli, which most are not. But, in any case, the intervention itself should have an effect, rather than needing background information for the person being subjected to it.

12.6.7 THE PASSING OF TIME

It is commonly known that people can experience time differently. Sometimes one minute lasts an eternity, and sometimes time flies. In the ICU, patients experience time very differently. As mentioned before, they do not understand time or the meaning of time. During the interviews with the former patients, someone said that time was experienced minute by minute. That you are just lying there, and you are waiting, wondering when it will be over. Generally, in the ICU (and the ICU scenario one), time is not experienced as moving fast because of the lack of distraction. As P5 stated about this environment:

"It may feel longer because you don't have stimuli." - P5

But one can imagine that the design intervention can influence how time is experienced. P1, P2, P5, P7, P9, P10, and P11 all said that they experienced the time going faster in scenario 2.

"The second one is a little faster. You have something to do. You're just going to think a little less by yourself." — P2

P8 did not know, and P3, P4, P6, and P12 thought that it was not necessarily the time that went faster, but the experience of the time passing improved.

"In the second scenario, I was less bored, so less concerned with time going by so slowly. But what I just said, you do see time passing, which is good." — P12

"Better time passing, not necessarily really faster." — P4

Either way, this shows the positive impact the design intervention could have on the experience of time or time perception.

12.6.8 NEED FULFILMENT

To follow up on the initial literature research into the fundamental needs and the design opportunity derived from the fulfilments of those needs, participants were asked to which extent they thought the identified six fundamental needs of an ICU patient (Stimulation, Comfort, Relatedness, Security, Autonomy and Recognition) were impacted by the design intervention.

Words that were mentioned a lot by the participants were: Distracted, Less alone, Reassurance, Peace and quiet, and Relaxation. Those were all on the list of the patient's needs. This list served as a tool to open up the conversation about the fundamental needs.

12/12 Participants answered that both Stimulation

and Comfort would benefit from the design intervention (figure 88). And a resulting feeling of security was mentioned three times (P10, P11, P12).

> *''Stimulation and therefore comfort. Stimulation contributes to comfort and therefore security derived from that." — P11*

> *''Stimulation allows you to relax more and therefore experience more security." — P9*

> *''Security, less left alone feeling 'Even when I'm alone, they carry care'." — P12*

> *''And comfort when you are less concerned with pain, so distracted." — P10*

> *''Sense of security by pairing sight with sound, that what happens is real that confirmation." — P10*

P8 was one out of four participants who identified a contribution to Recognition.

> *''Something is done for you' so also some kind of recognition. Which makes everything comfortable." — P8*

All participants understand that autonomy will be very hard to give to an ICU patient.

> *''Autonomy, not really, but you do feel more like you are being taken care of." — P9*

P4 suggested the impact the design intervention could have on Relatedness.

> *''I would like a family moment. I would like to use it for that. That you don't fall into silence immediately afterwards. I think it is good to have something else to focus on and not to start worrying when your family has just left." — P4*

In further research or a future design, exploring the possibility of fulfilling more needs or increasing the need fulfilment can be interesting.

12.7 DISCUSSION

Implementation challenges emerged during the interviews and will be discussed in more detail in the next section. These are challenges related to:

- The control of the intervention
- The ability to incorporate personal preferences
- Maintaining variety and eliminating repetition
- Improvements to the visual and auditory stimuli
- Distinguishing changes in the visual and auditory stimuli
- What to consider when using the intervention in a real-world setting

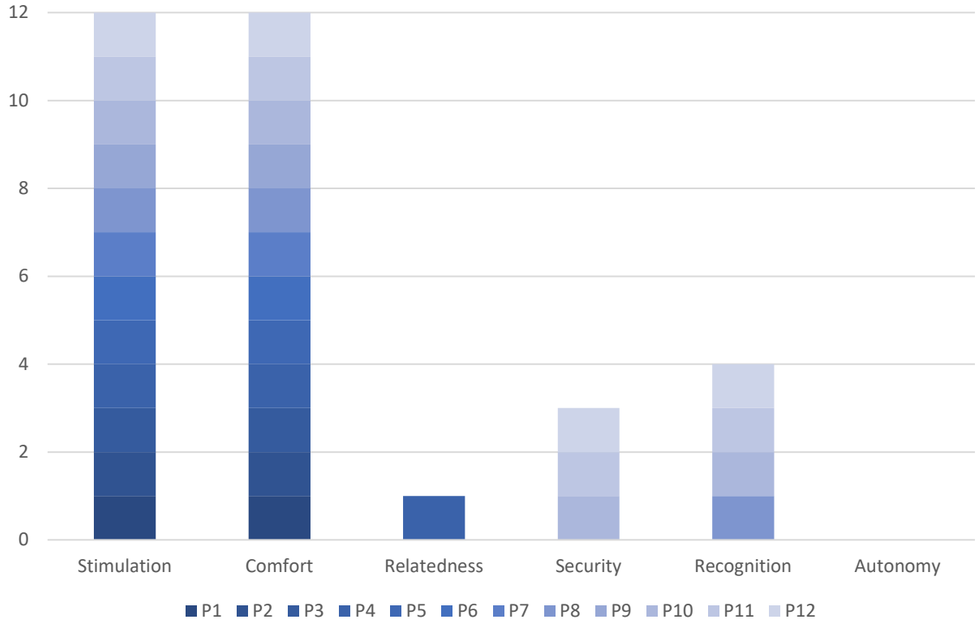


Figure 88: Need fulfilment of the design intervention.

12.7.1 THE CONTROL OF THE INTERVENTION

Implementation challenges occurred during the interviews, considering the control of the intervention:

When does the intervention turn off/on or change the volume?
Does it turn on/off or change the volume?
Who controls the intervention?
For how long does it play?
Does the patient have any influence on the intervention?

P1 & P7 mentioned the challenge of controlling the volume, and 8/12 participants suggested ways to turn on/off the design intervention. Some proposed giving the control to the patients (P1, P3, P4, P5, P7, P11) and others to the HCP (P2) or the family (P8, P10).

The participants shared their thoughts on what this future implementation may look like.

Patients control

> *''When you're done with it, you have to be able to stop." — P7*

This is a concern of many participants. However, because of the critical state the ICU patient is in, it is not desirable nor feasible to give (complete) control to the patient.

Control could be handed to the patient when they are ready for it, but at the core of the design, there should be a standard interaction for patients who cannot voice these types of concerns/preferences.

Therefore, it would be better to give the control to others so that they can estimate the patients' appreciation of the intervention. Another option would be to design the intervention in such a way that it, for example, learns (with the use of AI) when and how to perform.

Healthcare professionals control

> *''I think the healthcare provider then operates the device. (It's) hard to give control to the patient." — P2*

Giving control to the healthcare professionals is not only a good option because they are already busy monitoring the patient's condition, but also because patients trust and rely on the care of the HCP's. Patients experience being taken care of, and they will assume that the HCP knows best.

Also, sometimes you may need to force something a little, as P9 suggested:

> *''Maybe it can be too forced or someone doesn't want anything at all. But sometimes you have to experience something to know it's nice. It's best to force it a little bit. People don't know what they like or want to experience. '' – P9*

Family control

As mentioned earlier, P4 explained the impact of the design intervention on relatedness when using it during a family moment. It would prevent patients from falling into silence after the family leaves, letting them focus on something else. P8 agrees:

> *''It's not a crazy idea to combine it with the family leaving. For example, there is a snooze room where children often go with their parents, and now it's sort of in the same room. Some kind of timer would be attached to it." — P8*

Not only could it benefit the patient, but it could also benefit the family themselves.

> *''Visitors can also have less of a feeling that they are leaving someone. I can also imagine that people go to sleep after a visit so that they can fall asleep more comfortably. For the patient, the emotional turbulence can then also be less." — P10*

This creates the opportunity to give control to the family. Additionally, it could also be possible to let the family influence the behaviour of the intervention, for example, changing the colour or the type of sounds.

12.7.2 THE ABILITY TO INCORPORATE PERSONAL PREFERENCES

It can be interesting to explore the possibility of customizing some features of the design intervention. For example: What if you do not like the sea?

> *''If you have a bad experience with the sea, you might want a different kind of visual." — P4*

Allowing family members or caregivers to choose the colour or other settings may increase variability

and enhance inclusiveness and appreciation of the intervention.

12.7.3 MAINTAINING VARIETY AND ELIMINATING REPETITION

The participants were not able to notice any patterns or repetition. However, as mentioned previously, they emphasised that there should remain variations in audio and visual so it does not become annoying to watch or listen to.

> *"There should also be/remain variations." — P4*

P12 gave an excellent solution for further development:

> *"In scenario 2, I felt very much at ease, but during the last round, it did get more boring. This would require a little more variation. A sea in itself always remains interesting, so you could make your 'rules' by which the thing moves even more complex." — P12*

12.7.4 IMPROVEMENTS TO THE AUDITORY AND VISUAL STIMULI

Generally speaking, the participants liked the visual and auditory stimuli. But they did have some suggestions.

The visual

Many participants liked that the visual resembled a natural element: the sea and waves.

> *"Looking at nature made you less bored." — P5*

> *"The sea was nice. I like that." — P4*

> *"The visual was really nice." — P7*

But for some participants, the visual was too intense and reminded them of thunder. Additionally, 3/12 participants (P3, P6 and P9) agreed that the design intervention could be a bit happier.

> *"Visual nice to look at. I thought the visual was a little ominous. Storm and thunder. A bit dark. A bit like thunderbolts. Maybe it just needs to be a lighter blue." — P3*

> *"I found the sound really nice, but the visual I thought looked a bit like thunderclouds." — P6*

> *"I also found the visual a bit trippy. Maybe a little more blur was better. Like the sea from below. A little more natural. " – P11*

> *"Visual was a little too greyish." — P9*

> *"Distracted me for sure, but could have been a bit more cheerful. More warm colours, a little lighter. "—P9*

To prevent the problem of repetition, the visual behaved slightly differently all the time. Indeed, sometimes this visual became more cloudy than wavy. Because the visual had in the past not been generating motion for such a long time, this specific behaviour change was not foreseen.

Other behaviour changes could also be explored, as P5 suggested:

> *"You could also respond in a different way to sound, like speckles or colour." — P5*

In the future, this can be tested and adjusted.

One of the ways that the stimuli stay interesting is because they react to the environment. The generated motion of the waves is random, and when adding the extra motion due to the increased SPL in the room, it keeps on being unpredictable.

> *"The visual could be a bit more reactive." — P7*

Participant 7 proposed that the visual could be even more reactive. This would make it easier to detect the changes in the visual. However, you should be very careful because the intervention, both auditory and visual, can quickly become very intense or too intrusive. It would be best to aim for the right balance between distracting and relaxing. Besides, it is also based on the preference of an individual. Further research should delve deeper into this.

The audio

Overall, the natural sounds were the right fit for the design intervention. Of course, some improvements must be made to satisfy the personal preferences of patients, as some sounds were perceived as a little too much. There was some discussion considering the bird sounds sample in the audio stimulus.

P5 stated that the bird's sound could cause trouble, she further explained:

> *"Did like the sound. The novelty of the sound distracted me more than the volume. I would keep the audio turned on when the doctor visits and the sound variation. Watch the timing of variation. When the doctor stands and talks behind the patient out of sight, the patient shouldn't lose focus on the doctor. " — P5*

The bird sounds sample is the sound sample which plays when the highest SPL is reached in the room. This means it is only included in the most extreme or interesting soundscape. So P5 may not just be referring to the bird sound sample being too distracting but P5 may be concerned with the entire soundscape.
If so, it should be investigated if the composition of this soundscape is appropriate in every situation. Otherwise, some adjustments should be made to the audio stimulus, e. g. volume, sample selection or variation. This is important to create the right balance between distraction and still being able to hear the doctor.

> *"It is maybe annoying if you hit your head or something, you might have to try too hard to concentrate. So you need a good balance between distraction and still being able to hear the doctor. Volume was good." — P5*

However, we cannot draw a conclusion yet as opinions differ between participants, and further testing will be needed:

> *"There were bird sounds when the doctor started talking. A kind of transition. I found that pretty nice. Not too distracting." — P3*

But whatever this new design will be, you would have to keep in mind that it should not get in the way, and the patient should still be able to focus on the doctor:

> *"It should not get in the way when your doctor comes though. You couldn't communicate at the time anyway, so maybe not so bad, but you have to be able to focus." — P1*

12.7.5 DISTINGUISHING CHANGES IN THE VISUAL AND AUDITORY STIMULI

It is hard for the participants to detect all the changes in the second scenario because everything is new, and the test does not go on for hours or even days. But it is more likely that your stay in the ICU lasts longer than the evaluation test took.

The precise effect of the intervention cannot be obtained for these reasons. The participants were also aware of this:

> *"A whole day would be long, though. I would have to test, but a day of emptiness doesn't seem nice either anyway." — P2*

Nevertheless, it does not matter whether they perceive change, as long as the intervention retains its effect of distraction and comfort.

12.7.6 USING THE INTERVENTION IN A REAL-WORLD SETTING

Even though there was a lot of overlap in the ICU patients' and participants' experiences, you cannot assume that ICU patients will react similarly to the design intervention because the participants are not critically ill. This would need to be tested in the future.

Some of the participants did give a hypothesis about what the impact could be on the experience of both scenarios if it was tested on ICU patients:

> *"If you're really sick, I'd think you'd give the second environment the same grade and consider the first even worse, the grades would be further apart." — P4*

> *"Environment 1 is graded with a 6. Probably goes down though if you're really sick." — P10*

P10 and P4 guessed that the grading would only decrease for the first environment, meaning that the impact of the intervention may be even bigger. However, there is also the possibility of worsening the patient's experience, as the visual and/or audio could impact the perception of the environment in such a way that it contributes as a factor to causing delirium. The experience should not be trippy.

> *"I also found the visual a bit trippy." — P11*

Therefore, the statement of P11 should be seen as a warning to pay close attention and thoroughly test the impact of the stimuli.

The perception of the stimuli will always be a risk that cannot be controlled, but providing the patient with a comfortable and secure environment can be perhaps one of the ways to try to control the course of delirium.

Critical Illness, Brain Dysfunction and Survivorship (CIBS) Center (Patients and Families Overview,

2022) informs family and friends how they can help an ICU patient by providing them with favourite music or TV shows, talking about friends and family etc. These non-intrusive interactions help to distract the patient and to focus on something familiar and comforting. In line with that, the design intervention serves the same goal.

Furthermore, it is recommended to bring patients their glasses and hearing aid while there are staying in the ICU to help them sense the environment and prevent delirium (Patients and Families Overview, 2022)

So, when P12 asked:

> ***"Do you have/can you wear glasses?" — P12.***

The answer is: Yes, you should. It will not only allow you to experience the design intervention better, but it will also improve your entire ICU stay.

12.8 CONCLUSION

The evaluation test uncovered many new insights and answered the research questions. The audio/visual stimuli helped participants redirect their minds and contributed to fulfilling needs such as stimulation and comfort in particular.

As patient P7 puts it perfectly:

> ***"I think especially Stimulation and Comfort. It's nice to be engaged in something, not purely stuck in your head." — P7***

Overall, the intervention was perceived positively. In the future, the limitations and implementation possibilities need to be further investigated.

12.9 SUMMARY POINTS

- Many participants were impressed by the immersiveness of the simulation. As a result, the participants had experienced similar feelings as patients in an ICU.

- The experience of the first environment already shows a need for a distraction aside from a doctor's visit to help participants focus on something (else).

- Generally, all participants appreciated the design intervention, mainly because they were distracted from boredom, stress/ anxiety, negative thoughts (loneliness) or discomfort. It made the experience a bit more comfortable or relaxed.

- The design interaction does not only distract the participants. It also changes their perception of the transition from an eventful moment to a non-eventful moment and vice versa.

- Every participant rated the second environment with the design intervention as more pleasant.

- There are a few reasons why participants argue scenario 2 deserved a higher rating. It distracts, is relaxing, and the environment is more engaging and less alienating.

- Some focused more on the visual, others were mainly focused on the audio, and some were really focussed on both.

- Focussing on one stimulus more than the other did not make the other stimulus redundant. Many participants mentioned the great balance between the two and stated that both should be implemented as they complement each other.

- Audio: For most, it was calming and relaxing. It drowned out the unwanted noise of the machines, air-conditioning, or even the alarms.

- Not everyone appreciated every sound. They thought that it should not get repetitive. Naturally, this can become very annoying. Some sounds were a little too much.

- 7 Out of 12 were, in fact, mainly focused on the visual. The participants said they liked the choice for the projection and also on the ceiling and wall.

- Participants liked the slow but constant movement of the visual.

- Of the participants, 8 out of 12 noticed visual and 7 out of 12 noticed audio changes. When they could not notice a change, this did not influence their experience negatively.

- However, when participants noticed changes, the eventfulness transition was experienced more smoothly. As the noticed changes helped redirect the focus and to better connect to the environment.

- Compared to the changes in the audio, participants performed better in noticing differences in the visual stimulus when SPL increased.

- One participant (P10) implies that because of the audio/visual design intervention, the patient can see a sound and therefore see something happening. This makes a patient less dependent solely on their hearing and creates an opportunity to better connect and understand what is happening in the environment.

- The design intervention could positively impact the experience of time or time perception.

- 12/12 Participants answered that both Stimulation and Comfort would benefit from the design intervention. As a result, the feeling of security was mentioned three times. Four participants mention Recognition and one Relatedness.

- Implementation challenges occurred during the interviews, considering multiple aspects; the control of the intervention, the ability to incorporate personal preferences, maintaining variety and eliminating repetition, improvements to the visual and auditory stimuli, distinguishing changes in the visual and auditory stimuli, and what to consider when using the intervention in a real-world setting.

13.
IMPLEMENTATION

After the evaluation of the design intervention called the REFOCUS, it became clear what type of use cases there are for the design intervention to improve the patient experience at the ICU.

13.1 USE CASES

Even though further research is necessary, the goal of redirecting the focus of the patient was indeed achieved. The design intervention can help the patient refocus on something more positive and smoothen the transitions. Three use cases are suitable for implementation, including the transitions between:

1. Relaxation and anxiety
2. Entertainment and boredom
3. Together and alone

*Redirecting the focus from **anxiety***

When an alarm goes off inside the ICU box, it causes patients to experience stress, fear and especially anxiety. During the evaluation, we concluded that having audio/visual stimuli present, helped lower the alarm's impact. While the patient still responded to an alarm, it was experienced as less intense or frightening because there is less contrast between loud (eventful) and silent (uneventful) environments.

*Redirecting the focus from **boredom***

Time moves very slowly when you are bored. In the ICU rooms, there is not much to entertain the patients with. There is not something that is designed specifically for ICU patients and that helps them connect to the ICU environment but is not intrusive.
The design intervention can liberate patients from boredom and offer them something to experience and sense without being inappropriate, as it makes uneventful moments a little more eventful.

*Redirecting the focus from **loneliness***

During the research phase, we found that the impact of the family leaving the room harmed the patient the most. Hence they felt lonely afterwards. The design intervention can help reduce the patient's loneliness because patients are not left in an empty, quiet room after people have left. While distracting the mind, the REFOCUS reduces the gap between being together (eventful) and being alone (uneventful).
The transition moment towards uneventfulness likely is where the greatest gains for the patient experience can be made.

Other negative emotions like discomfort, shame, frustration, panic, and confusion are less related to the transition moment. However, they can also be expelled by the design intervention. Different requirements may apply to these different use cases, so the implementation will differ for future design(s).

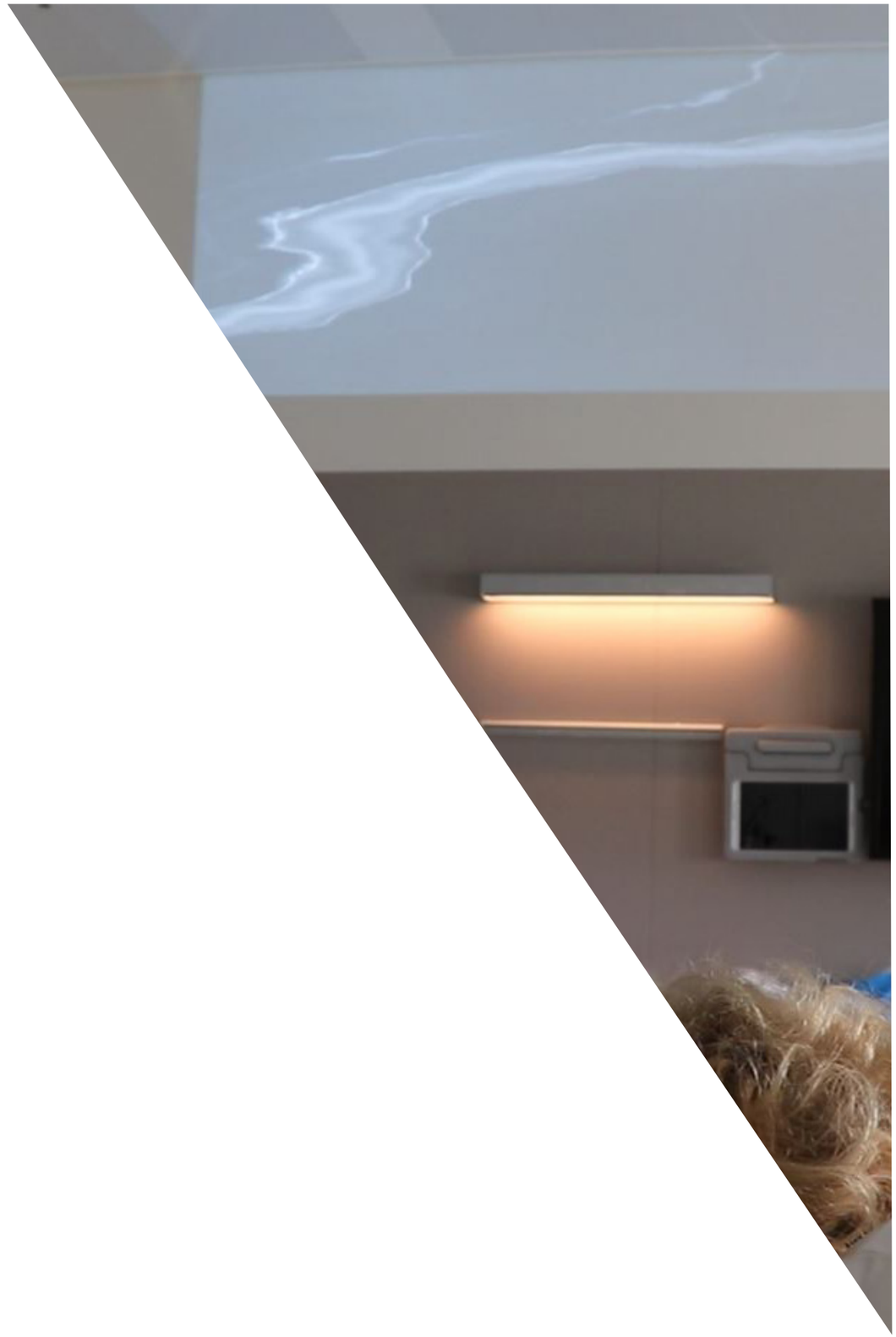
13.2 IMPLEMENTATION

Considering implementation, there are many possibilities. It could be offered to the patient by the HCP as part of their medical care. It could be offered to the patient by the family as a tool so that they can help and support the patient. Or it could be that it is integrated into the ICU environment and always active in the background.
In order to make a final decision, the purpose and use of the product should be obvious.

The current design supports full integration into the ICU environment, as according to the research described in this report, it is most beneficial for the patient. Mainly because there are so many (unpredictable) transition moments, and HCPs would not need to think about, using or doing anything to assist the working of the design intervention.

14.
RECOMMENDATIONS

Throughout the report, a lot of recommendations were mentioned. In this chapter, a general overview is given of all recommendations for future designers, future designs and future research.



14.1 FOR FUTURE DESIGNERS

Designers can take different approaches when designing for the IC environment. The approach used in this report can serve as a good example or inspiration to build upon. Throughout the analysis, the main goal was to understand the patient's experience, their needs and thus their perception of the ICU environment. All the insights gathered can help other designers better understand how and for whom to design in the ICU context.
Moreover, future designers can benefit from the ICU patient's needs analyses. Designing for the fulfilment of needs has proven to be a successful way to develop an appropriate and desirable design intervention in the ICU. We identified six fundamental needs future designers could attempt to fulfil more or other needs. The current design intervention mainly focuses on distracting the patient by connecting him/her to the environment. There are still many opportunities to explore, including how to connect patients and people and how to personalize the ICU to become more human (through data or preferences).
Furthermore, the proposed use case could be further defined, analysed and designed. Ultimately, this report could form the basis of a future design implemented in the IC environment.

14.2 FOR THE FUTURE DESIGN

After evaluating the proposed design intervention, it was clear that this could be a desirable design intervention, but the design is not yet final. Many things still require consideration. These are already mentioned in the report, but will be briefly discussed. It is recommended that attention is paid to the following topics:

Interaction

How the users will interact with the device is not defined yet. This, in the first place, depends on who will control the intervention. It has been suggested to give control to the patient, HCPs or family. All require a different user interface. The patient will want an easy and very intuitive tactile interface. The HCP would want one that does not need a lot of attention and is easy to control, or does not need to be controlled at all. So, maybe they want a digital interface integrated into the pager or a tablet on the wall. Finally, family/friends would perhaps want to have some more input and, consequently, an interface that is easy and accessible, like, e.g. an app.

Personal preferences

Adding personal preferences is seen as a great opportunity. This came to light not only during the research, but also during the evaluation phase. Many participants mentioned the advantages. The way to add personal preferences, what kind of preferences and how to make the changes in the settings (by the patient, loved ones, caregiver, or AI) still need to be figured out.

Monitoring

There is one possible feature that has not been discussed so far. This entails that the design intervention could measure not only the SPL (dB) but also the patient's response to changes in sound pressure level via changes in the heart rate (beats per minute) or EEG (Electro-encephalography, brain activity). The ratio of sound to response determines the sensory aspect: whether a sound is perceived.
This can be used to know when patients respond to an event, and therefore, when to introduce the design intervention and when it is unnecessary because there is no response. However, this responsiveness may be challenging to measure, and it may be hard to grasp what the patients do or do not experience, so this needs further investigation.
Secondly, the measured SPL or the SPL with the patient's response could be displayed to the HCPs. For example, on a screen a graph showing SPL over time. This way, it becomes immediately apparent how loud or quiet the room is and how long excessive noise or quiet periods take place. HCPs can adapt their behaviour, gain insights into the events that have taken place (intensity, duration, or the amount), and choose to adjust their care. For example, if it has been a busy day for the patient, they can decide not to brush the patient's teeth. As a result, care becomes more customized.

The stimuli

The stimuli consisted of an auditory and a visual component. The developed stimuli can, however, still be improved. Additionally, suggestions from Sylvia and Anil should be implemented in future iterations, and different stimulus types should be developed and explored. Using nature as a basis seemed to work for many participants, but different sounds (different birds or no birds) or a different visual (happier, less cloudy) could work even better. Also, it is interesting to explore other changes (smoother or sharper) and reactiveness (more or less intense) in both the audio and visual design.

The embodiment

A proposal was made for the embodiment of the design intervention. But with ever-improving technology, some choices might soon become obsolete (e.g., the choice of the projector). Moreover, the proposal is based on the current design, and the requirements may change in upcoming iterations. Nevertheless, the PC, for example, can already run a program such as MAX.
As a result of the changing requirements, the embodiment of the design could change. To know what works best, everything should be tested in the IC environment. In the end, it might be most convenient and beautiful to integrate the intervention into the Dräger system.

Risks

Because the ICU must be safe for all occupants, all risks should be identified and eliminated. So, it is recommended to test the design intervention in many different scenarios. Afterwards, you can make additional changes to the design so that the safety is not compromised in any circumstance.
For example, I could imagine that the power cables could be obtrusive, get tangled, or it can be unclear what device they power. So, giving the power cables of the design intervention a different colour or label could create more clarity and improve safety.

14.3 FOR FUTURE RESEARCH

A lot of research needs to be done considering the effect of the proposed design intervention on patients, loved ones and HCPs, to see what would work best and what will not.
The research should focus on the transition moment towards uneventfulness, as this is likely to benefit patients the most and so far has not been researched extensively.

Additionally, the proposed embodiment of the design intervention needs to be further researched and tested. But step by step, we will uncover what type of stimuli work best and how to best deliver the stimuli to the patient.
Most importantly, we will have to research the impact of the design intervention on the patient experience and the course of delirium. Delirium has often been mentioned, illustrating its effect on the patient's experience.
Patients can be helped by providing non-intrusive interactions that distract and shift the focus on something familiar and comforting. Doing so could contribute to a more positive experience. This is precisely the aim of the design intervention, so future research will have to prove it also does.

15.
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15. REFERENCES

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