Design guidelines towards humanization and Artificial intelligence in the Intensive Care Unit

Master thesis Strategic Product Design
Ruud Nagtzaam

TU Delft

Erasmus MC
Universitair Medisch Centrum Rotterdam

Critical Alarms Lab

Author
Ruud Nagtzaam
University of Technology, Delft
rhmqnagtzaam@gmail.com

Chair
Elif Ozcan Vieira
University of Technology, Delft

Mentor
Evangelos Niforatos
University of Technology, Delft

Company mentor
Jasper van Bommel
Erasmus MC

Design guidelines towards humanization and Artificial Intelligence in the Intensive Care Unit

Ruud Nagtzaam
September 2021

Acknowledgements

Dear Reader,

The completion of this thesis would not have been possible without the support of the Critical Alarm Lab, the staff of the ICU of the Erasmus MC, participants in my study and of course, my family, my girlfriend and many friends. You have helped me by inspirating, by supporting and by being critical to me. A special thanks goes out to Dr Elif Özcan Vieira, Evan Niforatos and Jasper van Bommel for your guidance and support during my graduation project. I have learned a lot from you.

With the end of this thesis my many years a student in delft will end. During my studies I have learned a lot and a lot about myself. Thanks for those who have been there along the journey.

Have fun reading my thesis.

Ruud Nagtzaam
Breda, September 2021

Abstract

Key words
Intensive Care Unit | Artificial Intelligence | (De)humanization | ICU Patient | Future ICU | Design guidelines | Patient experience

This report describes a graduation project for the MSc program Strategic Product Design. The client in this project is the Erasmus MC in the Netherlands and commissions this project incorporation with the Critical Alarms Lab (CAL) of the TU Delft. The Erasmus MC and CAL want to improve the experience of the Intensive Care Unit (ICU) both for patients and for the stakeholders surrounding the patient. They are also interested in using Artificial Intelligence (AI) and data to benefit ICU patients. A research project is set up to find how the experience for ICU patients can be improved and how AI can play a role in the ICU. Therefore, the research questions of this project is defined as: "How should the intensive care unit of the Erasmus MC innovate in the coming years to give critically ill patients a humane experience?". The research resulted in a future vision that describes different values for the ICU of the Erasmus MC. Also, it is described what consider concerning humanization and Artificial Intelligence in the ICU of the future. Secondly, the research results in design guidelines that can be used by the Erasmus MC or designers to design for the ICU and ICU patient. The investigation into the ICU, the ICU patient, stakeholders with influence on the ICU and the future vision come together in a website. This website can be used to retrieve information, used as a guide or function as an inspiration for designers for healthcare

Executive Summary

This thesis delivers design guidelines and a future vision for the Erasmus MC to provide humane care. In this thesis, research is performed to find design guidelines to benefit the patient's care and how the introduction of Artificial Intelligence can help the ICU and the ICU patient. Extensive research is performed to find more information about the ICU patient and the stakeholders that can influence the Intensive Care Unit.

For the research into the ICU patient, three elements need to be understood before designing for the ICU patient. Firstly, the patients' needs need to be understood. These can be categorized into four different contexts: physical, psychospiritual, environmental, and sociocultural. Or, the patients' needs can be categorized according to Maslow's hierarchy of needs. Secondly, the mental capacity of patients' needs to be understood. Patients in the ICU are often heavily sedated unconscious or kept unconscious, limiting what they can process and perceive. Thirdly, the physical capabilities of patients need to be understood. Patients have limited physical abilities and are bound to their beds.

For the stakeholders that can influence the Intensive Care Unit, six levels of influence are researched. The six levels consist of the patient, the family and loved ones of a patient, the hospital staff, the healthcare institute (Erasmus MC), the healthcare community and the national healthcare organization. All six levels can influence the ICU and developments for a future ICU. For example, patients can influence the development of a future ICU because they carry valuable information about their needs and wishes that can be used for input for new products, services or protocols. They have the first-row experience of the care they are provided. But also, the national healthcare organization can subsidize research into new healthcare technologies or set up campaigns to create more awareness on important healthcare topics. Research into the ICU, the ICU patients and the stakeholders that influence the ICU creates many insights. It delivers valuable information that is needed to design new products, systems or more. These insights and information make design guidelines that need to be followed and part of the future ICU's design process. The following design guidelines are the results of this research.

- Design enhances human ability (without replacing the human)
- Design for real patient experiences to improve
- Design with empathy and compassion for the ICU patient
- Understand the patient needs, their mental and physical abilities
- Educate what data-driven decision-making systems have to offer
- Be aware of (de)humanization.

Design guidelines are of help for individuals or teams to make an appropriate decision. They can be of benefit to the Erasmus MC or designers for the ICU and ICU patient. They can be used to reach the future vision made during this project for the Erasmus MC. The future vision for the Erasmus MC is created by using the road mapping method of Lianne Simonse. The method consists out of trend research into new technology, patient trends, medicine trends, and trend in the Intensive Care Unit discovers relevant topics that can influence the ICU patient's care. For example, the change in the general population and increase in ICU population could cause E-Health to be introduced, which means to relocate healthcare towards home and online, treating patients from a distance. To ensure examples like these won't become science fiction, the future vision is described with a vision statement that holds values that won't change over time. These values are created by following the road mapping methodology. Vision statement:

"'The Erasmus MC as an innovator in predictive and preventative healthcare, while providing ICU patients with high quality and personalized humane care that is supported by smart systems."

Abbreviations

AI	Artificial Intelligence
CAL	Critical Alarms Lab
ICU	Intensive care unit
ML	Machine learning
PICS	Post intensive care sydrome
WFSICCM	World Federation of Societies of Intensive and Critical Care Medicine

Table of content

1. Project introduction

In the first chapter of this thesis the project is introduced, the research question is discussed and the project approach is presented.

Chapter 1

1.1 Project Context
1.2 Research question
1.3 Project approach

1.1 Project introduction

The average human lifespan is increasing, lifestyle-related illnesses and obesity are becoming more common. This leads to more complex and invasive surgery, leading to a growing ICU patient population (Ho et al., 2020). Together with this growing ICU patient population, there comes a loss of sight to the human side of the patient. Patients can experience the loss of their identity. Instead of being identified by their names, how they dress, their interest, or their cultural background, they are identified by the patient number, room number, the disease or their treatment. Being in the ICU means wearing a standard hospital gown, not communicating at all times, or being unconscious (Wilson et al., 2019).

To counter this dehumanization in the ICU, Wilson et al. state that a culture swing of 'humanizing the ICU' is needed. This can be done by patient-focused behaviours and environment-related measures as shown in figure 1 (Wilson et al., 2019). Olausson et al. found that patients are treated to make them better, resulting in less attention to their comfort. Comfort as an outcome of treating patients addresses physical needs and illness symptoms, not so much emotional and psychological needs (Olausson et al., 2019)

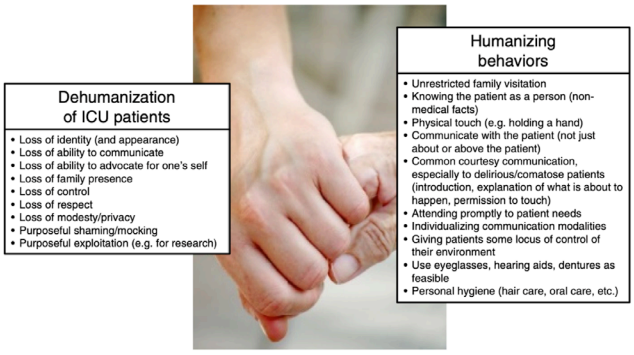


Figure 1: Dehumanizing and humanizing of intensive care unit patients (Wilson et al., 2019)

Patient comfort is affected by different factors, and it includes the patient's needs and how well these needs are met, how patients perceive these factors, and the environment they are in (Nural & Alkan, 2018)). Many patients feel discomfort in the ICU caused by different factors such as anxiety, pain, feeling restraint, lack of privacy, noise, the light at night-time, hunger, and lack of information (Lombardo et al., 2013). The experience of dehumanization and factors of discomfort can lead to Post Intensive Care Syndrome (PICS) or Post Traumatic Stress Syndrome (PTSD (Jackson et al., 2007; Rawal et al., 2017).

While patients are treated in the best way possible, they do not need surveys questioning their satisfaction with their hospitalization. They need solutions that help them to recover quicker and better during and after hospitalization. Design interventions should be thought of and implemented without compromising their wellbeing. Their recovery process should be enhanced, and they should be provided with different ways of recovery where humanization plays a role (Wilson et al., 2019)

In finding design solutions, new technologies could be introduced to change the experience and work for all stakeholders involved in the ICU. The main goal is to let interventions benefit the patient's wellbeing. This can also be indirectly achieved by designing for other stakeholders that influence the ICU and the ICU patient. A technology that the Erasmus MC points out to be of benefit in the (near) future possibly is Artificial Intelligence. Therefore, this project looks into the possibilities of using Artificial Intelligence for design interventions in the ICU of the Erasmus Medical centre. The project focuses on the future of the ICU of the Erasmus MC, where humane healthcare is the standard, and Artificial intelligence could be of benefit.

1.2 Research question

This project aims to deliver design guidelines and suggestions for the Erasmus MC to deliver humane care and to introduce Artificial Intelligence into the Intensive Care Unit (ICU). This project looks into (de)humanization of patients and the opportunities of using Artifical Intelligence for healthcare. Furthermore, this project looks into what to consider when designing for the patient in the ICU and the ICU itself. This project's goal is to deliver information and inspire (medical) designers or others interested in designing for the ICU or looking for information on designing for the ICU.

Research question:

How should the intensive care unit of the Erasmus MC innovate in the coming years to give critically ill patients a humane experience?

Sub questions:

1. How can humane Artificial Intelligence solutions improve the patient experience in the ICU of the Erasmus Medical Centre?

2. How can design solutions contribute to the delivery of humane care in the Erasmus Medical Centre?

3. How can artificial intelligence be used in the intensive care unit?

1.3 Project approach

The project approach is based upon the 'Design Roadmapping' book of Lianne Simonse to create a future vision (Simonse, 2017). It incorporates a strategic design process. Strategic design refers to the use of design principles and practices to guide strategic development and implementation towards innovative outcomes that benefit an organization and its stakeholders (Calabretta et al., 2016). The process is a double diamond with 4 phases, Discover, Define, Develop and Deliver.

The first diamond with the discover and define phase is called the value mapping and delivers a well-defined future vision. The second diamond with the develop and deliver phase delivers specific information on Humanization and AI, on the ICU patient, on the future vision and on possible next steps to be taken for the ICU in the future.

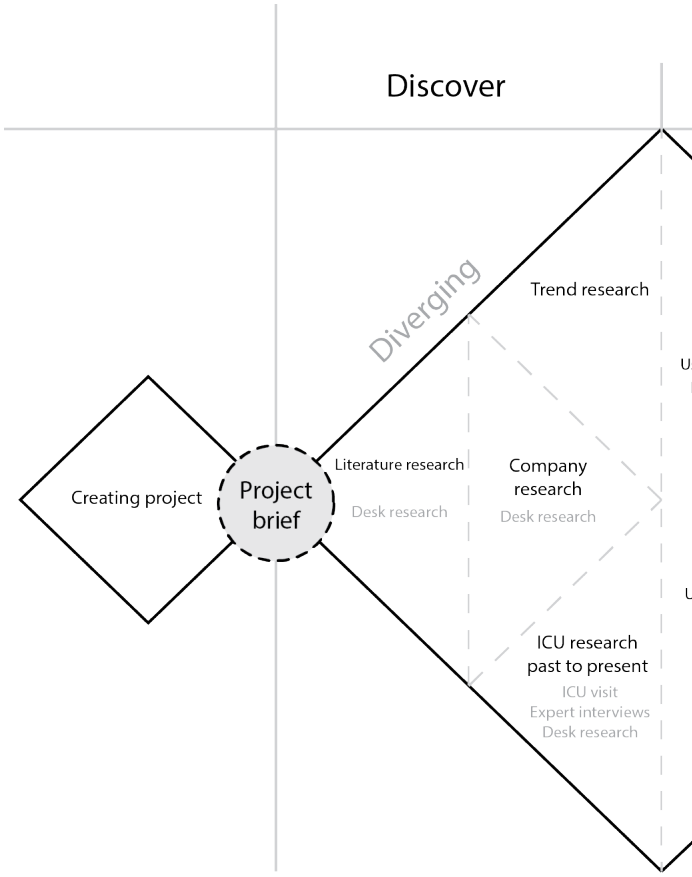
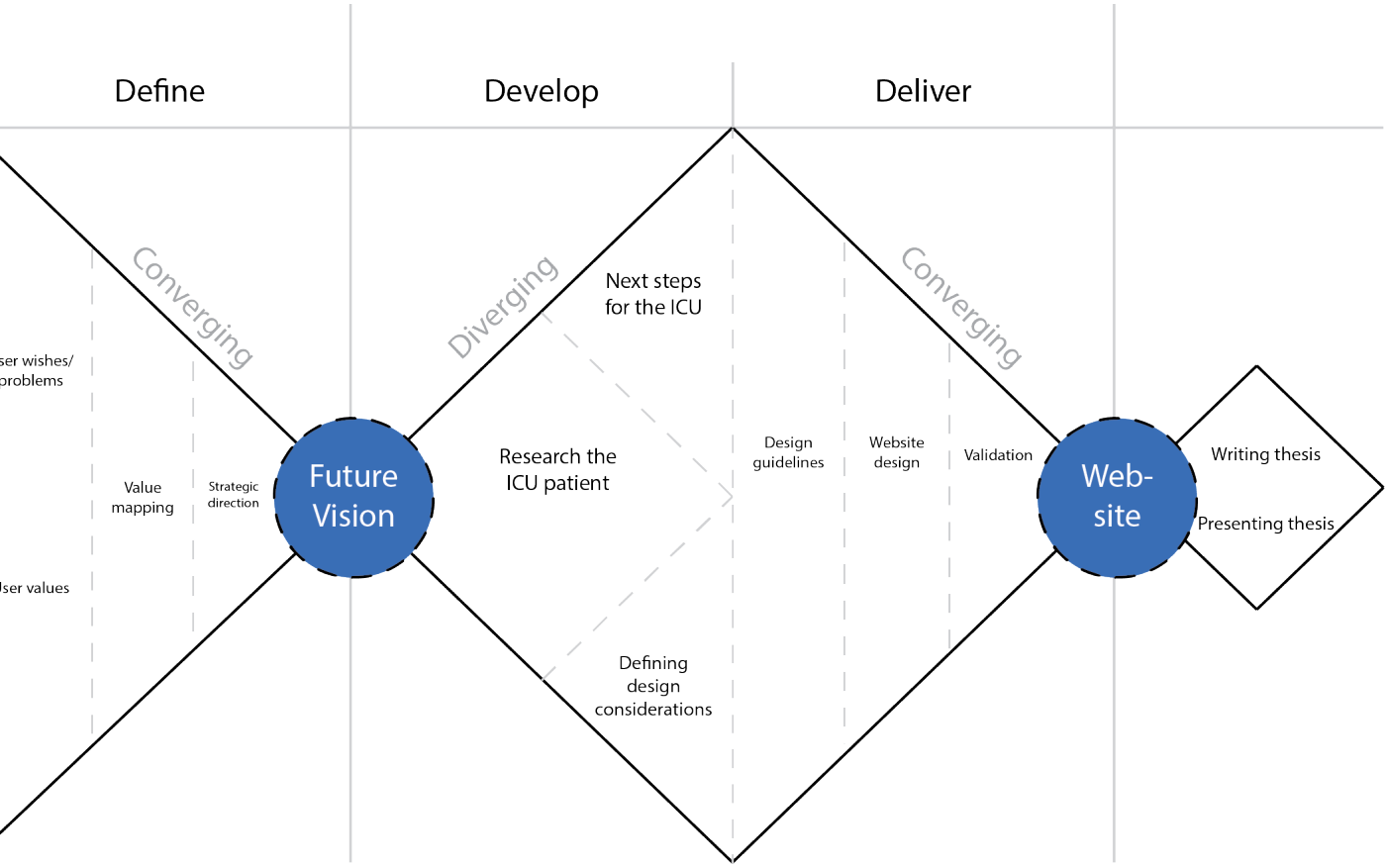


Figure 2 : Schematic overview of Design approach

Diamond 1

The discovery phase consists of literature research into the Intensive Care Unit, Artificial Intelligence, the different stakeholders involved in the ICU, and into preventive, curative, and caritive parts of healthcare. Company research into the ICU of the Erasmus MC and Critical alarms lab. Research into the ICU of the past to the present: researching the changing roles in the ICU of personnel and patients throughout history, containing expert interviews and an ICU visit. The trend research to create insights on trends that can influence the people and environment of the ICU of the Erasmus MC. It focuses on past developments and developments that are likely to come in the future.

The next phase is to converge and define the different directions and opportunities towards a future vision. At this moment, different unique value drivers will be formed that describe the direction in which the ICU of the Erasmus MC needs to be developed or needs to focus on. These value drivers form the basis of the future vision.



Diamond 2

The develop phase consist of research into the ICU patient. It entails analysis into the patient needs, mental capacities and physical capabilities to understand the ICU patient. It results in considerations to think of when designing for the ICU patient. Furthermore, six different levels of influence on the ICU are investigated and ways of influence has gernearted ideas for future steps.

The deliver phase consists of the synthesis where information comes together to be formed into the website. Research for the future vision and research into humanization and AI led to different design considerations and ideas. Ideas were generated by brainstorming and are influenced by technology scouting. Next, the website is designed to deliver information on the ICU patient, the future vision, ideas for humanization, the introduction of AI and the six levels of influence and their next steps. The last part consists of validating the webpage and finalizing the thesis.

2. (Literature) research into the intensive care unit

Chapter 2

2.1 The intensive care unit
2.2 The history of the intensive care unit
2.3 Stakeholders of the intensive care unit
2.4 Stakeholders over the years
2.5 Visit to the ICU of Erasmus MC
2.6 Patient (dis)comfort in the ICU
2.7 Artificial intelligence

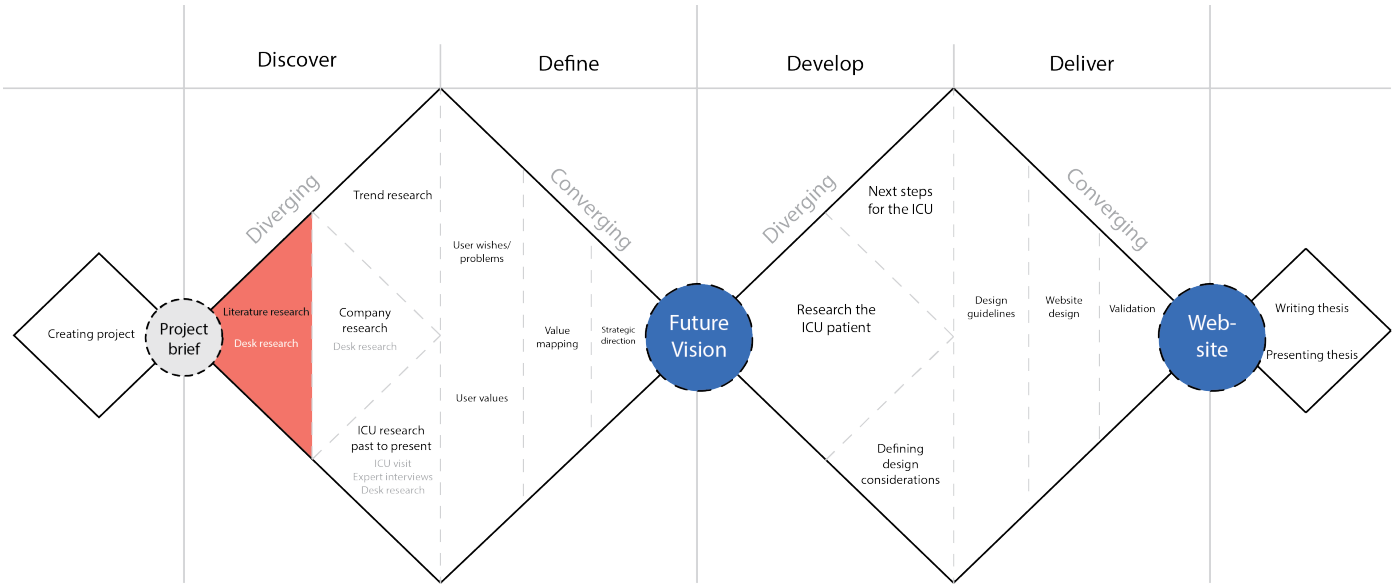


Figure 3 : Schematic overview of Design approach : Literature research.

In this chapter, literature research is executed into the Intensive Care Unit. The purpose of this literature research is to establish familiarity with and understand the ICU and the environment of the ICU. To get a complete idea of the Intensive Care Unit, multiple fields are researched.

First of all, there is taken a deeper look into the history of the ICU, so there is more understanding of why the ICU functions how it nowadays does. Secondly, the stakeholders that interact at or with the ICU are being researched, to understand the relationships and influences in the ICU environment. To understand the ICU environment even better, and make it more relatable, a visit to the ICU of the Erasmus MC was planned. The findings of this visit are described in this chapter. Some more literature research is executed about the patient (dis)comfort, because the ICU patient is one of the central stakeholders of an ICU. Last, some research is done on Artificial Intelligence, what has been designated by the Erasmus MC as a potential technical solution space to improve the ICU.

2.1 The intensive care unit

Definition of the intensive care unit

Over the years, intensive care units have evolved and have been defined differently. The World Federation of Societies of Intensive and Critical Care Medicine (WFSICCM) have studied different definitions of intensive care units in literature and have defined an intensive care unit as:

An intensive care unit (ICU) is an organized system for providing care to critically ill patients that provides intensive and specialized medical and nursing care, an enhanced capacity for monitoring, and multiple modalities of physiologic organ support to sustain life during a period of acute organ system insufficiency. Although an ICU is based in a defined geographic area of a hospital, its activities often extend beyond the walls of the physical space to include the emergency department, hospital ward, and follow-up clinic.

Clinicians working in the ICU are intensivists, Doctor-assistants, IC nurses, and IC nurses in training. They work closely with allied health professionals such as physiotherapists and dieticians, department assistants and logistics employees, and social workers and spiritual counselors (Marshall et al., 2017).

ICU equipment

The ICU is filled with equipment that monitors a patient's health and supports their bodily functions until they recover. Equipment that can be used is: (NHS, 2019)

Figure 4: ICU box Erasmus MC: equipment overview

The patient box in the ICU has a lot of space which allows for easy movement in the room and around the patients' bed. This also allows for other equipment to have more than enough space to be placed in the room when needed.

Figure 5: ICU box Erasmus MC: Box with a view

Next to the cabinet there is a window with blinds on the outside. Behind this window there is the nurse station from where nurses can keep an eye on patient without needing to walk into the room.

Figure 6: ICU box Erasmus MC: working station and nursing station window

In the patient box there is a cabinet with drawers full of supplies and with a large counter top for doctors and nurses to be used. There is also a televison for patients to watch anything they like if they can and want.

Figure 7: ICU box Erasmus MC: working station

The hallway of the ICU is big and wide with on the sides nurse stations for nurses to work and monitor their patients. Sliding doors connect the hallway with the rooms, which are very well isolated to minimize the noise inside patients rooms.

Figure 8: ICU box Erasmus MC: hallway ICU

2.2 The history of the intensive care unit

When talking about the future, it is very important to first understand the past. This timeline gives an overview of the timeline of the intensive care unit from the past to the present.

Figure 9: Portret of Florence Nightingale

1850's

In the 1850s, during the Crimean war, Florence Nightingale managed to segregate the most severely battle injured soldiers close to the nursing stations. This caused better and more intensive monitoring of these soldiers. Florence Nightingale can be seen as the matriarch of intensive (care) nursing. (Grenvik & Pinsky, 2009; Marshall et al., 2017; Özcan et al., 2019; Ristagno & Weil, 2009; J. Vincent, 2013; Weil & Tang, 2011)

1952

In 1952, the Blegdam hospital in the Danish capital Copenhagen was overwhelmed with many polio patients needing mechanical ventilation. The only mechanical respirator systems that were available were the iron lung and six chest ventilators. These seven mechanical ventilators were not enough to care for 316 patients. To ensure all patients got manually ventilated, hundreds of doctors, medical and dental students were asked to ventilate patients 24/7. Ventilation was done by pumping air into the patient's lungs via the tube connected to a rubber bag. The bags were manually pumped. The strategy Ibsen used saved numerous patients and developed the world's first Intensive Care Unit, with a dedicated ward and nursing staff. After Nightingale and Dandy, this was one of the first organized wards with a specially trained staff that delivered extra care to patients. (Ashworth, 1987; Grenvik & Pinsky, 2009; Ho et al., 2020; Kelly et al., 2014; Marshall et al., 2017; Özcan et al., 2019; Ristagno & Weil, 2009; J. Vincent, 2013)

Figure 10: Dr. Walter Dandy and his surgical team in 1946 (Blitz, 2019)

1923-1929

In the 1920s, Dr. Walter Dandy was the first after Florence Nightingale to organize a neurosurgical postoperative care unit in the Johns Hopkins Hospital in Baltimore. He arranged a specialized and separated site where nurses were trained by surgeons and anesthesiologists in their daily routines to care for patients. (Grenvik & Pinsky, 2009; Ristagno & Weil, 2009; J. Vincent, 2013; Weil & Tang, 2011)

Figure 10: A young patient manually ventilated, 1953 (Medical History Museum in Copenhagen

1960's

The introduction of intensive care to the Erasmus MC (then named Dijkzigt hospital)

Figure 12: Dijkzigt hospital, Rotterdam

1961's

Danish anesthesiologists Bendixen and Pontoppidan immigrated to Boston, where they opened the reputable respiratory ICU at Massachusetts General Hospital.

1980's

In the 1980s, training standards were developed in the USA. This caused other countries to react and start specialized training for critical care physicians as well. (Kelly et al., 2014)

2000's

ICU's over the past 10 - 20 years have the core capability of supporting or taking over the function of multiple-organ systems. There is a culture of constant quality improvement and at the same time shift to 'less is more' and 'doing the simple things well' (Kelly et al , 2014)

1957

The department of Anesthesiology of the Baltimore city Hospital established an intensive care unit. (Safar et al., 1964)

1958

The University of Southern California medical center build a ward called the "shock ward." Specialized Physicians and nurses worked together with technicians. They introduced equipment and a way of working to be to monitor, measure and have 'real-time' data of patients. Alarms were introduced to warn of immediate threats. These alarms are still in the ICUs of now. (Kelly et al., 2014)

Figure 11: Bedside monitoring system installed in 1962 (Wiener et al., 1982)

2.3 Stakeholders of the ICU patient

This simplified overview shows five stakeholders that interact with the patient during their stay in the ICU. The stakeholders of the ICU have different tasks, wishes, and demands and influence the patient in different ways. Besides interacting with the patients, the stakeholders also interact with each other.

Patient

Patients that are treated in the ICU are very ill. They have all different kind of life threatening diseases and trauma's. They are treated to save their lives and are often heavily sedated. It is not always clear if patients are conscious or unconscious while they are sedated. While they are in the ICU they are submissive to the nurses and doctors. (Genderen, 2021).

Intensivist

The Intensivist in the ICU is responsible for the treatment and the treatment strategy of the patient. They are in close contact with the ICU nurses to ensure their treatment goes according to plan. The Intensivist on duty works with multiple patients simultaneously, and their primary focus is to make patients better and keep them a life. While focusing on the treatment of patients, there is a lot more going on in the ICU. This requires them to manage time and talk to different nurses simultaneously and be resistant to stress. (Genderen, 2021)

Nurses

Nurses in the ICU are responsible for monitoring and caring for multiple patients at the same time. In the ICU of the Erasmus MC, the ICU nurses care for two or three patients simultaneously. They have a variety of different tasks at hand, such as supporting and informing the Intensivist on the happenings of a patient. They care for the patients both physically and mentally. (Genderen, 2021)

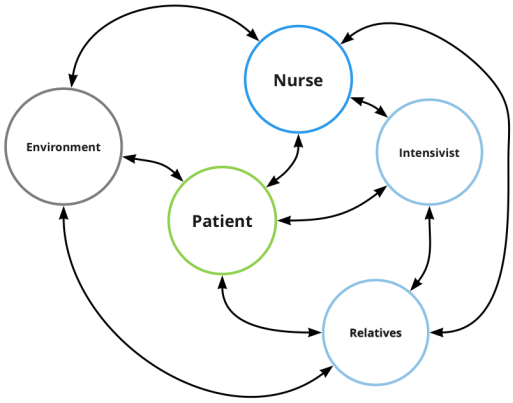


Figure 13: Schematic overview of stakeholders with arrows to show interaction directions.

Relatives

Relatives of patients visit patients in the ICU; they know the patient the best and are often worried about their wellbeing. Relatives require support by nurses and intensivists in helping them to understand the treatment the patient is going through and support them while visiting the patient. Relatives also play a significant role in processing the patients' stay in the ICU. They have followed the patient during its stay in the ICU and have, in some cases, more factual recollections than patients. This can help patients recover since some patients do not recollect their experience, while others have developed the post-intensive-care syndrome. (Genderen, 2021)

Environment

The environment of the ICU influences the patient, both while they are conscious and unconscious. This can be the room itself or the room's characteristics, and it can be the equipment in the room or how the room is used. For example, the equipment in the room can make noise or sounds, the presence or absence of natural light can influence the patient and the nurses and intensivists are using equipment that is perceived by patients.The environment can influence the patient in all sorts of ways, leading to comforts and discomforts (Lombardo et al., 2013).

AI- Solutions

This research project is about finding opportunities that can benefit the patient's comfort in the ICU. Therefore, AI-solutions are not a stakeholder but can be placed in between other stakeholders to influence and benefit the patient's comfort directly or indirectly. Figure 13 shows where AI solutions could interact and/or benefit and or interact with the stakeholders.

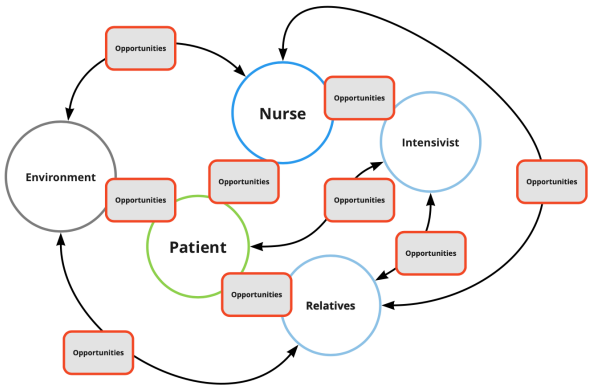


Figure 14: Schematic overview of stakeholders with opportunities for AI to interact with different stakeholders.

2.4 Stakeholders of the ICU patient over the years

In this subchapter, the stakeholders, identified and explained in subchapter 2.3, are investigated throughout history. This gives more background into the stakeholders, their goals, and how they influence the ICU (patient). In addition, how the technology has evolved over the years in relation to the ICU is explained.

Patients over the years

Humankind and thus patients in hospitals have changed over the years. Humans were able to treat themselves when they were ill, knew how to handle certain illness symptoms, or did not treat themselves, lived with it, and probably eventually died. They were curing themselves and passively reacting upon their own misfunctioning. This a very long time ago before doctors existed. At the time ICUs existed, doctors and nurses became specialized in treating patients. At the same time, patients put their trust in doctors who treated them but did not have their own resources or knowledge on what the doctors were doing. With the arrival of the internet, knowledge is at everyone's exposal. Patients are looking on the internet to find more about their symptoms or about their conditions. It is found that patients connect with other patients to compare treatments, to review and rate hospitals and staff (Hammond, 2019).

Nurses over the years

Nurses in the nineteenth century and early twentieth century provided basic care for patients and were expected to follow up orders from physicians. They were trained in hospital schools of nursing and were to perform basic tasks as a physician ordered them. They were not taught or explained how medicine worked or what they gave to patients. Only until the 1970s, specialized and trained ICU nurses were required to perform medical interventions in crisis situations. (Grenvik & Pinsky, 2009) This led to nurses specializing in different areas (Michaels, 2018).

Although nurses were not knowledgeable in the earlier stages of the development of the ICU, they have been at the center of the development of ICU since the beginning. Nurses have been working for the physicians by following orders. This has changed towards working with physicians being the eyes for the physicians, who need to oversee all the patients in their ICU ward. (Grenvik & Pinsky, 2009) (Genderen,2021)

ICU nurses are currently understaffed and experience a high workload (Wilson et al., 2019) (Genderen,2021). They are able and perform more medical interventions than regular hospital nurses. The most significant difference is that ICU nurses need to monitor the vital functions of a patient and need to be skilled to adequately act upon changes in a patient's functioning.

As mentioned before, nurses are in the middle of all the operations in the ICU. Since the nurse is always there, they know everything that is going on about the patient. They connect the doctors with the patients, the patients with the doctors, the family with doctors, and the patient. This is a daily task and happens while they are working and caring for the patient. Although ICU nurses experience a very high workload, there is no (technical) solution being developed yet to decrease this workload besides employing more nurses. Daily tasks that a nurse performs consist out of:

- Care for the patients
- Set up and execute a care plan together with other medical personnel (intensivists)
- Control the condition of a patient
- Inform the patient about their health status and treatment
- Answer questions from relatives and family about a patient's status.
- Execute a diverse range of medical actions
- Inform and assist doctors on the ICU
- Keep up the administration of the patient

Doctors in the ICU of the years

Over the years, the role of physicians changed. Until the nineteenth century, physicians operated on their own. They were experimenters, decision-makers, and the physician to carry out the intervention. For a long time, doctors were the only knowledgeable people in healthcare. They were the only educated professionals to be able to cure a patient. They examined their patients, diagnose illnesses and prescribe a cure to make them better. They work with different colleagues with different 'specialisms' and direct nurses to care for their patients by letting them perform basic nursing tasks or giving them medicine.

In the twentieth century, physicians were less likely to be experimenters, acting more as decision-makers and clinical judges. Currently, in the twenty-first century, physicians are still experimenters, decision-makers, and clinical judges, but they are also team managers. (Lagace, 2004)

Technology over the years

Technology that is used right now has changed over the centuries. In the late 1900's more life-support and invasive monitoring techniques were introduced. Furthermore, a lot of machines have become better, smaller, or are replaced with non-invasive or less-invasive alternatives (J. Vincent, 2013).

With the introduction of the computer, displays and storage and handling of information has changed. For example, patient data is stored in a system (Electronic Health Records) instead of on paper or partly on paper. Computer(systems) have entered the hospital rooms (ICU boxes) to store, read or modify patient data. Monitoring systems and 'treatment' systems can be linked to computers. This means that patient data is available everywhere with a computer, and doctors do not need to physically see the patient check on their vital signs or their status. (genderen,2021)

2.5 Visit to the ICU

During a visit to the intensive care unit of the Erasmus MC, Michel van Genderen, Intensivist at the Erasmus MC, and his colleagues showed me how doctors, nurses, and patients interact. The way of working, how prioritizing works, and how doctors and nurses interact, treat and care for patients were explained. Observing and asking different questions led to insights and interesting quotes.

Patient interaction insights

Patients that enter the ICU are the most severely ill patients there are. Patients are not able to communicate because of sedation or other reasons of unconsciousness. The primary goal of doctors and nurses is to make patients better, as good, and as quick as possible. What should be noted is that nurses try to care for patients in a humane way

but that a lot of work and interventions won't feel humane for a patient.

When a nurse or doctor enters a patient room, they will introduce themselves. Because, although patients are unconscious or sleeping, they can still notice someone entering the room, this is noticed by a rising heart rate, and the patient becomes active. According to one of the intensivists, this does not always go correctly. Since doctors make a judgment call on the status of a patient or how conscious they are, they will or won't introduce themselves.

General insights

The environment of the ICU is diverse and hectic. Nurses, Doctors, and support personnel are continuously walking around communicating about different patients. Doctors are aware of what is happening with all the patients. They are informed by nurses, by reading status reports, and by the hand-over at the beginning of their shift.

Doctors and nurses work with Hix, an electronic health records platform in which they update treatment strategies, patient statuses, or other patient data (Bossche, 2021). Working with a platform like this, where data needs to be added manually into a patient's files, takes up a lot of work. It is stressed that solutions to automate these tasks could lead to more time at hand to perform other tasks or lower the workload.

New technological devices and systems are welcome in the ICU as long as the workload does not increase. Introducing them needs to be done in little steps to implemented them in the workflow of hospital staff.

Interesting quotes

'My biggest dream is to walk into the ICU with an Ipad that shows me which patient has the most potential of getting more ill and is therefore in need of more medical attention.' - M. van Genderen, internist intensivist Erasmus MC

'My first concern is how a patient's physical well-being is evolving. Of course, I want to pay attention to a patient's comfort, but when someone is so critically ill, that is just not the priority.' - M. van Genderen, internist intensivist Erasmus MC

'We have the data of patients, we can read it, and we can store it. But we don't do anything with it right now. We could build algorithms, but why are we not doing it?' - H. Endeman,Intensivist Erasmus MC

'An unconscious/heavy sedated patient I was treating for a couple of weeks woke up after intensive treatment. When she was able to talk, she told me she recognized my voice, and she did not like me because I hurt her in the last weeks. ' - W van den Bossche, AIOS Neurosurgen Erasmus MC

2.6 Patient (dis)comfort in the ICU

Comfort is a word of French origin and is defined as "that which makes daily life easier." Others describe comfort as a pleasant state of physiological, psychological, and physical harmony between a human being and its environment (Slater, 1985). Alternatively, comfort is defined as: "comfort is seen as a pleasant state or relaxed feeling of a human being in reaction to its environment" and "discomfort is seen as an unpleasant state of the human body in reaction to its physical environment" (Vink & Hallbeck, 2012). Many people define comfort in different ways, but there is one point that is the same in every description, which is that comfort is a construct of a subjectively defined personal nature, comfort is affected by factors of different nature (physical, psychological) and comfort is a reaction to the environment (De Looze et al., 2003)

The context wherein comfort occurs is described by Kolcaba and Fisher (1996) as:

Physical

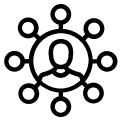
About bodily sensations, homeostatic mechanisms, immune function, and more.

Psychospiritual

About internal awareness of self, including esteem, identity, sexuality, meaning in one's life, and understood relationship to a higher-order or being.

Environmental

About the external background of human experience (temperature, light, sound, odor, color, furniture, landscape)



Sociocultural

About interpersonal, family, and societal relationships (finances, teaching, health care personnel, etc.) Also, to family traditions, rituals, and religious practices.

2.7 Prevention, Care and Cure of patients

To understand how the healthcare at the hospital, specifically at the ICU, is arranged, it is important to distinguish three crucial aspects of "healthcare". These are prevention, care and cure of patients and are elaborated in this section.

Prevention

Preventative care prevents disease, injury, or illness, rather than treating a condition that has already become catastrophic or acute. The goal of preventive care is to help people stay healthy and ensure they do not become ill. This can be done by for example, education or warning healthy people what effect the intake of food has on a human. (Genuis, 2007)

Cure

The word cure comes from the Latin Cura, which means care, concern, or attention. In healthcare cure, curative healthcare is described as healing, making well, and restoring to good health. Others describe Curative healthcare as making a patient better that suffers from an illness or a trauma. Curative healthcare is the healthcare that cures a patient that has become ill. It is about curing the patient by treating them after they became ill or suffered from trauma.

Care

Oxford languages describe care as "The provision of what is necessary for the health, welfare, maintenance, and protection of someone or something.

The World Federation of Societies of Intensive and Critical Care Medicine (WFCCN) describes a critical care nurse as "a person who holds a recordable or registered nursing qualification in

their own country and contributes to the field of critical care nursing. "Nurses who deliver care try to establish a therapeutic relationship with patients and their relatives and to empower the individuals' physical, psychological, sociological, and spiritual capabilities by the preventive, curative, and rehabilitative intervention (Ristagno & Weil, 2009)

When a patient enters the hospital, they need to be cared for. In the first place, they want the be cured and treated. In the second-placed, they want to be cared for while they are cured and treated. How a patient senses care can be different, patients can have a different experience with different nurse or doctor interactions. However, it could also be benefitted by a 'caring' environment.

Nursing care can be defined as helping a patient with their 14 daily living activities (Henderson, 1966). If a patient is in the ICU, some of these activities are not possible others are performed by nurses while a patient is unconscious. At that moment, a nurse becomes the consciousness of a patient's unconsciousness.
Nurses in the ICU have an extensive skill-set; they can work with various systems while using their medical skills to care for patients. Next to these experts, their supportive skills are of great value to patients. Showing compassion, encouragement, attention, giving comfort, relieving patients from fear, and creating security is of great importance for their wellbeing (Hofhuis et al., 2008). Nursing interventions can be described as comfort measures. Kolcaba (2003) describes three comfort measures: technical, coaching, and comfort food for the soul (K. Kolcaba, 2003).

Technical interventions - are designed to maintain homeostasis and manage pain.

Coaching interventions - are designed to relieve anxiety, provide reassurance and information, instill hope, listen, and help plan realistically for recovery, integration, or death in a culturally sensitive way.

Comfort food for the soul - are interventions that are not expected, are not technical, and are perhaps 'old-fashioned.' These interventions go further than usual comforting and are beyond the expectations of a patient. This entails for example, holding a patients hand, watch television with a patient or have a conversation with a patient to comfort.

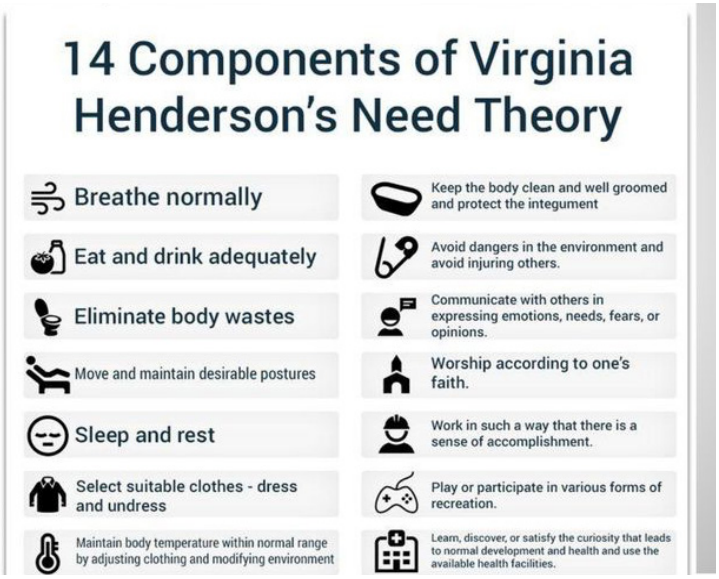


Figure 15 : Overview of the 14 components of Henderson's need theory (Ashworth, 1987)

Take aways

Healthcare is performed under Prevention, Cure and Care. They go hand in hand and often overlap to enhance or maintain the well-being of patients. It should be understood that by focusing more on prevention less curative healthcare could be the result.

2.8 Artificial intelligence

Definition of Artificial intelligence

Artificial intelligence is described by different sources and specified in different ways. Alan Turing suggested that a computer had artificial intelligence if it could successfully mimic a human and thereby fool another human (Hanson & Marshall, 2001). The Encyclopedia Britannica gives a very romantic definition of artificial intelligence and refers to a system "endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from experience" (Gutierrez, 2020). He (2020) describe AI in a more modern and general way as a branch of applied computer science wherein computer algorithms are trained to perform tasks typically associated with human intelligence (He et al., 2020)

AI in Healthcare

AI for healthcare can be defined as the overarching term to describe machine learning algorithms and software to analyze, present and comprehend complex medical and healthcare data. AI can be used as a data-driven decision support system. Data is analyzed to provide physicians in the ICU with suggestions on treatment (Hanson & Marshall, 2001). Alternatively, AI can be used in combination with agents that work autonomously and control an environment, for example. (Bozzon,2021)

It is found that using AI at the ICU could have many benefits for all stakeholders involved in the ICU. Since AI excels at finding complex relationships in large datasets and AI can simultaneously analyze many variables to predict outcomes of interest (Lovejoy et al., 2019), It has the possibilities to be used in different ways with different purposes. It can be used in drug discovery, personalized diagnostics and therapeutics, molecular biology, bioinformatics, and medical imaging (Gutierrez, 2020; Lombardo et al., 2013; Sande et al., 2020). Furthermore, AI could also be used for patient monitoring. The study of Davoudi shows that pervasive monitoring of patients at the ICU is feasible and can benefit the patient (Davoudi et al, 2018).

Will AI replace nurses or physicians in the ICU?

AI has the potential to take over the tasks of physicians. It can make decisions based on unlimited amounts of data in a short time. Nevertheless, AI cannot replace the patient-physician relationship or nurse-patient relationship (Ahuja, 2019). AI will inevitably be introduced to take a role in the ICU. It results in physicians taking on the role of gatekeeper for the introduction of AI into the clinical world (Nguyen et al., 2020). The introduction will lead to physicians being freed up with more time to become more personal, creative, and investigative in their treating and caring (Hammond, 2019).

3. Company research

Chapter 3

3.1 Erasmus MC
3.2 Critical Alarms Lab

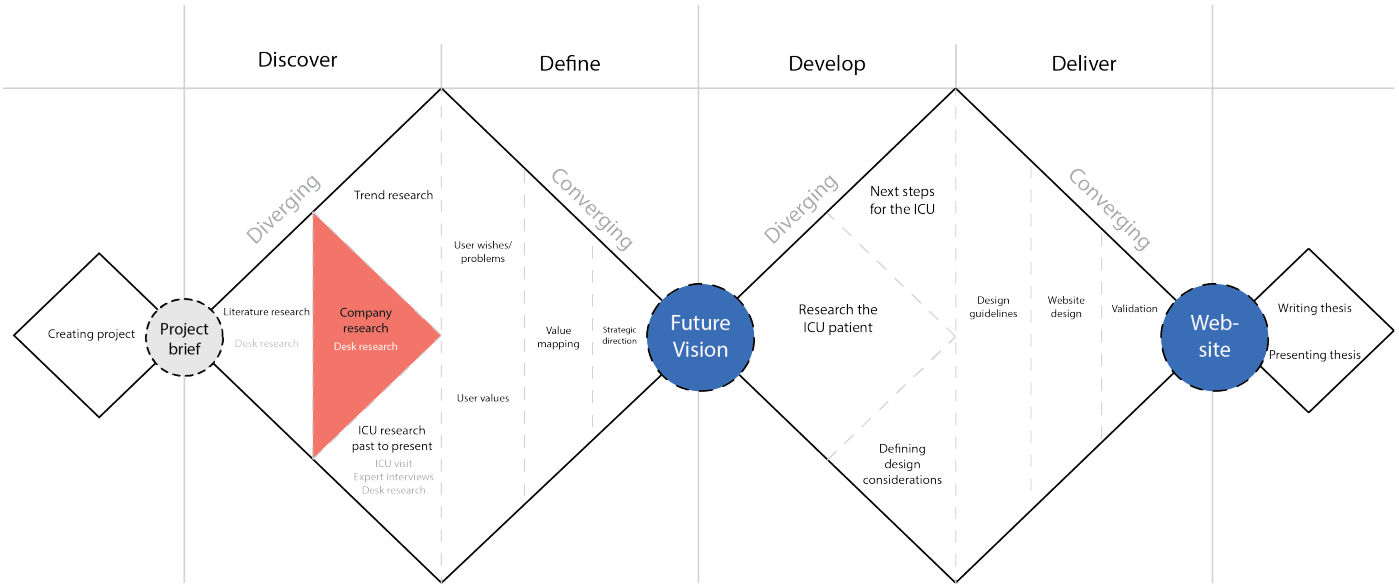


Figure 16 : Schematic overview of Design approach : Literature research.

In this chapter, company research is conducted. In the discovery phase, it is vital to discover the relevant stakeholders and companies with a specific interest and influence in establishing the future vision. For this project, the relevant companies are the Erasmus Medical Centre and the Critical Alarms Lab. In this chapter, these companies are described, and they are taken a look into their vision and goals.

3.1 Getting to know the Erasmus MC

The Critical Alarms lab has a strong collaboration with the Erasmus MC, which is hosting this project. Therefore, this project will focus on the ICU of the Erasmus MC. The Medical Centre is located in Rotterdam, in the mid-west of The Netherlands.

The ICU of the Erasmus MC treats around 4000 patients a year. About half of them are patients who have had planned surgery. The other half consists of hospitalization due to: (neuro)trauma, neurological disorder, sepsis or pneumonia, or other acute conditions. The ICU is a level 3 IC and has 121 beds on three different floors in the hospital. Thirty-eight beds of the general Adult IC are situated on the fourth floor, 18 beds are situated on the 6th floor, and the remaining 16 beds can be realized on the 8th floor. The ICUs on the sixth floor are called the Intensive Cardiac Care Units (ICCU), and the beds on the 8th floor were built because of Covid-19. The ICU consists of single bedroom boxes that are visually open from the corridor. They can be closed off with sliding doors to reduce environmental noise for the patient. Inside the rooms, there is all the medical equipment present that is needed to treat and monitor the patient (Erasmus MC, 2021)

Goals of the Erasmus MC

The Erasmus MC has a five-year strategy that consists out of 3 central ambitions (jaarverslag Erasmus MC, 2020):

1. Positioning as a partner, in which we focus on the patient as a partner and on working on regional cooperation in healthcare.
2. Innovate distinctively, with a focus on the convergence initiative of Erasmus MC, together with TU Delft and Erasmus University Rotterdam.
3. Attention to employee and organization, whereby personal development, diversity, and vitality of the employees, and the effective organization of the internal organization are central.

The second ambition includes the topic of human-centered technology & AI, which is the reason for this research project. The Erasmus wants to innovate distinctively by introducing data and technology to benefit the health of patients. The Erasmus envisions becoming the first technical university medical center of The Netherlands by cooperating with the Technical University of Delft and the Erasmus University of Rotterdam.

Figure 17 : Outside view or Eramus MC Rotterdam (yearly report Erasmus MC 2020)

3.2 Getting to know the Critical alarms lab

This research project is performed at the Critical Alarms Lab (CAL) of the TU delft. The CAL is part of the delft design labs, it has provided multiple digital solutions towards critical care and enables researchers, students, academic hospitals, industry, and regulatory agencies to work together to find solutions for critical care in hospitals.

Critical Alarms Lab

‘Our aim is to improve the work conditions of ICU clinicians and the recovery process of patients. New standards for intensive care have to be set up which should be applicable for the Erasmus Medical Center as well as other Dutch and foreign hospitals.’

- Critical Alarms Lab

4. Trend research for the ICU of future

Chapter 4

4.1 Technology
4.2 Patients
4.3 Medicine
4.4 Intensive care unit

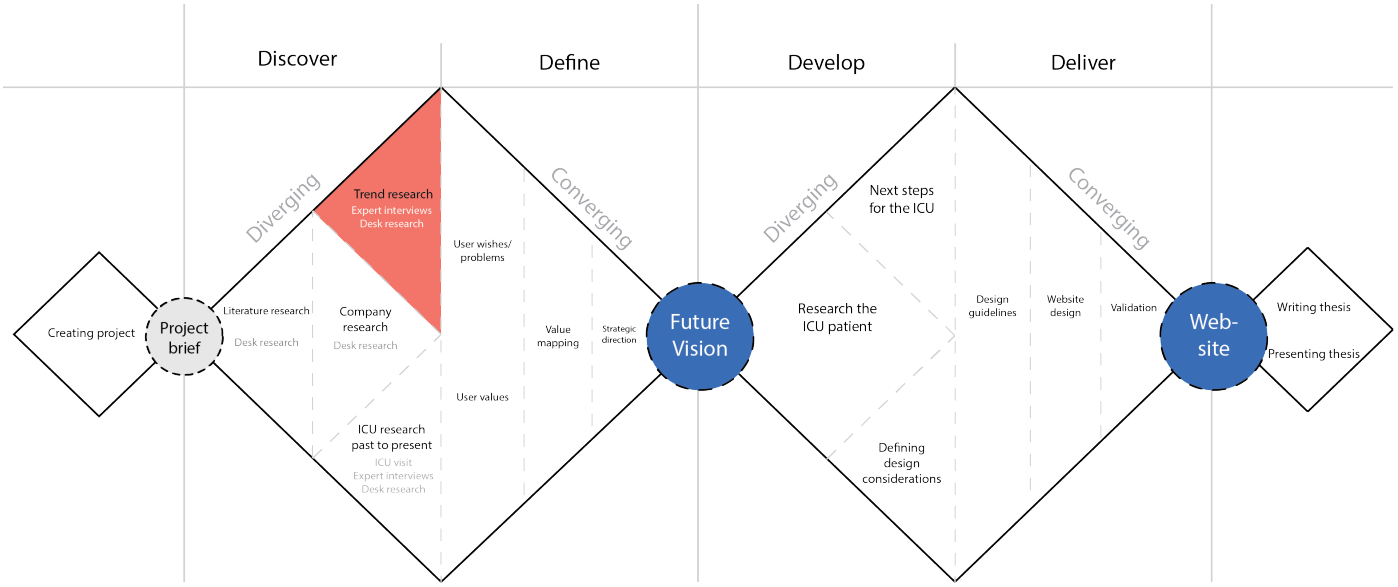


Figure 18 : Schematic overview of Design approach : Trend research

In this chapter, trend research is conducted. Trends are recurring patterns that indicate a change in the future. Trend research can help to see specific patterns in the future and help decide in which direction to move to. For this research, it is essential to discover relevant trends that can influence the care of the ICU patient on the one hand. On the other hand, it is crucial to discover relevant trends that can affect the solution space (e.g. technologies or medicines) to improve the ICU patient's care.

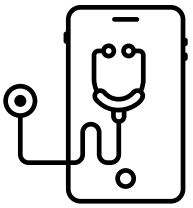
Knowing these trends at different sections (e.g., technology, patient etcetera) helps knowing how the needs, behavior and expectations of the ICU and their patients evolve. With the relevant information about technology trends, for example, the Erasmus MC has more information on how they can act and invest in improving the ICU of the future regarding the changing needs and expectations.

4.1 Technology trends

This subchapter describes four technology trends that are related to healthcare. When defining the future vision of the ICU and the ICU patient, it is crucial to understand what technology is in development and what is expected to be developed in a few years time. For this reason, four technology trends are identified and elaborated on. Artificial Intelligence is mentioned in this chapter as a trend because of trend research. It was concluded that Artificial Intelligence and Machine Learning (ML) would play a role in future healthcare solutions. These trends are used to define the future vision.

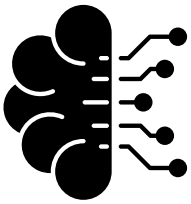
E-Health

People in society are using a lot of applications in their daily life. Many wearables could be used as data trackers to monitor a person's state. This does mean that (health) data can be collected everywhere and could be used by physicians, applications, and by people themselves to monitor their wellbeing. (Ahuja, 2019; Deloitte, 2017; Dunn et al., 2019; Gordon et al., 2017; Hammond, 2019)



Telemedicine

Telemedicine is a trend that could offer patients and healthcare professionals a different way of working. How patients and professionals interact with each other due to the use of technology can relocate and restructure the way of interaction. Telemedicine can lead to virtual medical consulting. This means consulting with your healthcare professional from a distance, in a virtual environment, with screens or by augmented reality (Deloitte, 2017; Dunn et al., 2019; Hammond, 2019; Sayess et al., 2015). This could also lead to decentralized care, care where you virtually meet with healthcare professionals that can diagnose a patient with data from home-diagnostics equipment (Deloitte, 2017). Another part of telemedicine can be the use of applications with chatbots. These chatbots can be used as substitute doctors to help people to answer questions about any healthcare-related topics, can help them understand the treatment, give information about their symptoms or other health topics (Hammond, 2019; He et al., 2020).



AI & ML
Bigdata

Artificial intelligence and machine learning are described in the literature as very promising. AI and ML can process and interpret (more) data faster, more accurately with fewer diagnoses (Sayess et al., 2015). It can support healthcare professionals to make a decision by systems that are called data-driven (decision making) systems (Halpern et al., 2017; Hanson & Marshall, 2001). It could help healthcare professionals in predicting which patient needs the most attention and help to prioritize the work of a healthcare professional by predictions on a patient's health based on patient data. (Dunn et al., 2019; Hammond, 2019; Mesko, 2017).

When AI is used to predict developments of a patient's health, this could also be used to predict when a patient can be discharged or when for example, a patient in a normal ward needs more intensive care (Benbenishty & Bülow, 2018; Gordon et al., 2017).

Robotic assistance

Robotic assistance could play a role in assisting healthcare professionals in their work. They could work next to each other to relieve healthcare professionals from easy, simple, and time-consuming tasks. This could mean that patients will be taken care of in a different way since nurses and doctors have time to perform different tasks and can focus on other aspects of their work. (Deloitte, 2017; Dunn et al., 2019; Gordon et al., 2017)

4.2 Patient trends

This subchapter describes four important patient trends. When defining the future vision of the ICU and the ICU patient, it is crucial to understand the (ICU) patient and the changes in needs, wishes, behavior and expectations of the patient in the future. For this reason, four critical trends regarding the (ICU) patient are identified and elaborated. These trends are used to define the future vision.

Humane care

Humane care, ensuring the delivery of care is humane, or ensuring patients are not being dehumanized are descriptions that are pointing in the same direction. The direction of treating a patient as a whole, also paying attention to their mental wellbeing while curing them. The focus of treating a patient should be developed wider to also include how care and treatment are delivered (Wilson et al., 2019). There could be many ways to focus on humane care because different patients have different understandings and different experiences when being treated. This suggests there should be solutions to personalize the patient experience to ensure humane care is delivered. (Gordon et al., 2017)

Privacy & Data

The storage of patient and hospital data has evolved over time. After the implementation and use of electronic health records, it is believed that the next step can be made. The next step is having real-time access to comprehensive data for patients, family, nurses and doctors. This includes data sharing and secured cloud storage. (Gordon et al., 2017; Guidet et al., 2017)

Awareness of wellbeing

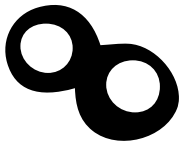
Patients and people in society are becoming aware of their physical and mental health. (Inayatullah & Van der Laan, 2016) They are becoming aware of what a balanced life has to offer and that a balanced life includes mental health. People want to take charge of their own health by monitoring it themselves. This could lead to self-medication unless the medical system supplies this alternative and supports people to take charge of their own (Gordon et al., 2017; Inayatullah & Van der Laan, 2016).

Change in population

It is found that the average age of the world population is increasing (Guidet et al., 2017; Hammond, 2019; Inayatullah & Van der Laan, 2016) At the same time, there are more degenerative diseases and emerging infectious diseases. Literature also stresses that people in the future will have more comorbidities (Guidet et al., 2017)

4.3 Medicine trends

This subchapter describes three medicine trends. Medicines are a crucial part of healthcare and influences the healthcare of patients directly. For this reason, it is interesting to look into some trends regarding medicines, so that knowledge can be gained about the role medicines can play in improving the ICU (patient) of the future.

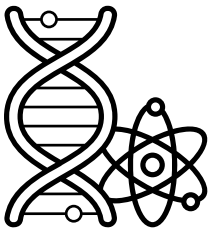


Stemcells

New technological advancements cause research into medicine to evolve. The use of stem cells to repair or regrow tissue and organs is argued to be one of the next steps in medicine developments (Hammond, 2019).

Nanoscale medicine

At the same time, technology on nanoscale is being developed what could result in drug delivery at submicroscopic levels. It is expected that in the future, nanorobots can be used to diagnose, deliver drugs, monitor, or actuate specific types of cells (Gordon et al., 2017; Hammond, 2019).



Personalized medicine

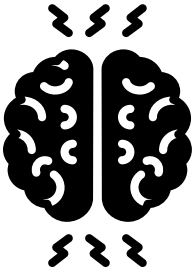
Another medicine trend is called personalized medicine, and it is described as medicine personalized for a patient or person based upon a person's DNA and health data. (Deloitte, 2017; Hammond, 2019)

4.4 Intensive care unit trends

This subchapter describes two trends regarding the Intensive Care Unit. It is crucial to understand the environment of the ICU patient, which is (for a significant part) the Intensive Care Unit itself. Changes in the future regarding the Intensive Care Unit can influence the care for the ICU patient, and therefore it is crucial to understand these trends.

Growing ICU

As described earlier, intensive care units are the most specialized units in the hospital. While trends point towards the decreasing amount of (normal) hospital beds, there will be a growing demand for ICU beds (J. L. Vincent & Creteur, 2017). Currently, there is a shortage of ICU nurses, causing difficulties for ICUs to grow (Hammond, 2019).



Post intensive care syndrome

The post-intensive care syndrome that patients after hospitalization struggle with are well described in the literature. The next step of handling PICS is suggested to be a solution before, during, and after staying in the ICU. A great example of a tool that can be used to help patients with PICS are VR goggles with an ICU experience. (Genderen, 2021)

5. Vision: The ICU of the Future

Chapter 5

5.1 Future scenario's
5.2 Value mapping
5.3 Value drivers
5.4 Future vision

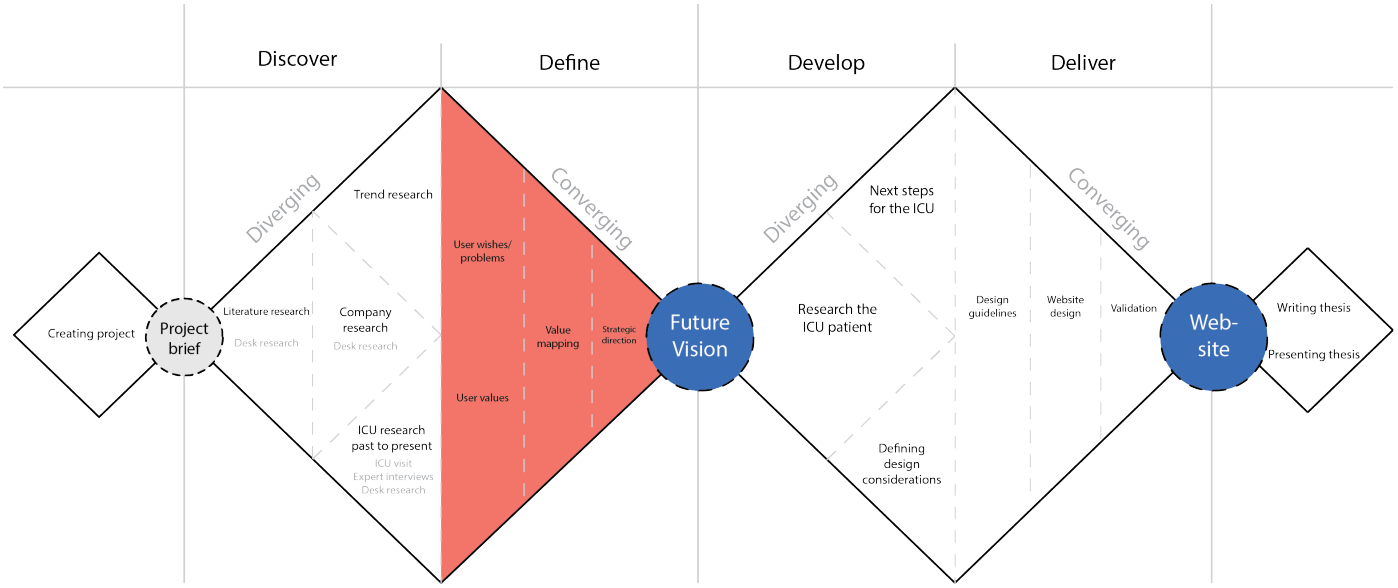


Figure 19 : Schematic overview of Design approach : Future visioning

In this chapter, the future vision for the ICU is established. This future vision is established by using and combining the knowledge gained from the literature research, company research and trend research in the discovery phase. The goal in this chapter is to combine the gathered information and to determine the future vision of the future ICU of the Erasmus MC.

To establish the future vision, future scenarios regarding the ICU are defined. These future scenarios help to identify what aspects are essential and available for the future ICU. Three relevant future scenarios are drawn and elaborated in subchapter 5.1. The next step is to use value mapping to establish the value drivers that are a vital part of the future vision. To identify the value drivers, different questions are asked and answered in subchapter 5.3. These questions help to determine the value drivers of the future vision. The value drivers form the basis for the future vision, and these value drivers are listed and explained in subchapter 5.4. Finally, in subchapter 5.5, the future vision for the ICU of the future of the Erasmus MC is defined. This future vision will help as guidance to work in the right direction towards the ICU of the future.

5.1 Future scenario's

In this subchapter, three future scenarios are explored. Setting up scenarios for the future help to identify the aspects of a future ICU and what possibilities are there for the future ICU. These scenarios give a specific scope when setting up the future vision, so it is clear what is possible and what scenarios regarding the future ICU are likely.

Healthcare as a service

Future hospitals will have predictive models that help physicians in their work. Anonymous data sharing between hospitals has ensured algorithms build and trained to be reliable. This will mean that predictive models can be used in hospitals to manage patients and work in a more effective and less time-consuming way. This leads to quicker and better decisions making and more time for healthcare professionals to focus on the caring part of healthcare.
Furthermore, these predictive models can be used to help customers/people in their daily life to track their wellbeing. Wellbeing can be tracked by applications that can be facilitated centrally or become commercialized. These systems and services could work with chatbots and physicians that can help people to prevent getting ill.

Smart systems for patient experience

Hospitals of the future will adopt physical and virtual devices to support, entertain and manage the wellbeing and experience of the patient. Autonomous working systems will adapt the surroundings of the patient to their wishes. Wishes are based upon sensory data from a patient when being unconscious or conscious compared to and based on personal data of their normal surroundings outside of the hospital. This will help patients in experiencing the hospital environment as pleasant and positive. Healthcare professionals have an important task in facilitating and working together with systems that benefit a patient's experience. Healthcare professionals in the future are used to working with autonomous and robotic systems to support them in their work so their human attention can focus on the patient.

Autonomous healthcare institutes

In the future, patients, people with trauma or illness are treated in an autonomous hospital 'guarded' by physicians. Patients can be brought in by autonomous vehicles (ambulances) and can be diagnosed from the moment they are ill or encounter trauma. Wearable and environmental monitoring devices are able to prevent you from becoming ill, but when a moment of acute illness or trauma occurs, then these wearables substitute for monitoring devices. Healthcare algorithms can analyze patient data to start specifying treatment strategies and configure personalized treatment.

Take aways

Creating future scenarios in which different trends and systems form a description of a future healthcare scenario gives the reader an idea of what could become a reality in the future. A scenario provides insight into what we are possibly working towards but mainly creates an understanding of what a trend, technology or service could mean for a bigger system.

5.2 Value mapping

Value drivers form the basis of the future vision because they give a clear understanding of the critical objectives for the future vision. In this sub-chapter, different questions are asked to determine these value drivers.

"Value drivers capture the key compelling benefits of value wishes: wherein the specific value fulfills an unmet need or solves a dilemma of a user target group in the future" (Simonse, 2017).

The methodology of Simonse (2017) gives an interesting quote that can be seen as the explanation of value drivers. From the quote three questions can be derived that need to be answered. The anwers on these questions give the value drivers of the future vision. The answer on these questions are based on literature research and information gathererd during a visit to the Erasmus MC.

What values could the Erasmus MC (ICU) bring to the future patient to fulfill their unmet needs?

Who are the future patients that will enter the ICU of the EMC? Are these patients' different' than the current patients?

How should the Erasmus MC of the future position itself concerning the development of critical care?

What values could the Erasmus MC (ICU) bring to the future patient to fulfill their unmet needs?

Humane healthcare that is evenly focused on mental as physical wellbeing.

Treat patients with the highest level of care there is.

Personalized environment for patients

Who are the future patients that will enter the ICU of the EMC? Are these patients' different' than the current patients?

The patients that enter the ICU, although they have been monitored in their daily life, need specialized care.

Patients that suffer unpredictable trauma.

Patients that enter the hospital because of surgery or due to other planned interventions

Patients will remain the same, namely critically ill, perhaps the patient population will change

How should the Erasmus MC of the future position itself concerning the development of critical care?

Be an innovator - Bringing data, technology, and medical science together to innovate and create better care.

Be a gatekeeper- Ensuring that the delivery of care will be supported and substituted by data-driven systems and data-driven devices while not losing the human side of a patient while caring and treating.

5.3 Value drivers

Value drivers form the basis towards the future vision. Solutions and design interventions to reach the future vision should be in line with the value drivers. Value drivers are generated by answering the questions from subsection 5.2. Using the value drivers as guidance gives guidance in idea generation and product development.

Humane care

The human side of patients, while they are being treated in the ICU, cannot be underestimated anymore. All patients should be cared for so they experience their stay in the ICU as positive. This means that while caring and treating patients, more attention should go to humanizing factors, and dehumanizing should be prevented, as described in figure 4 by Wilson (2019). The focus should be layed upon humanizing behaviours.

Physical and mental wellbeing

Besides to treating patients in a humane way, the balance between physical and mental wellbeing should be even important in the future. Nurses and doctors should be able to ensure that the whole wellbeing of the patient is taken care of.

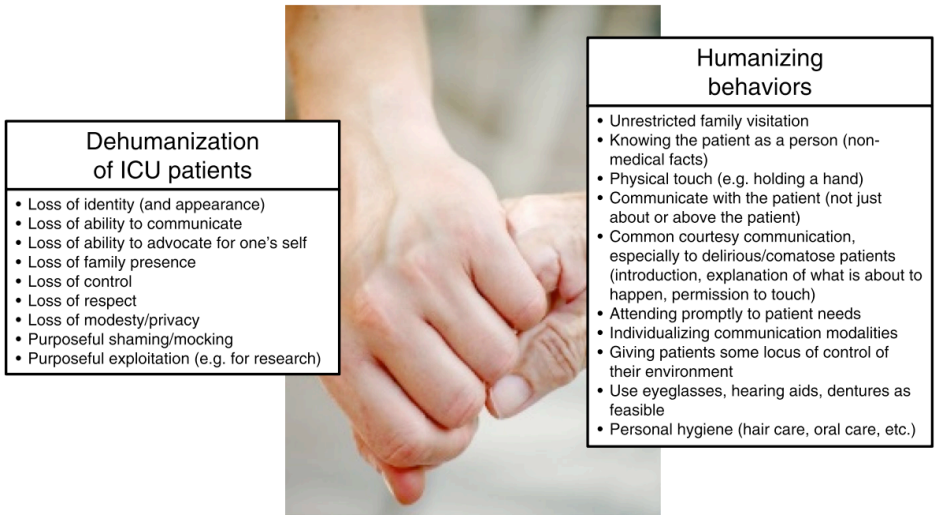


Figure 20: Dehumanizing and humanizing of intensive care unit patients (Wilson et al., 2019)

High quality of care

The Erasmus MC delivers the highest level of care. They treat the most severely ill patients in one of the most advanced Intensive Care Units in The Netherlands.

Innovative organization – a frontrunner in technology

The Erasmus MC wants to innovate distinctively by introducing data and technology to benefit the health of 'patients.' They envision becoming the first technical academic medical centre of The Netherlands by cooperating with the Technical University of Delft and the Erasmus University of Rotterdam.

Digital healthcare with Smart systems

Systems and devices inside and outside the hospital are becoming smarter and more connected. New systems that will be developed for patients and healthcare professionals need to be able to connect and communicate. Devices in the hospital and the environment of a patient can generate data to configure the patient's surroundings. The data can influence predictions or a patient's wellbeing and could also be of use to monitor a patient.

Predictive systems for preventive healthcare

While delivering the highest level of care, predictive models should be developed to generate more insights into a patient's wellbeing, both physically as mentally. Predictive models could have multiple purposes such as:
1. Predictive care for intake/firing of patients
- Predictions for doctors to warn them of patients in normal wards that need more critical care in the (near) future.
- Predictions for doctors to inform them about a patient that can leave the ICU to the normal ward or even home earlier.

2. Prediction/prevention for normal day life
- Smart devices could help the Erasmus MC to gather data to build algorithms that alarm, inform, suggest people on their wellbeing, both physical and mental. This could lead to more exercise, different nutrition, seeing a doctor, or taking medicines.

- Data from normal day life could be used to set-up/predict preferences during a stay in the ICU/hospital. Sleep cycles, normal food intake, amount of sunlight or other habits could be introduced or facilitated in the hospital environment to positively influence the patient experience.

3. Predictive care in the ICU
- Suggestions for nurses and intensivist/doctors to divide their attention to the patients that need the most care.

5.4 Future vision

The future vision is described with a vision statement. The vision statement is based on the value drivers, trend research and researching the context of the ICU. The future vision is made for the ICU of the Erasmus MC. It can help them steer innovation for the ICU in the right direction.

Vision:
In the future intensive care unit, a balance needs to be found between using technological devices and the delivery of humane care. While smart systems and predictive models can help patients and healthcare professionals, they should not take over and substitute the delivery of care if this results in dehumanizing care. If the use of technology does not interfere with the delivery of humane care or if the use, benefits the delivery of humane care, then technology should be used and implemented.

The use and introduction of new technology and smart systems should be done because there is a need or a problem to solve. It should make life easier, better and result in a higher quality of humane care.

‘The Erasmus MC as an innovator in predictive and preventative healthcare, while providing ICU patients with high quality and personalized humane care that is supported by smart systems.’

Humane care

Prevention by prediction

Innovator

By

Smart systems

6. The ICU patient

Chapter 6

6.1 Needs - capacity - capability
6.2 Patient needs
6.3 Patient mental capacity
6.4 Patient physical capacity
6.5 Designing for the ICU patient

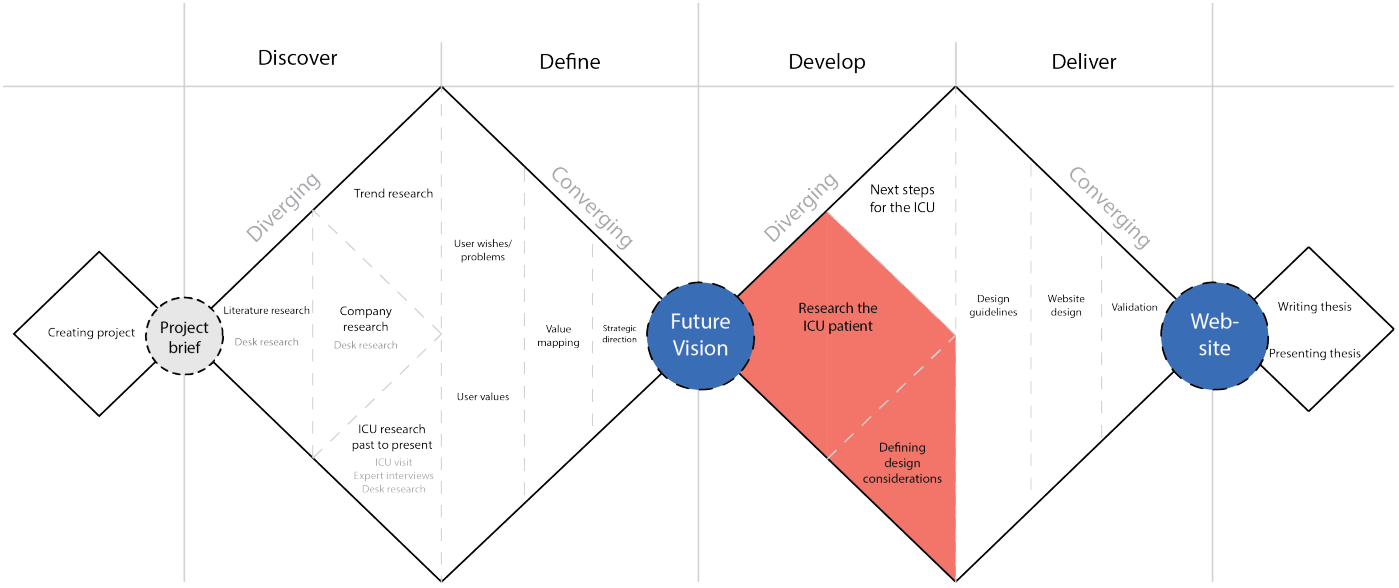


Figure 21 : Schematic overview of Design approach : The ICU patient

In this chapter, there is taken a deeper look into the ICU patient. This analysis is the first part of the development phase, where more research is conducted into the relevant aspects of the future vision. One of these aspects is the ICU patient, which is the centre of the future ICU, and therefore the ICU patient is analysed in more detail. This chapter aims to understand the ICU patient better, so design consideration when designing for the ICU patient can be determined.

To understand the ICU patient, it is essential to look into the needs and wishes of the patient and their capacity and capabilities. First of all, in subchapter 6.1, the distinction between needs, mental capacity and physical capabilities is explained. In subchapter 6.2, the needs of the ICU patient are identified and described, using literature research and experiences from the ICU visit. Subsequently, in subchapter 6.3, the mental capacity of the ICU patient is explained, which is the functional ability of a person to decide on their care. The mental capacity of the ICU patient is determined by using literature research and experiences from the ICU visit. Finally, in subchapter 6.4, the physical capabilities of an ICU patient are discussed. The analysis of the ICU patient's needs, mental capacity, and physical capabilities led to some interesting take aways that help to understand the 'complete ICU patient'. The gained knowledge about the ICU patient help to determine the design considerations when designing for the ICU patient, which are listed and explained in subchapter 6.5.

6.1 Needs, mental capacity, physical capability

To ensure the ICU patient is treated, both the mental and physical health should be cared for. Currently, the physical health of patients is taken care of. But, the mental health of the patient has less priority. As mentioned earlier, dehumanization plays a role, which influences the mental wellbeing of patients. Although, doctors and nurses don't have the intention of dehumanizing the patient, it still happens. To ensure patients in the future won't feel de-humanized, human-centred technologies could play role in humanizing the care in the ICU.

To ensure the ICU patient receives humane care the following questions need to be answered to understand the patient in the ICU.

- What are the needs of the ICU patients to ensure they receive humane care that focusses on both their mental and physical wellbeing?
- What are patients in the ICU physically capable of?
- What is the mental capacity of patients in the ICU?

By answering these questions, a better understanding is created on what the needs, mental capacity and physical abilities of ICU patients are. This is helpful when trying to generate idea's or trying to fulfil needs for ICU patients

6.2 Patient needs

Patients in the ICU need to be treated and cared for to stay a life and recover. At the same time, being in the ICU is an experience. How patients perceive their treatment, care and overal stay can result in a positive or negative experience. To ensure patients perceive their stay positive at the ICU their needs need to be fulfilled. There are different ways to look at the needs of patients in the ICU.

The context wherein needs for comfort occur is described by Kolcaba and Fisher (1996) as:

Physical – about bodily sensations, homeostatic mechanisms, immune function, and more.

Psychospiritual – about internal awareness of self, including esteem, identity, sexuality, meaning in one's life, and understood relationship to a higher-order or being.

Environmental – about the external background of human experience (temperature, light, sound, odor, color, furniture, landscape)

Sociocultural – about interpersonal, family, and societal relationships (finances, teaching, health care personnel, etc.) Also, to family traditions, rituals, and religious practices. (K. Y. Kolcaba & Fisher, 1996)

Needs can be categorised according to Maslow's hierarchy, consisting of physiological needs, safety needs, love and belonging needs, esteem needs, self actualisation needs. This hierarchy is adapted for the ICU and is showed in figure 6. (Jackson et al., 2014)

Kolcaba and Fisher describe the context of needs and Maslow descibes the different levels of needs. Two ways of categorizing patient needs can be used. The way how needs are looked at does not matter, the importance is understanding what kind of needs there are in what context or on what level.

Figure 22 : Maslow's Hierarchy of needs adapted for the ICU (Jackson et al., 2014)

6.3 Patient mental capacity

The mental capacity of a patient can be described as the functional ability of a person to make decisions about their care, it is an attribute that reflects the central ethical principle of personal autonomy (Stewart et al., 2020). Someone lacks mental capacity if they can't understand information about a particular decision, remember that information long enough to make the decision, weigh up the information to make the decision, or communicate their decision (Advance Decisions and Mental Health, 2016)

This means that if someone does not have the ability to make decisions for themselves they need to be helped or the decision making process should be taken elsewhere. For example, when a patient is unconscious in the ICU they are not able to make decisions. They are temporary unconscious so decisions could be made when they are conscious or in advance. In some cases this is not possible, which results in hospital staff or loved ones to take decisions for patients.

In the ICU of the Erasmus, nurses determine a patient's level of sedation according to the Richmond agitation sedation scale (RASS) presented in figure 7. According to nurses in the ICU they fill in the RASS score for a patient ones every shift. (Wagener, 2021). The scale is used to understand the level of sedation of a patient and to understand how to handle and interact with a patient. The way nurses interact with patients is different per nurse. There are no protocols in place how to interact with patients to benefit a patients mental wellbeing. What is in place are the norms and values of the nursing staff, that causes a way of interacting with patients and colleagues (Wagener, 2021).

TABLE 1. RICHMOND AGITATION–SEDATION SCALE

Score	Term	Description
+4	Combative	Overtly combative or violent; immediate danger to staff
+3	Very agitation	Pulls on or removes tube(s) or catheter(s) or has aggressive behavior toward staff
+2	Agitated	Frequent nonpurposeful movement or patient–ventilator dyssynchrony
+1	Restless	Anxious or apprehensive but movements not aggressive or vigorous
0	Alert and calm	
−1	Drowsy	Not fully alert, but has sustained (more than 10 seconds) awakening, with eye contact, to voice
−2	Light sedation	Briefly (less than 10 seconds) awakens with eye contact to voice
−3	Moderate sedation	Any movement (but no eye contact) to voice
−4	Deep sedation	No response to voice, but any movement to physical stimulation
−5	Unarousable	No response to voice or physical stimulation

Procedure

1. Observe patient. Is patient alert and calm (score 0)?
   Does patient have behavior that is consistent with restlessness or agitation (score +1 to +4 using the criteria listed above, under DESCRIPTION)?
2. If patient is not alert, in a loud speaking voice state patient's name and direct patient to open eyes and look at speaker. Repeat once if necessary. Can prompt patient to continue looking at speaker.
   Patient has eye opening and eye contact, which is sustained for more than 10 seconds (score −1).
   Patient has eye opening and eye contact, but this is not sustained for 10 seconds (score −2).
   Patient has any movement in response to voice, excluding eye contact (score −3).
3. If patient does not respond to voice, physically stimulate patient by shaking shoulder and then rubbing sternum if there is no response to shaking shoulder.
   Patient has any movement to physical stimulation (score −4).
   Patient has no response to voice or physical stimulation (score −5).

Figure 23: Richmond agitation sedation scale (RASS) (Sessler et al., 2002)

6.4 Patient physical capabiliteis

Next to the patient's needs and mental capacity, it is crucial also to consider the patient's physical capabilities. Physical capabilities are the degree to which a person can manage the physical tasks of daily living.

The World Health Organization created an International Classification of Functioning framework which describes the different elements of a person's physical functioning (Parry et al., 2017). It distinct three constructs and describes that an individual's health condition and contextual factors are affected by these , which are:

Body functioning and structure - Physiological and anatomical structure of the body systems

Activities - Execution of a specific task within a standardised environment

Participation - Involvement in everyday life situations.

Based on the three constructs the physical capabilities of patient can be evaluated.

The physical functioning at the level of *individual organs or body systems*. The focus lies on, neurological, cardiac, respiratory and musculoskeletal systems.

The physical functioning at the level of *performance and limitations in specific activities*, such as sitting, standing, walking, talking, hearing.

The physical functioning at the level of *participation in the ability to perform daily living activities*.

Take aways

Patient needs
When investigating a patients needs, it should be understood that there are different levels of needs a patient can have. Also, needs can be placed in different contexts. Understanding the needs of a ICU patient is important to be able to treat and care a patient. When designing for patients the context and level of needs should be determined to deliver a valuable solution for a patient.

Patient mental capacity
Patients in the ICU have limited mental capacity. By scoring a patient according to the Richmond Agitation Sedation Scale, nurses can understand how to interact with patients. How nurses interact with patients is based up their norms and values but is not strictly determined with protocols. This means that it is depended on the interpretation of nurses, which could vary per individual. When thinking of solutions or products for ICU patients, the limited mental capacity should be considered.

Patient physical capabilites
The physical capabilies of patient are highly dependent of their illnes. They are limited to move in their rooms/bed due to tubes and IV-lines and other treating equipment. When designing for patients in the ICU the capabilites should be determined since they are lim-

6.5 Designing for the ICU patient

Designing for what patient?
Research into the ICU patient shows that the patients are very limited in what they can do. They have limited mental capacity and physical capabilities and their needs are not always sensible due to their limited mental capacities and physical capabilities. When designing products for patients to interact with it, then these limitations should be taken into account. Or a way should be found to go around these limitations to design a product or service that benefits the patient without directly interacting with it.

How is the mental wellbeing of patients taken care of in the ICU?
The research part shows that there is a priority to treat the physical side of a patient's wellbeing and less attention is paid towards the mental side of a patient's wellbeing. It is found that nurses do pay attention towards the mental side of patients but there are no written rules or protocols on how to treat the mental side of patients. This can give the patients the feeling of being treated in a de-humanizing way.

Are patients able to interact while they are in the ICU?
Patients are helped by nurses in the ICU to make the best of their time there but at the same time they are highly depended on them. Nurses describe that patients try to interact by speech but often can't speak properly. Nurses need to be creative to understand what a patient wants or likes. Having the family from a patient involved in explaining what a patient wants and likes helps the nurses to care for the patient. (Wagener, 2021). If for example, nurses are aware of a patients love for a particular kind of music then they can turn that music on when that is possible.

Does designing for ICU patients mean that patients need to use the design?
Due to the limitations of patients, desiging for their wellbeing could also mean that others need to control or use a product. It could also mean that the environment needs to be redesigned or adapted to benefit the patient. Thus only focussing on what a patient can do, wants and needs is not enough to design for the whole patient.

What to consider when design for the ICU patient?

These considerations are based upon the research in the total patient (chapter 6), based upon research into artificial intelligence (2.8) and based upon the vision for the future ICU (chapter 5).

General
When designing for a ICU patient designers should consinder:

Consider designing for a patient for both: before, during and after a patients stay.

Consider to design solutions for a patients family and loved ones

Do not design solutions that cause for a higher workload for hospital staff

Consider that implementing and installing a device or hardware for a device in a ICU room, can lead to negative influences on the ICU environment. (installing a camera can help monitoring a patient but can also give the feeling that a patient has no privacy and is being watched)

Patients mental capacity

The capacity of patients in the ICU is limited. When designing for patients in the ICU the capacity of patients should be understood. Designers should consider:

Consider that patients with limited or no capacity can't consciously use/control devices.

Consider wether the design is of benefit to different capacities of patients

Design for solutions that can be used for patients with limited capacity

Consider to design a solution so patients without capacity can have benefit from it. Think of using preferences from patient before they lost capacity.

Patient needs

The wellbeing and environment of a patient influence a patients needs. Designing for patients in the ICU means understanding their environment and their wellbeing thus finding their needs. When designing for a ICU patient designers should consider:

Investigate which category of patient needs is not designed for to find design opportunities.

Consider designing for a patients mental needs to benefit a patients wellbeing.

Do not design solutions that lead to de-humanizing the ICU patient.

Consider in what context the product delivers comfort to a patient

Examine for who, in or outside the hospital, is designed for to benefit the patient wellbeing.

Patients physical capabilites

Patients in the ICU have limited capabilities and are restricted in their movements. To design for patients in the ICU designers should consider:

Consider different capabilities of patients when designing to fulfil a need of a ICU patient

Develop applications that can be used in multiple ways. Patients in the ICU have limited capabilities thus an application that can be adapted to a patients capabilities is desired. Which implicates less different applications are needed to serve patients with different capabilities.

Artificial intelligence - Data

Artificial intelligence is associated with being the solution for problems. It is widely used by everyone in their daily life and could also be used in the ICU. When thinking of using AI in the ICU designers should consider:

Consider the use of AI solutions in the near future to benefit the ICU that are easy to comprehend and understand.

Develop and use AI solutions if it is of addition to the work in the ICU. Don't only replace or substitute current solutions or devices because it is possible.

Create a data infrastructure to share patient data for predictions on diagnosis and prognosis

Consider using data driven decision making systems to manage patient intake and discharge

Develop a platform to review ICU patients status and need for attention for management of personnel

Find a balance in using technology to replace and/or assist hospital staff in their work. Some work or tasks can't be done better by devices but others

7. From now to the future ICU

Chapter 7

7.1 Who is influencing innovation in the ICU
7.2 What can different levels of influence do for humanisation in the ICU?
7.3 What can different levels of influence do to introduce AI in the ICU?

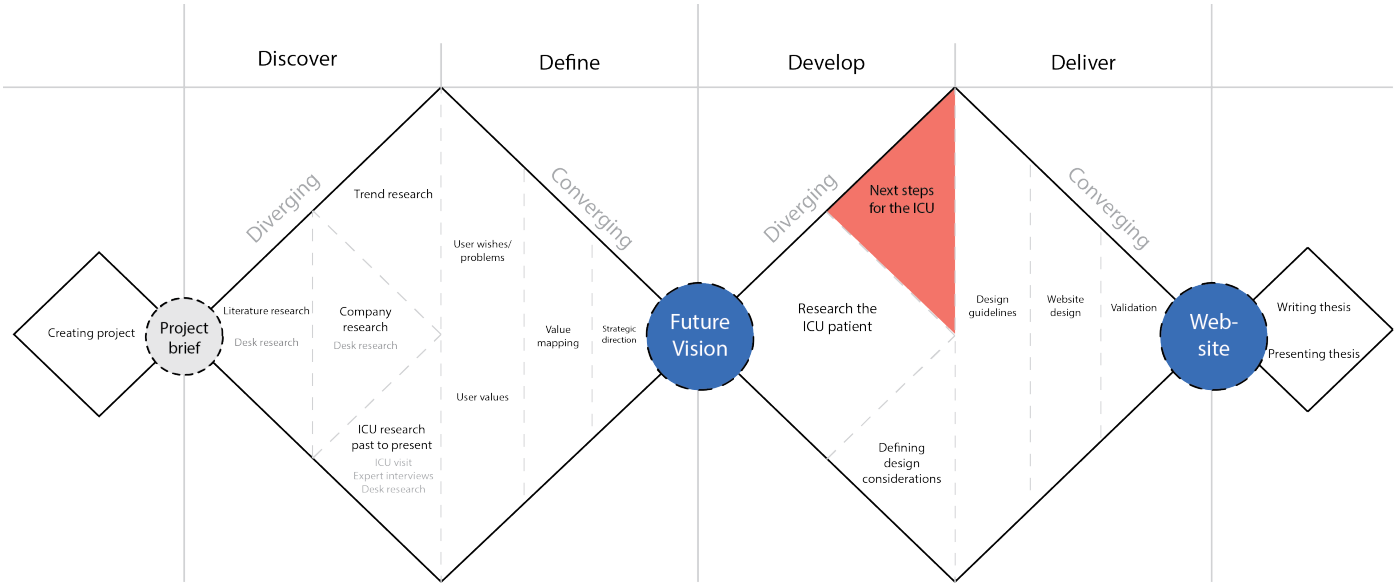


Figure 24 : Schematic overview of Design approach : Next stepts for the ICU

In this chapter, the following steps to the ICU of the future are analyzed and described. It is essential to understand the influences in the environment of the future ICU. This chapter aims to have a more detailed look at the different stakeholders in the environment and their different levels of influence. If we understand how stakeholders can influence the ICU of the future, we can use this when designing for the ICU patient and the future ICU.

The first step is to identify the stakeholders that can influence the ICU of the future. These stakeholders are explained in subchapter 7.1, and their influence is described. In the following subchapters, there is taken a look into how these stakeholders can take the next step into the ICU of the future. The future vision statement determines that humane care at the ICU is essential and that Artificial Intelligence can improve the ICU. Because humane care and Artificial Intelligence are crucial aspects of the vision statement, the stakeholders' influences on these aspects are researched. In subchapter 7.2, the question is asked how the six stakeholders can take the next step to increase the humanization at the ICU. In subchapter 7.3, the question is asked how the six stakeholders can take the next step in introducing Artificial Intelligence at the ICU.

The gained knowledge in this chapter helps determine design considerations and guidelines when designing for the ICU and the ICU patient.

7.1 ICU stakeholders of influence

High quality of healthcare in the intensive care unit is influenced by different factors. On different levels stakeholders in healthcare have direct and indirect influence on the wellbeing of patients and on the practice in the ICU. Direct influence means that the stakeholders have a direct link to the healthcare practice and thus the care and treatment of patients. Indirect influence means that the stakeholders are not directly able to influence the practice of care and treatment of patients.

Six different stakeholders are described which give insight in the different levels of influence. The 6 levels of influence are used to show the current situation of de-humanizing and humanizing the ICU patient and the use of data and (Artificial) Intelligent solutions.

Patient

Patients are the center of attention in the ICU. Everything is done to make their lives better or even save their lives. They are the ones who have (unfulfilled) needs but also restrictions and limitations. By working with developers, research institutes or the hospital they are able to share their stories and deliver valuable insides so future patients can be helped. When designing for the patients in the ICU they should always be taken into the loop of development.

Family and loved one of a patient

The family and loved ones of patients are the individuals that are the closest to the patient. They are there the whole journey of a patient's illness or trauma. They are able to directly influence the wellbeing of their loved ones, either mentally or perhaps physically. They are there when patients leave the hospital and are the ones to care for their 'ex-patient's'. They have valuable information and could have valuable inspiration for developing or designing products for the ICU and ICU patient.

ICU staff

Clinicians working in the ICU are intensivists, Doctor-assistants, IC nurses, and IC nurses in training. They work closely with allied health professionals such as physiotherapists and dieticians, department assistants and logistics employees, and social workers and spiritual counselors (Marshall et al., 2017). They are continuously busy with different patients and trying to make them better. They can directly influence the patient's wellbeing and are on top of everything that is going on in the ICU. Therefore, they can deliver valuable information on how devices could be used in the ICU.

Healthcare community

The healthcare community consists of designers for healthcare, equipment suppliers, researchers for healthcare or healthcare associations such as the NVIC (Nederlandse Vereniging Voor Intensive care). This level is able to indirectly influence the care for patients by supplying knowledges, products, set standards, do research and much more.

Healthcare institutes

Healthcare institutes are responsible for the whole hospital for all the different departments. They are able to set up research projects and set up long- and short-term strategies for the development of healthcare. They can indirectly influence the care of patients by developing protocols, set standards or develop and acquire new products to benefit patients and staff.

National healthcare organization

The National healthcare organization consists of the ministry of health, the Dutch healthcare authority (NZA), the zorginstituut (ZN) and also the European medicines agency. They are able to influence the care of patients indirectly by stimulating development, create national campaigns, setting up directions for development, and determine were funding for development and research is going towards.

7.2 What can different levels of influence do for humanization in the ICU?

Patient

Patients have different kind of needs. From physiological needs to self actualisation needs. In the ICU the physiological needs are currently the priority. Which means a lot of other needs are not fulfilled which is experienced as de-humanizing.

Family and loved ones of a patient

Family and loved ones of a patient feel with a patient. They want to help the patient and influence their recovery. They want to help and create a good environment for their loved ones. They will do anything to help the patient.

ICU staff

The main priority in the ICU is to keep a patient a live. The focus is on their physical wellbeing and when there is time for taking care of some mental aspects than nurses and clinicians will do that.

Patients are not treated in a humanising way all the time. They are patients, but need to be treated as humans. Hospital staff is not fully aware of the needs of patients next to their physiological needs. More attention should be payed toward humanising needs and treating the whole patient.

Healthcare institute - Erasmus MC

Healthcare institutes such as the Erasmus MC are focussing on the delivery of high quality care. They are becoming more aware of the importance to treat the mental side of a patient. Both while patients are in the hospital as when they are recovering at home.

They are currently not actively influencing the humanisation of patients. But are willing to create more awareness and set up research to different categories of patients needs to be able to treat the total-patient.

Healthcare community

Healthcare suppliers who design and deliver products for the hospital and the ICU in particular have an influence on the humane treatment of patients. They can develop products specifically for the mental wellbeing of patients. Or they can add features to other equipment or products to ensure the patient feels treated in a humane way and no de-humanising is guaranteed.

National healthcare organisations

Policy makers play a role on the standards and quality of care in hospitals in The Netherlands. There are different associations that work together to form new guidelines for healthcare institutes on the organisation on- and the collaboration surrounding the care in the ICU's. Currently, there are no clear guidelines or standards applying to the mental wellbeing of patients.

What is the next step for patients concerning humanization in the ICU?
The way patients expect to be treated is in a humane way. The treatment and care for their mental and physical wellbeing needs to become more balanced.

Find the needs of patients and unfulfilled humanising needs of patients for healthcare staff and applications too fulfil.

What is the next step for family and loved ones concerning humanization in the ICU?
Create a platform for interaction with patients and to receive information of the patient. Loved ones should be kept in the loop and be given information whenever they need it.

What is the next step for ICU staff concerning humanization in the ICU?
The hospitals staff has become more aware of the effects of treating patients in a more humane way. They have adapted their way of working to fulfil the patients needs for different categories laying the emphasis on humanising and the mental health of patients. This can help and influence the comfort of the total patient.

Next to the awareness of hospital staff, they see opportunities for product and service development to help humanising a patient.

Create awareness for healthcare staff on the effects of de-humanisation and educate healthcare staff how to humanise patients in their daily work.

What is the next step for the Erasmus MC concerning humanization in the ICU?
Healthcare institutes create awareness for treating the total-patient. They focus on showing the benefits of also focussing on the treatment of the mental side of the patient while they are critically ill.

Next to the creation of awareness, the hospitals enable hospital staff to reserve time for treating the mental side of the patient.

Create awareness on humanising patients for healthcare staff and make room for treating the mental side of patients.

What is the next step for the healthcare community concerning humanization in the ICU?
Healthcare suppliers should design solutions for the total patient taking into account the patients needs, their mental capacities and physical capabilities.

Create campaigns for awareness of the mental health of patients and people in normal day life. Educate people to look after their total-wellbeing, both physical and mental health.

Create products that take the total patient into account, looking at all the levels of patient needs. Also making solutions and products available and useable for patients with different mental capacities and physical capabilities.

What is the next step for National healthcare organisations concerning humanization in the ICU?
Policy makers could play a role in humanising patients by stimulating research on the topic of mental wellbeing for the development of protocols or devices that create value for patients and hospital staff. They could set standards on the delivery of care for the mental health of patients. Or develop standards - guidelines for humanizing, develop protocols for treating both the physical and mental wellbeing of patients and also create awareness with campaigns.

7.3 What can different levels of influence do to introduce AI in the ICU?

What is the current influence of the 6 levels of stakeholders on the use and development of Artificial intellingence for the ICU and the ICU patients?

Patient

ICU patient data is stored in electronic health records. Real-time patient data is transferred and collected but not used as input for automated decision making systems. The patient data is used by nurses and clinicians to diagnose, prognose, treat and care for patients.

Family and loved ones of a patient

The family and loved ones of a patient are getting their information from nurses and doctors. They are able to call nurses and ask doctors for information about their loved ones. They would like to have as much information as possible but there are currenty no systems in place that deliver this information automatically.

ICU staff

ICU data of patients is handled by the hospital staff. Clinicians, nurses or others who treat the ICU patient, use monitoring data and treatment data of patients to help them diagnose and prognose patients. They transfer information from monitoring equipment to electronic health records and use this as a platform to look back at a patients developments and medical history.

Healthcare institute - Erasmus MC

Healthcare institutes such as the Erasmus MC are focussing on the introduction of data and systems to benefit the healthcare system. They want to innovate distinctively and see a role for Artificial intelligence and Machine learning in their healthcare systems.

Healthcare community

Suppliers and researchers who design and deliver products for the hospital and the ICU in particular can develop products that use data and contain AI. They can do a technology push and deliver new features to the hospital to benefit the patient. There are big companies that are investing and developing products containing AI and are build to use data from patients. They are still being developed and not used in daily practise.

National healthcare organisations

The public health care organisation and policy makers influence the development of healthcare and the standards of healthcare. They are able to change and make policies and stimulate development and research towards using data, AI, facilitation of data sharing and others. . At the same time they also fulfil the role of controlling the quality of care and protecting the patients and their values.

What is the next step for patients concerning the development of AI?

The next step for patients is to communicate and discuss their unfilfilled needs. They should be open to share data of their wellbeing since this could possibly help in their treatment.

What is the next step for ther Erasmus MC concerning the development of AI?

Perform research on predictive algorithms for diagnosis and prognosis of patients.
Create data infrastructure that collects and stores patient data that can be used for analysis.
Create a base of support on the projected advantages of using data decision making systems and patient data management systems (Kwaliteitszorg standaard zorg en organisatie, 2021)

What is the next step for Family and loved ones concerning the development of AI?

Create a platform for interaction with patients and to receive information of the patient. Loved ones should be kept in the loop and be given information whenever they need it. This way loved ones can also react on information to help nurses in caring for patients.

What is the next step for the healthcare community concerning the development of AI?

Develop products that are compatibel to share data with different platforms so algorithms can be build. To be able to do this safely, protocols for data sharing and the use of data driven decision making systems should be made. Then Co-development can lead to AI/ML algorithms that can help and support clinicians and nurses in their work.

What is the next step for ICU staff concerning the development of AI?

The next step for the ICU staff is to be supported by products driven by data and AI that benefit the total-patient or the ICU staff.

Also, decision making systems for prognosis and diagnosis should be co-developed to help the ICU staff. This could be helpful for patient intake and discharge, for patient management, for (fixme).

Create a workflow were the ICU staff can be helped by data in the treatment of patients by aiding them in prognosis and diagnosis.

What is the next step for national healthcare organisations concerning the development of AI?

Fund research towards the use on data and artificial intelligence in hospitals wil cause the actual development of products. But before using these products, rules and policies upon the use of data should be made. So that sharing, storing and securing patient data is possible. This can be boosted by creating and stimulating collaborations between different disciplines to develop what is needed for the next step of ICU. This could mean funding and/or subsidising the development of AI related products and services for healthcare.

8. Design guidelines & website

Chapter 8

8.1 Design guidelines for humanization and AI in the future ICU
8.2 Webpage ICU of the future
8.3 Who can us this information?

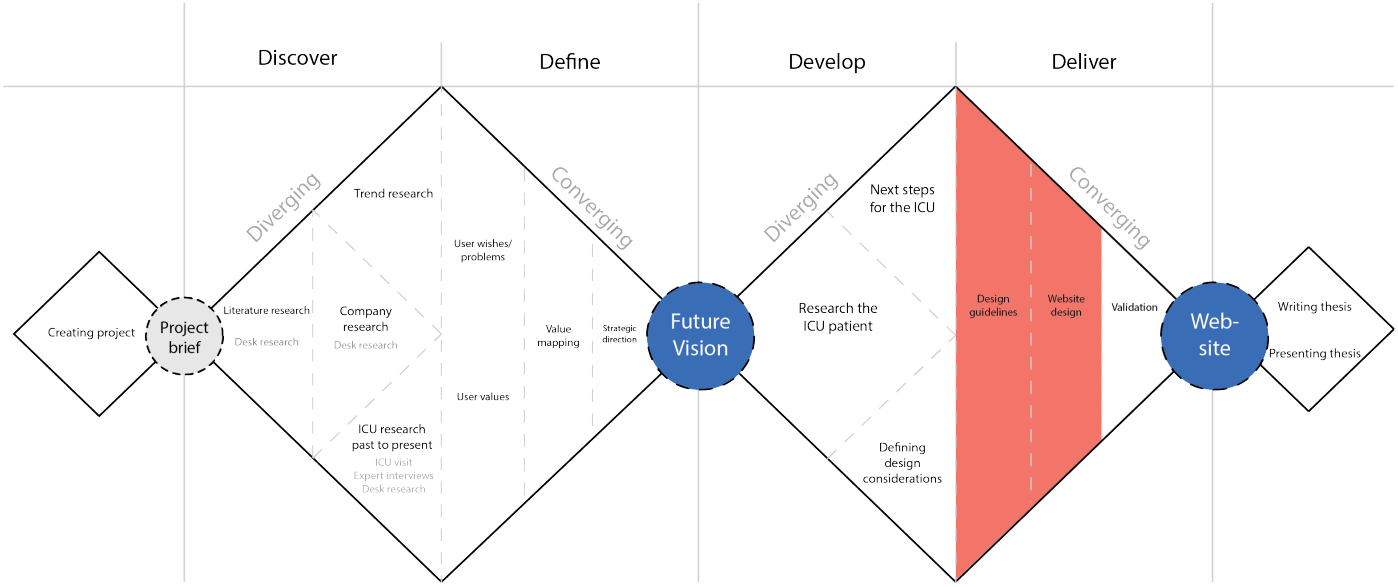


Figure 25: Schematic overview of Design approach : Design guidelines and webpage

This chapter aims to deliver the results from this project and who can use the results. The design guidelines for humanization and AI in the future ICU are delivered, and the link to the website is presented. In subchapter 8.1, the design guidelines are explained and elaborated on. The guidelines are created to help designers to develop products or services for the ICU of the future. They are the result of the research performed in this project. In subchapter 8.2, the website is delivered. The website shows the results from this research project and can be used by designers to find information or be inspired to design for the ICU or ICU patient. In subchapter 8.3, the intended use and intended users of the website are elaborated on.

8.1 Design guidelines for humanization and AI in the future ICU

This project aims to find guidelines or design principles for designing for the ICU patient. As described earlier, (de)humanization is an essential aspect in the ICU. At the same time, the suggestion is made by the Erasmus MC that Artificial Intelligence could benefit the ICU. During this project, different directions are investigated. Investigating includes exploring the ICU, the ICU patient, (de)humanization, artificial intelligence, the stakeholders involved in and surrounding the ICU and more. The research in this project resulted in the following design guidelines that will help guide in designing for the ICU and ICU patient.

- Design enhances human ability (without replacing the human)
- Design for real patient experiences to improve
- Design with empathy and compassion for the ICU patient
- Understand the patient needs, their mental and physical abilities
- Educate what data-driven decision-making systems have to offer
- Be aware of (de)humanization.

Design enhances human ability (without replacing the human)

If designing for ICU patients, there should be a focus on enhancing the ability of patients. Their capabilities should be supported with technology, and their lives should be made easier. This also counts for the design for the ICU and the people surrounding the patient. Delivering care or communicating with patients should be carried out by humans but could be supported or facilitated by technology.

Design for real patient experiences to improve

The key in innovating is to find the needs and wishes of the primary stakeholders (the ICU patient) and their surrounding stakeholders. The focus in designing for the ICU patient, especially for the ICU of the future, is to find authentic experiences of patients who desire improvement. Innovations should be fueled by stakeholder needs and wishes, not by a technology push.

Design with and for empathy and compassion

The ICU patient is very vulnerable and in a critical state. As can be read in this thesis, the abilities of ICU patients vary and are often minimal. How ICU patients are handled, spoken to or treated is highly dependent on who is performing this action. Showing compassion and empathy to ICU patients is of great importance for hospital staff. Therefore, designing for the ICU and ICU patients should go hand in hand with empathy and compassion.

Understand the patient needs, their mental and physical abilities.

Designing for the ICU patient and the ICU means investigating who is there, what the context is and what they need, want and can do. This means for the ICU that it is of importance to what mental and physical abilities patients have.

Educate what data-driven decision-making systems offer

Artificial intelligence and data-driven decision-making systems are seen as means for solving solutions. What the technology does or how it could benefit stakeholders in the ICU, including the patient, should be educated to let it become a success.

Be aware of (de)humanization

Part of designing for the ICU patient is understanding what happens in the ICU and understanding what ICU patients experience. Dehumanization is experienced by patients in the ICU and should be prevented(Wilson et al., 2019). When designing for the ICU and ICU, patient awareness should be created on the effect of dehumanization and how it can be prevented. Also, awareness should be created on how people surrounding them can prevent it from happening.

8.2 Website: ICU of the future

To bring the different guidelines together a website is designed. This website consists out of information that lead to the different design guidelines. The website is made and showcased in the program Adobe XD. Figure 26 shows a glimpse of the home page.

To reach the website paste the following link in your web browser, or look up the pages in the appendix.

https://xd.adobe.com/view/994fe422-b977-4bb7-ac99-4261e73605bc-cc1c/?fullscreen

8.3 Who can use this information?

The information on the website is intended for three specific target groups to use. These target groups are elaborated below.

Medical design students

The website is designed for students interested in designing for the ICU. The webpage offers information that can inspire and learn students about what to consider or to think of when designing for the ICU.

Designers for healthcare

The site is designed for designers for healthcare that are interested in designing for the ICU and in particular the ICU of the future where humanization and AI play a role. It can be used to answer specific questions and deliver more information for their field of interest.

Other interested parties

Other interested parties that want to know more about designing for the future ICU can visit the webpage to get inspired, to perhaps learn new things or get inspired.

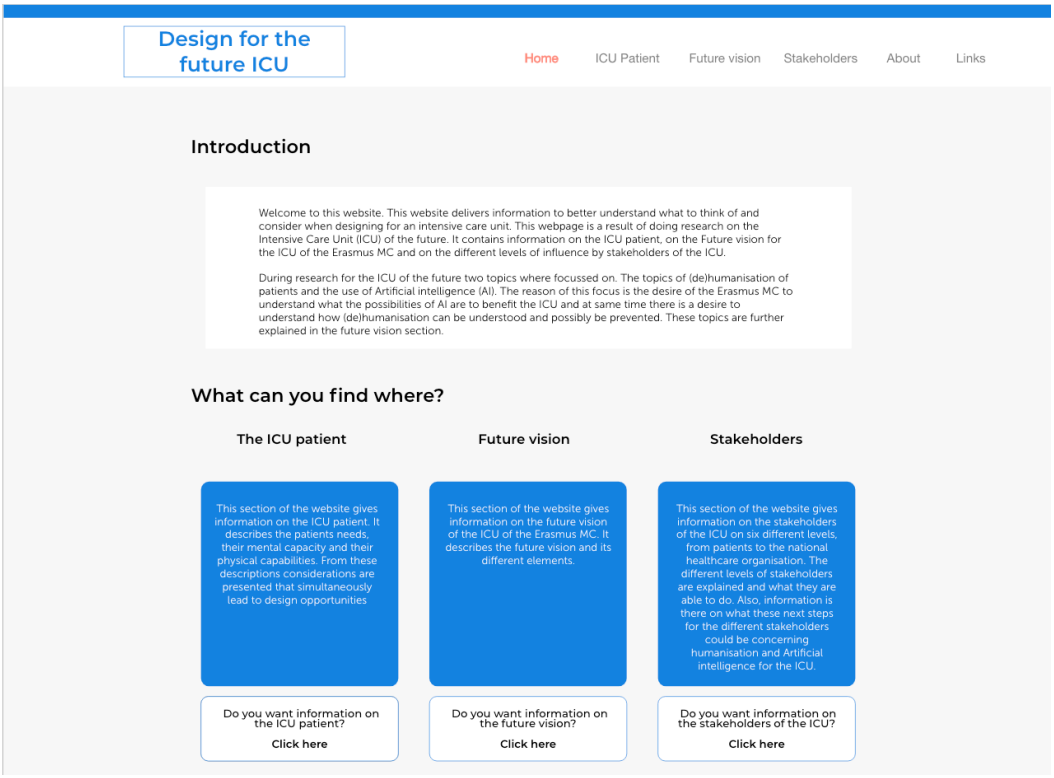


Figure 26: Home page of website, enter the following link in browser for higher quality : https://xd.adobe.com/view/994fe422-b977-4bb7-ac99-4261e73605bc-cc1c/?fullscreen

9. Validation

Chapter 9

9.1 Participants
9.2 Evaluation design
9.3 Procedure
9.4 Results
9.5 Discussion
9.6 Limitations

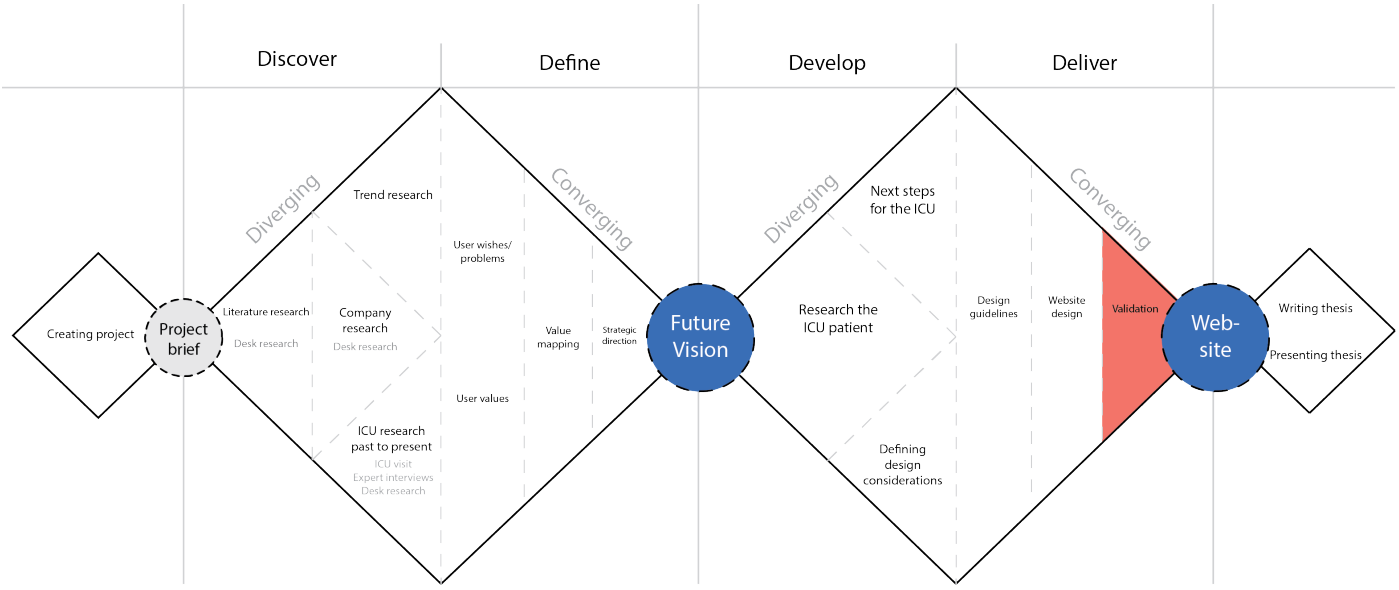


Figure 27 : Schematic overview of Design approach : Validation

In this chapter, research to validate the project is performed. This chapter aims to explain the validation. In subchapter 9.1, the participants that participated in the validation are elaborated on. Subchapter 9.2 explains the validation design and describes how results from the validation are analyzed. In subchapter 9.3, the procedure of the validation is explained. This is the procedure where the participants went through during the validation session. In subchapter 9.4, the results of the validation are delivered and elaborated upon. Subchapter 9.5 aims to discuss the results and findings from the validation research. The results are described and elaborated on—quotes from the participants are given to explain and argue the discussion.

9.1 Participants

This website is validated to find whether the information helps designers to design for ICU patients.

In the validation of the website, eight design students from the Technical University of Delft participated. The participants vary between 22 to 28 years of age and consist of six male and two female participants. Seven participants are in their first- or second-year master of strategic product design, and one participant is finalizing his bachelor. Three of the eight participants follow a specialization. One follows the entrepreneurship specialization, and two the Medisign specialization. Furthermore, one participant is Spanish, and the other seven are Dutch.

9.2 Validation design

The validation is a within-subject design. In which all participants answer open and closed questions and perform two assignments.

First participants are asked to sign a consent form. Next, the participants are asked about general demographics and receive five questions answered twice, before and after the assignments. The questions are answered on a seven-point Likert scale. Next, the participants receive two assignments, separated by the introduction of the website. Lastly, the participants are asked to answer five open questions.

The answers from the five Likert-scale questions that are filled in before and after the assignment are analyzed using SPSS. The responses are analyzed to find whether the intervention of the website that interrupts the two assignments contributes to the participants level of confidence, knowledge, experience and how informed they are. The data is analyzed using a Wilcoxon signed-rank test. This test is chosen because there is no normality in the data and the evaluation is a within-subject design, meaning that the two data sets are from the same participants.

The open-ended questions are analyzed to find whether the participants can design by using the website and what else they would need to design for the ICU patient. These questions are analyzed by dissecting and clustering the answers inspired by the course of Context and Conceptualization. From these clusters, conclusions can be drawn.

The assignments A and A* are compared and analyzed to find the differences and thus the website's influence on the participants' designs. The differences are compared and clustered to find common topics. These topics can be used to conclude how the website influence the participants and their designs.

9.3 Procedure

The participants answer the five questions before completing the first assignment and after the second assignment. The participants answer on a seven-point Likert scale that questions the participant on their confidence in designing for the ICU patient, on their knowledge in designing for the ICU patient, on how informed they are in designing for the ICU patient and on their experience on designing for the ICU patient and the medical world.

Participants perform two assignments during a physical or online session using the online program Miro. The assignments let the participants design for the ICU patient of the future and are asked to design a communication device for them. The assignment is interrupted by the introduction of the website. Participants are asked to read and get familiar with the information delivered on the website, from where participants are asked to perform the same assignment as before but then with the help of the website.

The evaluation session is concluded with five open questions that question how the design or ideas have changed due to the website, why the designs or ideas have changed, what they would want to have to be able to design for the ICU patient, what they would need to design for the ICU patient of the future and what parts of the website did not explain enough to be able to design for the ICU patient.

The questions are answered on a 7-point Likert scale and question the participant on their confidence in designing for the ICU patient, on their knowledge in designing for the ICU patient, on how informed they are in designing for the ICU patient and on their experience on designing for the ICU patient and the medical world. The five questions before and after the assignment are completed to assess whether the intervention of the website that interrupts the two assignments contributes to their level of confidence, knowledge, experience and how informed they are.

9.4 Results

Level of confidence

The level of confidence before the assignments is scored with a median of 3 and after the as-signments with a median of 5. This results in a significant ($p=0.047$) increase in the level of confidence after using the website.

Level of informed

How informed participants felt before the assignment is scored with a median of 2 and after the assignment with a median of 5. This results in a significant ($p=0.011$) increase in how informed participants felt after using the website.

Level of knowledge

The level of knowledge before the assignment is scored with a median of 3and after the assignments with a median of 4. This results in a significant ($p=0.016$) increase in the level of knowledge after using the website.

Level of experience in designing for the ICU patient

The level of experience in designing for the ICU patient before the assignment is scored with a median of 1 and after the assignment with a median of 3. This results in a significant ($p=0.016$) increase in the level of experience after using the website.

Level of experience in designing for the medical world

The level of experience in designing for the medical world before the assignment is scored with a median of 4 and after the assignment with a median of 4. This results in a not-significant ($p=0.157$) increase in the level of experience after using the website.

What information would participants like to have to design for the ICU patient?

The participants describe the following to be wished to be able to design for the ICU patient. Firstly, information on what nurses and doctors do, want and don't want. Secondly, participants wish to have information on the needs and wishes of ICU patients. Thirdly, information on the interaction between stakeholders that surround the patient. Fourthly, information on current problems/ pain points of ICU patients and information on the patient population that enters the ICU and the status plus abilities of ICU patients. Lastly, participants wish to have information on the experience of ICU patients and examples in the context of the ICU.

What are the necessities to design for the ICU patient of the future?

The participants describe the following as necessary for them to design for the ICU patient of the future. Firstly, participants need a future vision, with future goals created by the healthcare institute. Secondly, participants need trend research on technology that is being developed, research on the current ICU situation, and trend research on the general future. Thirdly, clear boundaries to design in and knowledge of the ICU context that will evolve in the future is needed. Fourthly, to design for the farther future, a well-connected data system, connected devices, high-speed internet and tech-savvy users are required.

What has changed in designing for the ICU patient when you could use the website?
The design of participants changed by having a better understanding of the needs and capabilities of patients and by reading about stakeholders created a complete picture for them. The website inspired participants to think of a vision and to think of technology like VR and AR. Information on the ICU context enabled the participant to envision designing for the ICU patient.

Why has the design changed?
The design changed because participants were able to be inspired, pick idea's or just learn more about the information presented on the website. Having more details to their exposal led to more 'robust' or 'complete' designs.

What parts of the website did not explain enough to be able to design for the ICU patient?
All the participants were able to design for the ICU patient with and without the website. But the participants also felt that real experiences of patients delivered in story's, interviews or others would contribute to the ability to design for the ICU patient. Also, participants argued that they would like visual examples of current and future products, concepts, and ideas to give them a better understanding of what designing for the ICU could mean.

Assignment A and A*
The results of assignments A and A* are analyzed to investigate whether the website influenced the participants in designing for the ICU patient. From the clusters made during the analysis, the following differences caused by the website can be concluded. Firstly, participants learned about new technology's and used this information to add parts to their design. Secondly, the participants were inspired by the website to come up with new idea's. Thirdly, participants used information on the website to adapt their current idea's by either making them more specific, more realistic or more focussed on goals. Fourthly, participants used the information on the website to learn more on the topic of humanization and integrated this knowledge into their idea's.

9.5 Discussion

The analysis of the Likert scale questions shows that all five questions have an increase of mean. However, four questions show a significant increase. This means the website significantly influences the level of confidence, knowledge, how informed participants feel and the level of experience for designing for the ICU patient. It can be concluded that the website has a positive influence on the participants to design for the ICU patient. What should be noted is that due to the small sample size, limited time and resources, the significance can be argued as high or too high. Therefore, the analysis concludes that the website positively influences the participants and helps design for ICU patients.

The analysis of the open-ended questions and the assignments contribute to answering the general question of "were participants able to design for the ICU patient?". This question can be answered with yes. All participants were able to design for the ICU patient. As can be read in the results section, participants describe their needs and wishes for designing for the ICU patient and ICU patient of the future in different ways. What can be concluded is that the website contributes to the designs of participants. What also needs to be concluded is that there is never enough information and much more to investigate to create a website that delivers all the necessary information to design for the ICU patient, let alone for the ICU patient of the future.

I would like to have more information on the personal experiences of ICU patients. We can think of everything in there now by researching, but I would want information from the patients, doctors, and nurses. -Participant KM, 25 years old, SPD (medisign)

The analysis of the assignments shows the website contributes to expanding and enriching the designs of the participants. The participants used the website in different ways. The participants used the

website to be inspired, to enhance their designs by including more technology, more focus or specified their design to be more future-oriented.

If we look at the first idea, the information is digitally presented to the patient, family and staff. A human touch should be added here - we could have a digital person speaking (and in the future interacting)- Participant CR , 27 years old, SPD (entrepreneurship)

I thought of more stakeholders after looking at the website. I started paying more attention on the future vision, so the topic of humanization and AI came in extra here. – Participant FK, 27 years old, SPD (medisign)

9.6 Limitations

The validation is performed with limited time and resources to find suitable participants. The limited time and resources resulted in a small sample size of participants to evaluate the website. The participants are design students who represent only a part of the intended users of the website. Therefore, the evaluation is not representative for all intended users. But the evaluation can function as the first indication of improvements towards iterations in the future.

10. Conclusion, reflection and recommendations

Chapter 10

10.1 Conclusion

This project aimed to find how the intensive care unit of the Erasmus MC should innovate in the coming years to give critically ill patients a humane experience. Based on desk research, ICU visits, Future visioning and evaluations, the Erasmus MC should innovate itself and distinguish itself by creating more awareness for patients' mental wellbeing of patients. Innovation should include humanizing patients by the behaviour of hospital staff and by introducing (technical) solutions to stimulate or facilitate humanization. Artificial intelligence can be part of these solutions but should not be mistaken as the 'holy grail' to benefit the patient experience. There needs to be a balance between treating the physical and mental wellbeing of patients. Also, a balance between introducing Artificial intelligence solutions, non-AI solutions and changing the way of working of the ICU staff.

Artificial intelligence for the ICU

Artificial intelligence has the potential to be of benefit to different stakeholders in the Intensive Care Unit. AI should be used for data analysis for diagnosis and prognosis but could also analyze real-life data to support systems and tools to benefit the stakeholders.

The potential to benefit the ICU patient is depended on how AI is used and introduced to the patient and the ICU. This means that AI solutions need to be tailored to ICU patients to be of worth for them. But this is precisely the struggle and opportunity with AI in designing for the 'ICU patient'. AI has the potential of analyzing large amounts of information of the ICU patient and its surroundings to initialize systems and feed systems with input.

The struggle is the large variety and difference in the patient population of the ICU. Understanding what a patient mentally needs and wishes while in the ICU is challenging and different for every patient. This is not determined frequently or regularly and is determined by interpretation of ICU nurses if patients cannot communicate by themselves or with help. Understanding the ICU patient and their physical and mental needs is essential to find areas for innovation. But the difficulty is in fact-finding a patient's needs. Thus, next to using AI to fulfil unmet patient needs and wishes, AI should identify the patients' needs and wishes.

Humanization

Dehumanization is a problem for patients in the ICU. The way a patient's care is provided or how a patient is handled and spoken to depends on who is providing the care. Every person working in the ICU has a different level of experience and interprets the patient differently. This is not a bad thing but looking to the future, where it is wished no dehumanization takes place, more control over 'how' care is delivered is desired. Humanization could be stimulated by creating awareness and education on the effect of dehumanization and thus stimulating to change the way of working of ICU staff who surround the patient. In addition, this could mean protocolizing treatment and behaviour related to humanizing patients. On the other hand, design solutions could also benefit the humane experience of patients. This can mean introducing new products or systems that can be used to benefit the patient. There is no right or wrong to be described in introducing new products or systems. These products and systems need to be tested with patients, used in real life and the development needs caused by real-life patient experiences that need to be improved.

Humanization versus Artificial Intelligence

In this research, dehumanizing patients is made clear, and the introduction of AI into the ICU is explored. How artificial intelligence can cause for humanization of patients is contradictory to the definition of artificial intelligence. Artificial intelligence is described as systems trained to perform tasks typically associated with human intelligence. So, taking over tasks of humans or substituting for humans. What can be concluded from this research is that AI can be of value for the ICU and the ICU patient. AI can be of value for humanizing the ICU patient as long as AI supports products or services for humanization and does not take away the most crucial aspect in humanizations, the human itself.

10.2 Limitations

The following section elaborates on the challenges and limitations I faced during this graduation project.

Covid-19

During this graduation project Covid-19 caused the world to adapt, and so did my graduation. The graduation has mostly been performed from home caused due to the limitations of the university. Also, researching the ICU was limited due to the strict corona measures in hospitals. Visits to the ICU were limited, and meetings or appointments were held online. These limitations caused a different way of working and limited forms of gathering insights in this project.

Time

The graduation project has a fixed period in which the research is needed to be conducted. In the first few weeks of this project, I wished to gather information on the experience of ICU patients. By retrieving this information from patients, themselves and not solely from desk research. Due to the limited time to perform this project, it was concluded that retrieving experiences from ICU patients themselves would not be plausible. This caused the project to use information from other research to find ICU patients' values, needs, and wishes.

10.4 Recommendations

Need for real-life patient experiences

Research needs to be performed on ICU patients to find their needs and wishes. This research is needed to find what current patient needs and wishes are. The post-intensive care syndrome (PICS) needs to be involved in such research to find solution space to prevent PICS from occurring.

Human in the loop machine learning

As described in this thesis, artificial intelligence can greatly value the ICU and ICU patients. There is a wish to use it. The question is, for what do we develop it? The first thing that needs to be investigated is to find what the hospital will use AI for. When the goal is determined, I would suggest looking at a principle called human in the loop learning. It is a method to develop machine learning algorithms that use human knowledge to learn actively and give the machine learning system feedback.

Co-development with relevant stakeholders.

Many different stakeholders can influence the development of new products for the ICU and ICU patients. I believe that all stakeholders need to be involved in deciding, for example, if we need or want AI in the ICU. Introducing technology such as AI into the ICU because an organization or policymakers fancy it is not the road to the highest level of care. The approach should be bottom-up, where patients, relatives, and nurses significantly influence what is being developed and how it should be used.

Recommendations for the website

The current website is made to showcase the information found in this project. It shows different elements and a high volume of written information. The website would benefit from a more visual style. Secondly, the website functions as a platform to portray information from this project. If this website is to be used for a longer period, it should be made possible to add more in-depth information or experiences of the different elements of the website. Think of a forum for patients and relatives to learn more about the ICU or share their stories. A place on the website where patients and other stakeholders could think along with ideas or propose ideas that benefit the healthcare in the ICU.

10.4 Personal reflection

During this graduation project, I learned a lot about the medical system. From the beginning to the end of my graduation project, I have been learning new things about the ICU and ICU patient, managing my own project, learning how to argue findings scientifically, and many more things. I feel it was a long journey that I will never forget. On the one hand as a positive, because of finishing my study's, learning a lot, meeting very interesting people. But on the other hand, as less positive due to the Covid-19 situation, thus doing a project from home for almost half a year. I believe the covid situation has taught me a lot about managing, arranging and planning further ahead. But also kept talking to people to get insights, reassurance, or just inspiration to take it a step further.

I believe this project has helped to reach my personal goals. I am still very interested in working in the medical field as a designer. I have learned a lot about managing a project by myself. I have improved my presenting skills and became more confident in the quality of my work. The competence that I wanted to develop but did not strengthen was becoming an expert on design road mapping. This competence is partly improved since only half of the road mapping method is used due to a different direction of my project.

References

Ahuja, A. S. (2019). The impact of artificial intelligence in medicine on the future role of the physician. PeerJ, 2019(10). https://doi.org/10.7717/peerj.7702

Ashworth, P. (1987). The needs of the critically ill patient. Intensive Care Nursing, 3(4), 182–190. https://doi.org/10.1016/0266-612X(87)90077-0

Benbenishty, J. S., & Bülow, H. H. (2018). Intensive care medicine in 2050: multidisciplinary communi cation in-/outside ICU. Intensive Care Medicine, 44(5), 636–638. https://doi.org/10.1007/s00134-017-4915-9

Blitz, A. M., Ahmed, A. K., & Rigamonti, D. (2019). Founder of modern hydrocephalus diagnosis and therapy: Walter Dandy at the Johns Hopkins Hospital, Journal of Neurosurgery JNS, 131(4), 1046-1051. Retrieved Aug 23, 2021, from https://thejns.org/view/journals/j-neurosurg/131/4/article-p1046.xml

Busch, I. M., Moretti, F., Travaini, G., Wu, A. W., & Rimondini, M. (2019). Humanization of Care: Key Ele ments Identified by Patients, Caregivers, and Healthcare Providers. A Systematic Review. Patient, 12(5), 461–474. https://doi.org/10.1007/s40271-019-00370-1

Calabretta, G., Gemser, G., & Karpen, I. (2016). Strategic design: Eight essential practices every strategic designer must master. Bis publishers.

De Looze, M. P., Kuijt-Evers, L. F. M., & Van Dieën, J. (2003). Sitting comfort and discomfort and the relationships with objective measures. Ergonomics, 46(10), 985–997. https://doi.org/10.1080/0014013031000121977

Deloitte. (2017). Life sciences and health care services: Innovation and practiable solutions to drive the future of myanmar. https://www2.deloitte.com/content/dam/Deloitte/mm/Documents/life-sciences-health-care/mm-lshc-platform-of-services-brochure.pdf

Dunn, A. M., Hofmann, O. S., Waters, B., & Witchel, E. (2019). The AI Effect. 395–410.

Erasmus MC. (2021). Intensive Care (IC). https://www.erasmusmc.nl/nl-nl/patientenzorg/specialismen/intensive-care

Fonseca, L. (2020). An introduction to artificial intelligence: the four types of AI. https://www.thediffer enceengine.tech/blog/2019/11/an-introduction-to-artificial-intelligence-the-four-types-of-ai

Genuis, S. J. (2007). An ounce of prevention: a pound of cure for an ailing health care system. Canadian Family Physician Medecin de Famille Canadien, 53(4), 597–599, 605–607. http://www.ncbi.nlm.nih.gov/pubmed/17872698%0A http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC1952577

Gordon, R., Perlman, M., & Shukla, M. (2017). The hospital of the future: How digital technologies can change hospitals globally. Deloitte. https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Life-Sciences-Health-Care/us-lshc-hospital-of-the-future.pdf

Grenvik, A., & Pinsky, M. R. (2009). Evolution of the Intensive Care Unit as a Clinical Center and Critical Care Medicine as a Discipline. Critical Care Clinics, 25(1), 239–250.

https://doi.org/10.1016/j.ccc.2008.11.001
Guidet, B., van der Voort, P. H. J., & Csomos, A. (2017). Intensive care in 2050: healthcare expenditure.
Intensive Care Medicine, 43(8), 1141–1143. https://doi.org/10.1007/s00134-017-4679-2
Gutierrez, G. (2020). Artificial Intelligence in the Intensive Care Unit. In Critical Care (Vol. 24, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s13054-020-2785-y
Halpern, N. A., Anderson, D. C., & Kesecioglu, J. (2017). ICU design in 2050: looking into the crystal ball! Intensive Care Medicine, 43(5), 690–692. https://doi.org/10.1007/s00134-017-4728-x
Hammond, R. (2019). THE WORLD IN 2040 The future of healthcare, mobility, travel and the home. In
Allianz Care (Issue July). https://image.health.allianzcare-emails.com/lib/fe9b12747766047874/m/1/30a0836e-6ce7-4b9c-8b47-99a206299502.pdf
Hanson, C. W., & Marshall, B. E. (2001). Artificial intelligence applications in the intensive care unit. Critical Care Medicine, 29(2), 427–435. https://doi.org/10.1097/00003246-200102000-00038
He, J., Baxter, S. L., Xu, J., Xu, J., Zhou, X., Jolla, L., Jolla, L., Jolla, L., Tongren, B., Hospital, B. T., Ophthalmology, B., & Science, V. (2020). The practical implementation of Artificial intelligence technologies in medicine. 25(1), 30–36. https://doi.org/10.1038/s41591-018-0307-0.The
Ho, S., Wong, A., Butnar, A., & Malbrain, M. (2020). The future of critical care: The human capital. Critical Care Clinics, 20(3), 163–169. https://doi.org/10.1016/j.ccc.2004.07.004
Hofhuis, J. G. M., Spronk, P. E., van Stel, H. F., Schrijvers, A. J. P., Rommes, J. H., & Bakker, J. (2008). Experiences of critically ill patients in the ICU. Intensive and Critical Care Nursing, 24(5), 300–313. https://doi.org/10.1016/j.iccn.2008.03.004
Human centred technology. (2000). In Collins dictionary of sociology (Issue 3rd). Harpercollins publishers. https://encyclopedia2.thefreedictionary.com/human-centred+technology
Inayatullah, S., & Van der Laan, L. (2016). Health Care Foresight: Identifying megatrends. Deloitte. https://www2.deloitte.com/content/dam/Deloitte/sg/Documents/life-sciences-health-care/sg-lshc-healthcare-foresight-megatrends.pdf
Jackson, J. C., Hart, R. P., Gordon, S. M., Hopkins, R. O., Girard, T. D., & Ely, E. W. (2007). Post-traumatic stress disorder and post-traumatic stress symptoms following critical illness in medical intensive care unit patients: Assessing the magnitude of the problem. Critical Care, 11. https://doi.org/10.1186/cc5707
Jackson, J. C., Santoro, M. J., Ely, T. M., Boehm, L., Kiehl, A. L., Anderson, L. S., Wesley Ely, E., to, C., & Paine, T. (2014). Improving Patient Care Through the Prism of Psychology: application of Maslow's Hierarchy to Sedation, Delirium and Early Mobility in the ICU A long habit of not thinking a thing wrong, gives it a superficial appearance of being right, and raises at first. J Crit Care, 29(3), 438–444. https://doi.org/10.1016/j.jcrc.2014.01.009.Improving
Jaiswal, S. (2021). Artificial intelligence tutorial. https://www.javatpoint.com/artificial-intelligence-tutorial
Jajal, T. D. (2018). Distinguishing between Narrow AI, General AI and Super AI.
Kelly, F. E., Fong, K., Hirsch, N., & Nolan, J. P. (2014). Intensive care medicine is 60 years old: The history and future of the intensive care unit. Clinical Medicine, Journal of the Royal College of Physicians of London, 14(4), 376–379. https://doi.org/10.7861/clinmedicine.14-4-376
Khan, B. A., Guzman, O., Campbell, N. L., Walroth, T., Tricker, J. L., Hui, S. L., Perkins, A., Zawahiri, M.,
Buckley, J. D., Farber, M. O., Ely, E. W., & Boustani, M. A. (2012). Comparison and agreement between the richmond agitation-sedation scale and the riker sedation-agitation scale in evaluating patients' eligibility for delirium assessment in the ICU. Chest, 142(1), 48–54. https://doi.org/10.1378/chest.11-2100
Kolcaba, K. (2003). Comfort Theory and Practise. NY:Springer.

Kolcaba, K. Y., & Fisher, E. M. (1996). A holistic perspective on comfort care as an advance directive. Critical Care Nursing Quarterly, 18(4), 66–76. https://doi.org/10.1097/00002727-199602000-00009

Lagace, M. (2004). The changing Roles of Doctors and Patients. https://hbswk.hbs.edu/archive/the-changing-roles-of-doctors-and-patients

Lombardo, V., Vinatier, I., Baillot, M. Lou, Franja, V., Bourgeon-Ghittori, I., Dray, S., Jeune, S., Mossadegh, C., Reignier, J., Souweine, B., & Roch, A. (2013). How caregivers view patient comfort and what they do to improve it: A French survey. Annals of Intensive Care, 3(1), 1–8. https://doi.org/10.1186/2110-5820-3-19

Lovejoy, C. A., Buch, V., & Maruthappu, M. (2019). Artificial intelligence in the intensive care unit. In Critical Care (Vol. 23, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s13054-018-2301-9

Marshall, J. C., Bosco, L., Adhikari, N. K., Connolly, B., Diaz, J. V., Dorman, T., Fowler, R. A., Meyfroidt, G., Nakagawa, S., Pelosi, P., Vincent, J. L., Vollman, K., & Zimmerman, J. (2017). What is an intensive care unit? A report of the task force of the World Federation of Societies of Intensive and Critical Care Medicine. Journal of Critical Care, 37, 270–276. https://doi.org/10.1016/j.jcrc.2016.07.015

Mesko, B. (2017). Artificial intelligence is the stethoscope of the 21st century. https://medicalfuturist.com/ibm-watson-is-the-stethoscope-of-the-21st-century/

Michaels, D. (2018). Specialty Nursing: Critical care. https://www.americannursinghistory.org/contact

Nguyen, D., Ngo, B., & vanSonnenberg, E. (2020). AI in the Intensive Care Unit: Up-to-Date Review. Journal of Intensive Care Medicine. https://doi.org/10.1177/0885066620956620

NHS. (2019). Intensive Care. https://www.nhs.uk/conditions/intensive-care/

Nural, N., & Alkan, S. (2018). Identifying the Factors Affecting Comfort and the Comfort Levels of Patients Hospitalized in the Coronary Care Unit. Holistic Nursing Practice, 32(1), 35–42. https://doi.org/10.1097/HNP.0000000000000245

Olausson, S., Fridh, I., Lindahl, B., & Torkildsby, A. B. (2019). The Meaning of Comfort in the Intensive Care Unit. Critical Care Nursing Quarterly, 42(3), 329–341. https://doi.org/10.1097/CNQ.0000000000000268

Özcan, E., Birdja, D., Simonse, L., & Struijs, A. (2019). Alarm in the ICU! Envisioning Patient Monitoring and Alarm Management in Future Intensive Care Units. Service Design and Service Thinking in Healthcare and Hospital Management, 421–446. https://doi.org/10.1007/978-3-030-00749-2_24

Parry, S. M., Huang, M., & Needham, D. M. (2017). Evaluating physical functioning in critical care: Considerations for clinical practice and research. Critical Care, 21(1), 1–10. https://doi.org/10.1186/s13054-017-1827-6

Rawal, G., Yadav, S., & Kumar, R. (2017). Post-intensive care syndrome: An overview. Journal of Translational Internal Medicine, 5(2), 90–92. https://doi.org/10.1515/jtim-2016-0016

Ristagno, G., & Weil, M. H. (2009). History of critical care medicine: The past, the present and the future. In Intensive and Critical Care Medicine: WFSICCM World Federation of Societies of Intensive and Critical Care Medicine. https://doi.org/10.1007/978-88-470-1436-7_1

Safar, P., De Kornfeld, T., Pearson, J., & Redding, J. (1964). the Intensive Care Unit, A three year experience at Baltimore city hospitals. Military Medicine, 129(3), 306–309. https://doi.org/10.1093/milmed/129.4.306

Sande, D. Van De, Genderen, M. E. Van, Rosman, B., Diether, M., Endeman, H., Akker, J. P. C. Van Den, Ludwig, M., Huiskens, J., Gommers, D., & Bommel, J. Van. (2020). Predicting thromboembolic complications in COVID-19 ICU patients using machine learning. Journal of Clinical and T ranslational Research, 6(5), 179–186. https://doi.org/10.18053/jctres.06.202005.003

Sayess, D., Schmitz-Hubsch, J., Tohme, W., & Azizova, L. (2015). The future of neuroarchitecture has arrived.

Sessler, C. N., Gosnell, M. S., Grap, M. J., Brophy, G. M., O'Neal, P. V., Keane, K. A., Tesoro, E. P., & Elswick, R. K. (2002). The Richmond Agitation-Sedation Scale: Validity and reliability in adult intensive care unit patients. American Journal of Respiratory and Critical Care Medicine, 166(10), 1338–1344. https://doi.org/10.1164/rccm.2107138

Simonse, L. (2017). Design Roadmapping. BIS.

Slater, K. (1985). Human Comfort. Charles C. Thomas publisher.

Vincent, J. (2013). Critical care: the present. Critical Care, 17(Suppl 1), 1–6.

Vincent, J. L., & Creteur, J. (2017). The hospital of tomorrow in 10 points. Critical Care, 21(1), 1–4. https://doi.org/10.1186/s13054-017-1664-7

Vink, P., & Hallbeck, S. (2012). Editorial: Comfort and discomfort studies demonstrate the need for a new model. Applied Ergonomics, 43(2), 271–276. https://doi.org/10.1016/j.apergo.2011.06.001

Weil, M. H., & Tang, W. (2011). From intensive care to critical care medicine: A historical perspective. American Journal of Respiratory and Critical Care Medicine, 183(11), 1451–1453. https://doi.org/10.1164/rccm.201008-1341OE

Wiener, F., Weil, M. H., & Carlson, R. W. (1982). Computer systems for facilitating management of the critically ill. Computers in Biology and Medicine, 12(1), 1–15. https://doi.org/10.1016/0010-4825(82)90008-7

Wilson, M., Beesly, S., Grow, A., Rubin, E., Hopkins, R. O., Hajizadeh, N., & Brown, S. (2019). Humanizing the intensive care unit experience. NAACOG"s Clinical Issues in Perinatal and Women"s Health Nursing, 3(3), 369–376. https://doi.org/https://doi.org/10.1186/s13054-019-2327-7

Appendix A : Project brief

DESIGN FOR our future

4844

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy". Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Nagtzaam

initials: RHMQ given name: Ruud

student number: 4238435

street & no.:

zipcode & city:

country:

phone:

email:

Your master programme (only select the options that apply to you):

IDE master(s): ( ) IPD ( ) DfI (★) SPD

2nd non-IDE master:

individual programme: - - (give date of approval)

honours programme: ( ) Honours Programme Master

specialisation / annotation: (★) Medisign ( ) Tech. in Sustainable Design ( ) Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: dept. / section: Critical Alarms Lab

** mentor: Evangelos Niforatos dept. / section: Human-AI Interaction

2nd mentor: Jasper van Bommel

organisation: Erasmus MC

city: Rotterdam country: The Netherlands

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

IDE TU Delft - E&SA Department /// Graduation project brief & study overview /// 2018-01 v30 Page 1 of 7

Procedural Checks - IDE Master Graduation

TU Delft

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Elif Ocan Vieira date 03 - 03 - 2021 signature EÖzcan

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 36 EC

Of which, taking the conditional requirements into account, can be part of the exam programme 30 EC

List of electives obtained before the third semester without approval of the BoE

★ YES all 1st year master courses passed

NO missing 1st year master courses are:

name C. van der Bunt date 19 - 03 - 2021 signature CB

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: V APPROVED NOT APPROVED

Procedure: V APPROVED NOT APPROVED

- also approved for Medisign

comments

name Monique von Morgen date 29/3/2021 signature MvM

Initials & Name RHMQ Nagtzaam Student number 4238435

Title of Project AI Roadmap towards positive patient experience solutions in the ICU

Personal Project Brief - IDE Master Graduation

TU Delft

AI Roadmap towards positive patient experience solutions in the ICU — project title

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

start date 02 - 03 - 2021 — 02 - 08 - 2021 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The context of this project is the Intensive Care Unit (ICU) of the Erasmus Medical Centre in Rotterdam. During this project I will be working at the Critical Alarms lab from the faculty of Industrial Design Engineering. The Critical Alarms lab has provided multiple digital solutions towards critical care and has a strong collaboration with the Erasmus MC which is hosting this project. This project will focus on the ICU of the Erasmus MC. The Medical Centre located in Rotterdam, in the mid-west of The Netherlands. The Erasmus MC has 54 Intensive Care Units with one bed per room.

The intensive care units in hospitals are rooms filled with a variety of technological equipment needed to treat patients. These rooms are used by clinicians working in the ICU which have the sole purpose of helping the patient. At the same time patients are living in these units while being treated or recovering. The growing number of devices in these units used to monitor patients is not benefiting the comfort or recovery of the patients (Özcan et al., 2019). Next to current threats of the wellbeing of the patients in the ICU the demand of Critical care is growing (Vincent, 2013). This gives an opportunity for developing human centred Artificial Intelligence (AI) solutions for critical care of the future.

From research is found that using AI at the ICU could have many benefits for all stakeholders involved in the ICU. Since AI excels at finding complex relationships in large datasets and AI can simultaneously analyse many variables to predict outcomes of interest (Lovejoy et al., 2019), It has the possibilities to be used in different ways with different purposes. It can be used in drug discovery, personalized diagnostics and therapeutics, molecular biology, bioinformatics and medical imaging (Gutierrez, 2020; Lombardo et al., 2013; Sande et al., 2020). Furthermore, AI could also be used for patient monitoring. The study of Davoudi shows that pervasive monitoring of patients at the ICU is feasible. By monitoring different factors, a system could be built that modifies the noise and light in an ICU in real-time (Davoudi et al., 2018).

In the context of this research, the possibilities of using AI in combination with tools, products and/or systems will be explored. Human centred AI solutions could be found to improve a patient's comfort or experience. Solutions could benefit patients before, during and after hospitalization. The goal is to create a vision that positions the ICU of the Erasmus MC as an experience-driven ICU.

Current identified stakeholders with main interest in this project are the following:
- Clinicians of the ICU
- ICU nurses
- ICU patients
- Family and friends of ICU patients
- Hospital/ICU infrastructure

This research will be exploring human centred AI solutions towards an experience driven ICU of the future. Therefore, there are no limitations on funds, technology or time. It should be noted that the study will be focussing on a vision for the near future. So, directions of development or products that will be showed in the roadmap will be realistic and feasible in the near future.

space available for images / figures on next page

introduction (continued): space for images

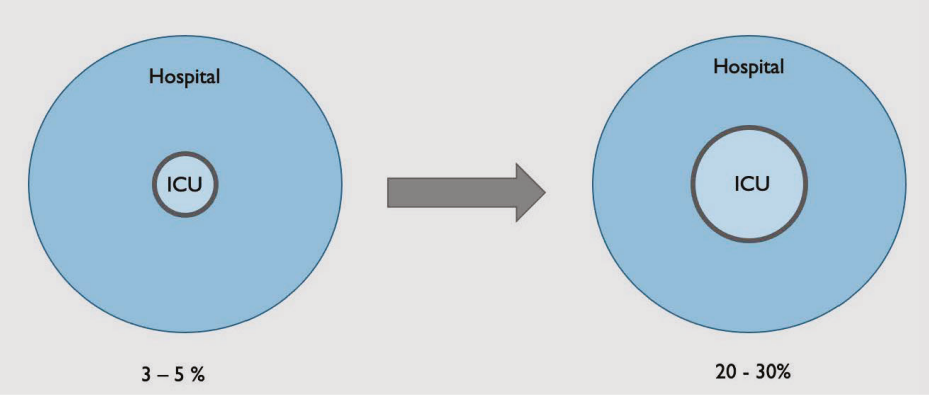


image / figure 1: Changing place of the ICU within the hospital (Vincent, 2013)

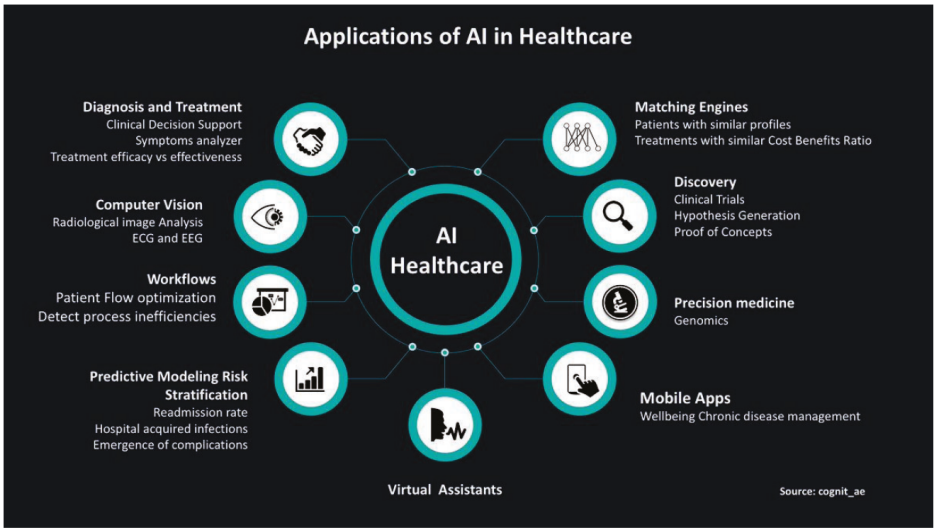


image / figure 2: Applications of AI in Healthcare (source: cognit.ae)

Personal Project Brief - IDE Master Graduation

TU Delft

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Research shows that while average human lifespan is increasing, lifestyle-related illnesses and obesity are becoming more common. This leads to more complex and invasive surgery that translates to a growing ICU patient population (Ho et al., 2020). Together with this growing ICU patient population there comes a loss of sight to the human side of the patient. To counter this dehumanisation in the ICU Wilson et al state that a culture swing of 'humanising the ICU' is needed. This can be done by patient-focused behaviours and environment-related measures (Wilson et al., 2019). Olausson et al found that patients are treated with the purpose of making them better, can result in less attention to their comfort. Comfort as an outcome of treating patients, addresses physical needs and illness symptoms, not so much emotional and psychological needs (Olausson et al., 2019). Many patients feel discomfort in the ICU caused by different factors such as anxiety pain, feeling restraint, lack of privacy, noise, light at night-time, hunger and lack of information (Lombardo et al., 2013). The experience of these factors of discomfort can lead to the Post Intensive Care Syndrome (PICS) or Post Traumatic Stress Syndrome (PTSD) (Rawal et al., 2017) (Jackson et al., 2007).

While patients are treated in the best way possible, they don't need surveys questioning their satisfaction of their hospitalization. They are in need of solutions that help them to recover quicker and better during and after hospitalization. Solutions to take away their discomfort should be thought of and implemented without compromising their wellbeing. Their recovery process should be enhanced and they should be provided with different ways of recovery where humanisation plays a role (Wilson et al., 2019).

In order to get to this result, a research question must be composed. Questions that arise are the following:
- How can human centred AI solutions improve the patient experience in the ICU of the Erasmus Medical Centre?
- What Human centred design interventions will benefit a patient's stay or recovery in the ICU?

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

The aim of this project is to position the ICU of the Erasmus MC as an experience driven ICU by understanding the patient needs and values for more human centred AI solutions. In order to achieve this positioning a roadmap will be made that will lay out a variety of design interventions that can increase the value of a patient's stay or recovery.

Roadmap

With this project I will deliver a road map that lays out the road to an Experience driven ICU at the Erasmus MC. It will show different horizons which represent short term goals followed by long term goals. Laying out the road to the future vision of positioning the ICU of the Erasmus MC as experience driven. The roadmap will also show design interventions for the short- and long-term goals. These will be presented in a visual matter as directions for development or future research.

A vision for an experience driven ICU

Before starting a roadmap, a clear vision needs to be created to be able to map towards. In this vision the needs and wishes from all stakeholders will be taken into account concerning a positive patient experience in the ICU and the application of AI.

Initials & Name RHMQ Nagtzaam Student number 4238435

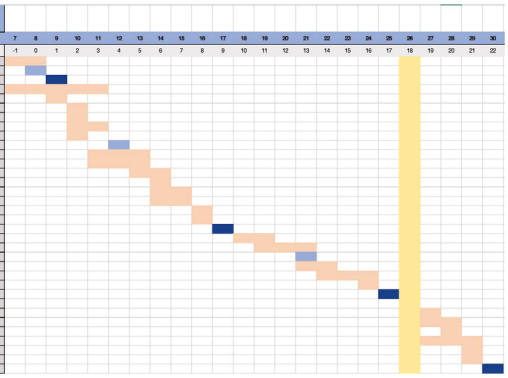
Title of Project AI Roadmap towards positive patient experience solutions in the ICU

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 2 - 3 - 2021 2 - 8 - 2021 end date

Weeks	Date	Time	Attendees
			Weeks
			Project weeks
Writing project brief			
Pre kick off meeting	22/02/2021	11:00	Evan, Ruud
Kick-off meeting	02/03/2021	14:00	Whole Team
Literature study			
Graduation method outline			
Destructuring current/existing solutions, current interactions in ICU			
Expert consultation (AI expert- ICU Expert)			
Trend research			
Set up interview			
Team meeting	25/03/2021		Whole team
Interviews ICU personnel			
Interviews Ex ICU patients			
Analysing interviews			
Future visioning			
Technology scouting			
Idea generation			
Prepare midterm meeting			
writing report			
Midterm meeting	30/04/2021		Whole Team
Timepacing			
Pathway mapping of innovation activities			
Team meeting	26/05/2021		Whole Team
Visual design of roadmap			
Writing report			
Preparing greenlight meeting			
Green light meeting	02/07/2021		Whole Team
1 week Holiday			
Validation			
Writing report			
Write publication			
Build presentation			
Make graduation poster			
Hand-in thesis			
Graduation	02/08/2021		Whole Team



The plan, as can be seen in the Gantt chart, is to start my graduation project at the beginning of March and graduate in the beginning of August. This means that my project will be ongoing for 22 weeks including 1 week of holiday and national holidays. Every other week I will be working 5 days a week on my graduation as I have no parallel activities.

In the first phase of my project, I will do an intensive literature study on AI, AI in healthcare, patient and clinicians needs in the ICU and the ICU itself. I will define my stakeholders and examine their relationship to each other. Next. I will consult with AI expert Alessandro Bozzon and ICU specialists from the Erasmus MC, Jasper van Bommel and Davy van de Sande. Furthermore, I will perform trend research to find new developments in the AI and medical field that can benefit patients in the ICU. The second phase of the project will focus on patient and clinicians needs in the ICU. This will be done by interviews followed up by an analysis. From there the designing will start were the future vision needs to be made followed by idea generation and technology scouting. After the midterm most of the input for the roadmap will be there and from there it will be key to make them tangible and lay them out on the roadmap itself. The last phase will be about presenting the results in an easy to understand but rich roadmap. The final touches on the different horizons will be made and the horizons and results will be validated. Finally, the report needs to be written together with the presentation, possible publication and graduation poster.

Meetings:

Weekly/ two weekly meeting: Evan, Ruud
Monthly team meeting: Whole team

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

By setting up this project I will be finishing my Master Strategic Product Design with the Medisign specialization. Before going to university, I wanted to become a doctor. Not being able to start a Medicine study shifted my interest to Industrial Design. I knew before starting my bachelor that there was a possibility to come back to the field of medicine by doing the Medisign specialization. This has been my goal from the start and this project gives me the opportunity to reach it. I have had an interest in the medical field for a very long time and therefore I also did the minor of Biomedical Engineering in my bachelor.

I believe that AI is a very interesting to do my graduation project on. It is being used in more and more fields and is showing its benefits. I am really eager to learn more about AI in combination with such a specific part of medicine, the ICU.

By setting up this project I will also generate knowledge about the comfort of patients at the ICU and I will generate knowledge on how to use AI at the ICU. Combining this knowledge in my research, it can show how AI can help the medical field to benefit its patients. Bridging the gap of the medical and technological field. Next to possibly bridging this gap, I hope to have impact on the wellbeing of patients in the future.

Furthermore, this project will give me insight if my interest in the medical field is correct and if I want to continue in this direction after my study. This could lead discovering if I want a job in the medical field at for instance Philips.

Competences:
- Become an expert on Design road mapping in combination with the method Vision In Design. (Simonse, 2017) (Hekkert & van Dijk, 2011)
- Dive in the world of artificial intelligence and its applicability in the healthcare domain.
- I want to broaden my skills of presenting information to an audience with a diverse background. In this case, engineers versus healthcare professionals. I think this can be a challenge and by tackling the challenge I think I can broaden my skill set.
- Manage a project by myself
- Write a publication

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Appendix B : Validation data

The raw data from the evaluation session can be found on the following miro link: https://miro.com/app/board/o9J_l594V_E=/

Raw data: Demograhics and likert scale questions

	Participants	Age	Gender	Nationality	Study	Year of study	specialization
KM	1	25	Male	Dutch	SPD	2	Medisign
JJ	2	22	Male	Dutch	IO Bachelor	3	Design engineering
FK	3	27	Male	DUTCH	SPD	2	Medisign
MK	4	27	female	dutch	spd	2	-
HS	5	24	Male	Duthc	SPD	2	
CR	6	27	Male	Dutch	SPD	2	Entrepeneurship
NVV	7	28	female	Spanish	SPD	2	
FE	8	25	female	duthc	spd	1	

Q1						Q3				
1	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**
3	2	3	2	5		5	6	5	3	6
2	1	1	1	1		3	2	2	1	1
2	2	1	1	3		5	5	4	3	4
2	2	1	2	1		3	5	3	3	4
6	3	3	1	5		6	5	3	5	4
5	2	4	1	5		6	5	5	5	6
6	5	5	3	5		5	6	6	4	5
3	2	3	1	2		5	5	4	2	2

Analyses output SPSS: Likert scale questions

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles 25th	50th (Median)	75th
Q11	8	3.6250	1.76777	2.00	6.00	2.0000	3.0000	5.7500
Q12	8	2.3750	1.18773	1.00	5.00	2.0000	2.0000	2.7500
Q13	8	2.6250	1.50594	1.00	5.00	1.0000	3.0000	3.7500
Q14	8	1.5000	.75593	1.00	3.00	1.0000	1.0000	2.0000
Q15	8	3.3750	1.84681	1.00	5.00	1.2500	4.0000	5.0000
Q21	8	4.7500	1.16496	3.00	6.00	3.5000	5.0000	5.7500
Q22	8	4.8750	1.24642	2.00	6.00	5.0000	5.0000	5.7500
Q23	8	4.0000	1.30931	2.00	6.00	3.0000	4.0000	5.0000
Q24	8	3.2500	1.38873	1.00	5.00	2.2500	3.0000	4.7500
Q25	8	4.0000	1.77281	1.00	6.00	2.5000	4.0000	5.7500

Test Statistics[a]

	Q21 - Q11	Q22 - Q12	Q23 - Q13	Q24 - Q14	Q25 - Q15
Z	-1.983[b]	-2.555[b]	-2.414[b]	-2.414[b]	-1.414[b]
Asymp. Sig. (2-tailed)	.047	.011	.016	.016	.157

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Q21 - Q11	Negative Ranks	1[a]	2.50	2.50
	Positive Ranks	6[b]	4.25	25.50
	Ties	1[c]		
	Total	8		
Q22 - Q12	Negative Ranks	0[d]	.00	.00
	Positive Ranks	8[e]	4.50	36.00
	Ties	0[f]		
	Total	8		
Q23 - Q13	Negative Ranks	0[g]	.00	.00
	Positive Ranks	7[h]	4.00	28.00
	Ties	1[i]		
	Total	8		
Q24 - Q14	Negative Ranks	0[j]	.00	.00
	Positive Ranks	7[k]	4.00	28.00
	Ties	1[l]		
	Total	8		
Q25 - Q15	Negative Ranks	1[m]	2.50	2.50
	Positive Ranks	4[n]	3.13	12.50
	Ties	3[o]		
	Total	8		

E

Consent Form for [*Designing for the ICU patient*]

Please tick the appropriate boxes Yes No

Taking part in the study

I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction. ■ □

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason. ■ □

I understand that taking part in the study involves audio recordings of the evaluation session being made, a questionnaire needing to be filled in and results of two assignment will be used for evaluation. ■ □

OPTIONAL (delete if not needed)

Risks associated with participating in the study

I understand that taking part in the study involves the following risks: none ■ □

Use of the information in the study

I understand that information I provide will be used for evaluation and will be used in a graduation report. ■ □

I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team. ■ □

I agree that my information can be quoted in research outputs ■ □

Signatures

Name of participant [printed] Signature 9-9-21 Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Ruud Nagtzaam [printed] Signature 9-9-21 Date

Study contact details for further information:

Ruud Nagtzaam
0644494878
ruudnagtzaam@hotmail.com
r.h.m.q.nagtzaam@student.tudelft.nl

Q1

1. **Age:**
2. **Gender:**
3. **Nationality:**
4. **Study program:**
5. **Year of study:**
6. **Specialisation:**

You are about to design a product or service for a patient in the Intensive care Unit, please answer the following questions by dragging the red square to you answer!

		1	2	3	4	5	6	7	
How confident are you in designing for the ICU patient?	Not confident at all	●	●	●	■	●	●	●	Very confident
How informed are you to be able to the design for the ICU patient?	Not informed at all	●	●	●	■	●	●	●	Very informed
How knowledgeable are you to design for the ICU patient?	Not knowledgeable at all	●	●	●	■	●	●	●	Very knowledeable
How experienced are you in designing for ICU patients?	Not experienced at all	●	●	●	■	●	●	●	Very experienced
How experienced are you in designing for the medical world?	Not experienced at all	●	●	●	■	●	●	●	Very experienced

Assignment **A**

This evaluation assignment is about design for the Intensive Care Unit patient of the future. You are asked to design, generate ideas and come up with different features for the ICU patient and/or the ICU of the future. Your design, ideas and features need to be implementable between 2030-2040.

Your assignment is to design a communication tool/device/service for the ICU patient of the future. You have 15 minutes to perform the assignment, there are no wrong answers or weird ideas. You may use all the tools in Miro to design

Website

Go to the website by clicking the link → https://xd.adobe.com/view/994fe422-b977-4bb7-ac99-4261e73605bc-cc1c/?fullscreen

rame 92

Assignment **A***

The goal of the second assignment is to continu with assignment A. Thus, design a communication tool/device/service for the ICU patient of the future. But now you are able to use the website to search for information.

Q3

You have just finished designing a product or service for a patient in the Intensive care Unit, please answer the following questions by dragging the red square to you answer!

		1 2 3 4 5 6 7	
How confident are you in designing for the ICU patient?	Not confident at all	●—●—●—■—●—●—●	Very confident
How informed are you to be able to the design for the ICU patient?	Not informed at all	●—●—●—■—●—●—●	Very informed
How knowledgeable are you to design for the ICU patient?	Not knowledgeable at all	●—●—●—■—●—●—●	Very knowledeable
How experienced are you in designing for ICU patients?	Not experienced at all	●—●—●—■—●—●—●	Very experienced
How experienced are you in designing for the medical world?	Not experienced at all	●—●—●—■—●—●—●	Very experienced

Please answer the following questions:

What has changed in designing for the ICU patient when you could use the website?

What information would you like to have to design for the ICU patient?

Why has the design changed?

What are the necessities to design for the ICU patient of the Future?

What parts of the website did not explain enough to be able to design for the ICU patient?

Consent Form for [*Designing for the ICU patient*]

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
I understand that taking part in the study involves audio recordings of the evaluation session being made, a questionnaire needing to be filled in and results of two assignment will be used for evaluation.	☐	☐
OPTIONAL (delete if not needed):		
Risks associated with participating in the study		
I understand that taking part in the study involves the following risks: none	☐	☐
Use of the information in the study		
I understand that information I provide will be used for evaluation and will be used in a graduation report.	☐	☐
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	☐	☐
I agree that my information can be quoted in research outputs	☐	☐

Signatures

_____	_____	_____
Name of participant [printed]	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	9-9-21
Ruud Nagtzaam [printed]	Signature	Date

Study contact details for further information:

Ruud Nagtzaam
0644494878
ruudnagtzaam@hotmail.com
r.h.m.q.nagtzaam@student.tudelft.nl