ALARMTRACK+

Master Thesis

# OPTIMIZING ALARM MANAGEMENT IN THE NICU

## Designing Interfaces For Supporting Nurses To Customize Alarm Limits

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# Abstract

In the realm of healthcare, the effective management of alarm systems within the Neonatal Intensive Care Unit (NICU) is of paramount importance to ensure patient safety and reduce alarm fatigue among nurses. This study presents a comprehensive exploration of designing interfaces tailored to nurses' needs for adjusting alarm limits, aimed at enhancing their decision-making and patient care. Leveraging a multidisciplinary approach, this project amalgamates insights from nursing practices, user-centered design, and data visualization.

Drawing on meticulous literature review, direct observations, interviews, and user surveys, the project meticulously dissected the intricacies of nurses' interactions with alarm systems. This investigation highlighted the necessity for a dashboard that not only reduces the cognitive load on nurses but also empowers them to make informed decisions based on alarm data. The resulting system interfaces offer data customization and visualization capabilities, facilitating rapid and accurate alarm limit adjustments.

Therefore, this project has generated interfaces that involves tracking, analyzing, and visualizing the data logged by the nurses in response to alarms and their evaluations, thus supports nurses in adjusting alarm limits for an individual patient.

The evaluation of the designed interfaces through two kinds of questionnaires reflects a promising usability score, with nuanced insights about nurses' varying levels of comfort and trust with the interface. Future recommendations include personalized information delivery based on experience levels, Leverage machine learning algorithms and so on.

However, the study acknowledges limitations, including the lack of professional medical background and time constraints. This underlines the need for collaboration with medical experts and continuous monitoring to ensure the design remains attuned to the ever-evolving healthcare landscape.

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# Introduction

## 1.1 Assignment introduction

The priority of a neonatal intensive care unit is to provide appropriate care for critically ill newborns, including the provision of a quiet acoustic environment. However, when stay inside the NICU, you will hear a lot of sound: Hum and alarm from bedside's equipment, conversations between caregivers, operation sounds for routine care. One area in particular that presents a great challenge in is in the use of alarms and alarm fatigue. As defined by the American Association of Critical Care Nurses, alarm fatigue occurs when clinicians (especially nurses) become insensitive to alarms due to the excessive number of alarm signals(Woo, 2022).

Due to patients in critical condition, alarms are everywhere in NICU. Nurses, are particularly susceptible to the alarm fatigue which can lead to missed alarms or delayed responses. With the future tendency to design NICU units as single-patient room, alarm fatigue will become more prominent. This is because the healthcare team will choose conservative alarm thresholds that may lead to an excessive number of alarms.

Studies show that the majority of alarms are false or unrelated to emergencies, accounting for over 85% of all auditory signals(Purbaugh, 2014). Nurses view the existing alarm system as too frequent and disruptive to patient care so that they often do not respond directly and immediately to alarms[3]. Yuval et al. found that overall likelihood of a nurse responding to an alarm was very small, and, for more than 90% of alarms, the nurse did not attend to the patients during the minute following the alarm(Yuval et al., 2014).

Given this situation, NICU nurses emerge as the primary drivers of change. Their clinical acumen, combined with their on-the-ground experiences with alarm systems, make them pivotal for improvement of alarm management. They value efficient, easy-to-use, and reliable systems that minimize false alarms and enhance patient care quality.

### Problem statement

The crux of the problem arises from the conservative and generalized alarm limits currently employed in the NICU settings. To ensure the utmost safety of neonates, alarm limits on monitoring equipment are typically set conservatively, triggering an alarm for even minor deviations from the norm. This approach results in an overwhelming number of alarms, many of which are not indicative of a genuine health emergency.

This conservative setting of alarm limits, coupled with the 'one-size-fits-all' approach, fails to account for individual variations in newborn health statuses. Consequently, this lack of personalization and over-reliance on alarm systems significantly disrupts the calm environment that is vital for neonate recovery and hinders the efficient delivery of patient care. Nurses find themselves constantly interrupted, leading to disrupted workflows and elevated stress levels. Moreover, the frequent triggering of alarms, often unrelated to genuine emergencies, erodes the nurses' trust in these systems. The result is a delay in response or, in certain cases, overlooking alarms, which could potentially have severe implications for patient safety.

The primary problem to address, therefore, is the need for an alarm management tool that strikes a balance between patient safety and efficiency. This tool should support nurses to adjust alarm limits according to individual patient needs, rather than relying on conservative, generalized limits.

It should also provide a mechanism to assess alarm urgency and effectiveness based on nurses' expertise, ensuring alarms retain their intended function – to alert healthcare professionals to real and immediate threats to the infants they are caring for.

### Solution Space

In response to the identified problems, this graduation project proposes an innovative solution that draws from the learnings of previous works undertaken by the Critical Alarms Lab (CAL) and adopts a more holistic approach towards alarm management. While previous projects have focused on the track and map sound data(Viñas, 2021), this project aims to track, analyze, and visual interaction data between nurses and alarms.

The overarching goal of the project is to simplify and make more understandable the often complex and overwhelming alarm of the NICU for the nurses. This is to be achieved through the design interactive interfaces for alarm management. The interface will collect data to identify and map alarm events within the NICU, thereby giving nurses a comprehensive view of the alarm situation at any given moment.

Furthermore, the proposed solution enables the representation of areas most affected by these alarm events. And the interface can help nurses and other healthcare professionals strategically plan their responses and optimize patient care. It will also allow nurses to input their assessment of the alarm based on their clinical judgement, thereby adding a layer of human discernment to the alarm management process.

In addition, the project provides tools to empower nurses. By providing a visual representation of alarm data and nurse interactions, it supports decision-making, giving nurses the confidence to adjust alarm parameters according to each individual patient's needs.

In essence, this graduation project endeavors to revolutionize alarm management in the NICU. Through the design of interactive interfaces and a comprehensive dashboard, the project aims to streamline alarm response, reduce alarm fatigue among nurses, and ultimately contribute to the creation of a quieter, more efficient NICU environment.

# Research question

To more precisely delineate the scope of this thesis and pinpoint potential areas for design development, the following preliminary questions have been formulated to steer the literature reviews and user researches:

Main research question (RQ):

*"How can the experience of nurses be leveraged to evaluate alarms so as to optimize the current alarm management system in the neonatal intensive care unit?"*

Sub research questions

- What are the current alarm management practices in the NICU, and how do they contribute to alarm fatigue?
- How is nurses' experience currently utilized in alarm management in the NICU, and what are its limitations?
- What are the reasons for the nurse determining whether and how to respond to an alarm?
- What factors should be considered when allowing nurses to adjust alarm settings according to individual patient needs?

# 1.2 Project stakeholders

## TU Delft

This project is a collaborative effort between three organizations: Delft University of Technology (TU Delft), Critical Alarms Lab (CAL), and Erasmus University Medical Center (ErasmusMC). It forms a significant part of the master's program in Design for Interaction from TU Delft's faculty of Industrial Design and Engineering. TU Delft provided essential resources and guidance to facilitate the project's completion.

## Critical Alarms Lab

The Critical Alarms Lab (CAL) is a specialized design lab within the Industrial Design Engineering (IDE) Faculty. It is dedicated to sculpting the future of alarms and soundscapes within socio-technological contexts. Currently, the lab concentrates on resolving sound-related challenges in healthcare. The lab's approach brings together a diverse group comprising students, researchers, academic hospitals, industry professionals, and regulatory agencies, with a common goal of improving critical alarm systems.

## Erasmus MC

Erasmus MC Sophia Children's Hospital, another crucial stakeholder in my graduation project, is a leading institution dedicated to providing comprehensive healthcare services for children. The specific focus of my thesis is the Neonatal Intensive Care Unit (NICU) within this hospital. The NICU is a specialized department that provides intensive care to newborns suffering from severe conditions or those born prematurely and in need of vital support.

# 1.3 Project approach

For clinical systems where safety is paramount, it's crucial to cater to the specific needs and demands of users to create a highly usable system that will be willingly adopted and used. As such, this project adheres to the human-centered design process (HCD) as outlined in ISO standard 9241-210. This standard prescribes iterative design approach that ensures user involvement at every stage of development.

The main 4 phases include:

**Understanding and Specifying the Context of Use:** It involves understanding the users' needs, tasks, and the environment in which they'll interact with the system. Various methods would be employed, such as interviews, observations, and surveys to get a broad and deep understanding of the user and their context.

**Specifying the User Requirements:** We identify and define what users expect and require from the product. In addition, through literature research, we understand the design requirements for clinical decision support products.

**Producing Design Solutions:** With a understanding of the context of use and user requirements, we start generating solutions to meet those needs. This phase involves creating multiple design concepts and iteratively refining them. Low fidelity prototyping was used in the ideation stages. Conducting co-creation session with users to iterate design.

**Evaluating the Design:** This phase involves user testing, where we observe user using your design and collect feedback. You analyze the feedback and use it to refine and improve the design.

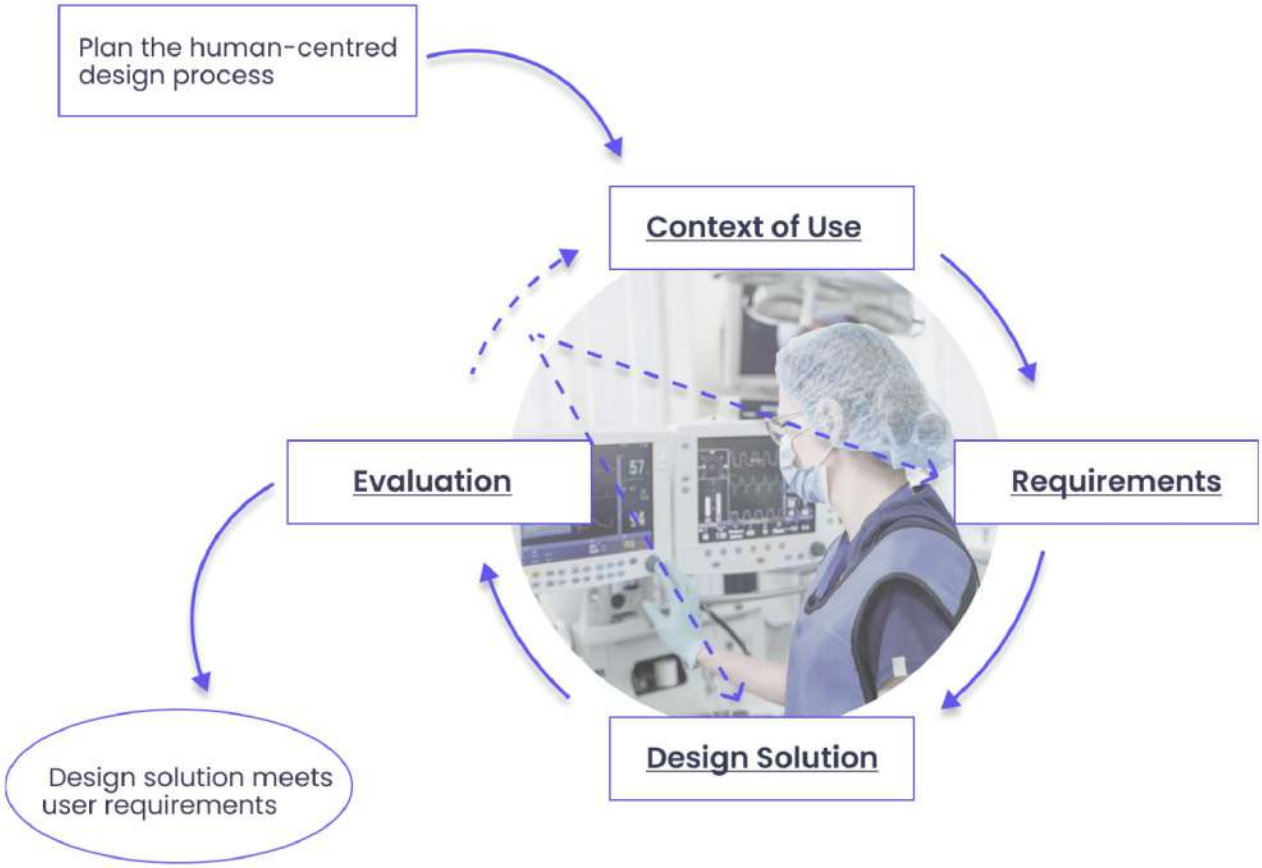



**Figure 1: The design process**

# Chapter 2

# The NICU Environment

## Chapter Overview

2.1 Patients

2.2Architectural layout

2.3 Equipment

2.4 The team

# 2.1 The NICU context

## Patients

A significant proportion of patients in the NICU are infants born prematurely, specifically at less than 32 weeks gestational age. These patients have unique and complex needs due to their delicate health status. These neonates often grapple with a variety of health complications including but not limited to prematurity, low birth weight, congenital malformations, genetic abnormalities, infections, and a spectrum of other neonatal disorders like respiratory distress syndrome, neonatal jaundice, and hypoglycemia. Such conditions often demand constant monitoring for vital signs like heart rate, breathing rate, blood pressure, temperature, and oxygen saturation, reinforcing the need for effective alarm management systems.

The nature and intensity of care provided in the NICU are tailored to each infant's individual needs, from respiratory and nutritional support to potential surgical interventions and specialized therapies. Beyond medical care, the NICU environment also promotes parent-infant bonding, such as through skin-to-skin contact, integral to the babies' overall well-being.

## Architectural layout

The neonatal intensive care unit at Erasmus has a total of 35 beds. These are distributed across four distinct units, each providing a unique type of care for newborns, in addition to four separate individual rooms(Spagnol et al., 2022).

The four units are the traditional 'open bay-area' design(Harris et al., 2006 ). A typical unit in the NICU integrates eight meticulously equipped beds and a central station. Each bed is surrounded by a variety of medical equipment, including incubators, ventilators, and a variety of monitors that constantly measure vital signs.

The central station is a vital hub of activity where medical staffs monitor patients' vitals, respond to alarms, manage health records, coordinate care, administer medications, support families, and prepare for emergencies(Taylor, 2014).

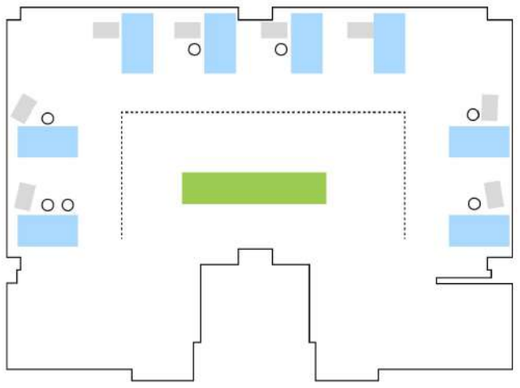


Figure 2. NICU structure inside Unit 1 of Sophia Children's Hospital

In the last twenty years, there's been a shift towards using single-family room (SFR) layouts in NICU instead of the conventional 'open bay-area' style(Harris et al., 2006). As a hospital that continually strives for improvement, Erasmus is also planning to implement such changes.

The Single-family room presents a chance to enhance control over factors like light and noise, boost satisfaction levels among parents and staff regarding care, improve the working conditions for nurses, and potentially lower the cost of care without escalating negative outcomes.

However, the SFR setting, with its diminished patient visibility and heightened reliance on patient monitoring, poses a difficulty in ensuring a safe environment for infants. This situation would Lead to:

1. changes in communication methods and workflows.
2. Nurses would have a greater reliance on remote monitoring.
3. A tendency among healthcare professionals to establish more conservative alarm thresholds.

Therefore, optimizing alarm management, and particularly establishing appropriate alarm settings, becomes significantly more critical.

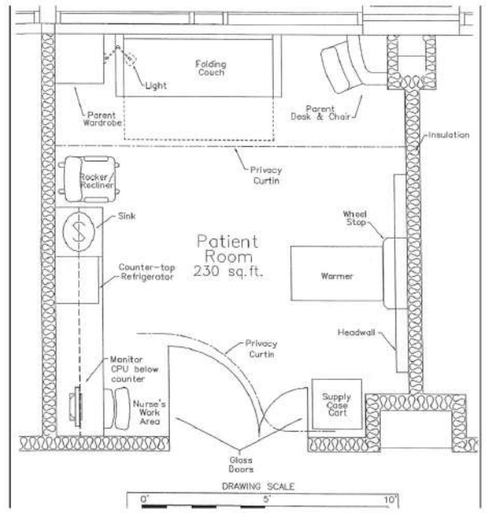



Figure 3. Floor plan of the single-family NICU room(Stevens et al., 2007).

Figure 4. Configuration of the single-family NICU room(Örtenstrand, 2014).

# Equipment

The technological sophistication of these units encompasses diverse devices tailored to the unique physiological requirements of neonates. These range from incubators, which furnish a controlled environment for newborns, to mechanical ventilators offering respiratory support, and a multitude of monitoring systems that meticulously track vital parameters such as heart rate, blood pressure, and oxygen saturation. Additionally, the administration of nutrition and medication is facilitated through the use of feeding tubes and intravenous lines.

All units of NICU at Erasmus are equipped with Dr¨ager Infinity®M540 patient monitors, with one assigned to each bed. These devices account for the majority of the acoustic alarms generated in the unit. The said monitors are integral components of the Infinity® Acute Care System (IACS) provided by Dräger(Spagnol et al., 2022).

Almost every piece of equipment is designed to generate alarms, each serving a different function. Ventilators, for example, generate alarms for high or low pressure, apnea, or disconnections. Cardiovascular monitors issue alarms for changes in heart rate, blood pressure, and other parameters, while pulse oximeters and CO2 monitors alert to significant fluctuations in oxygen saturation and carbon dioxide levels, respectively. Infusion pumps signal when there are issues like low fluid levels or line occlusions, and temperature monitors alert when a neonate's body temperature falls outside the set parameters.

Therefore, the majority and diversity of these alarms necessitate the optimization of current alarm management system. Such optimization could be achieved by minimizing false and non-actionable alarms while ensuring that true alarms are acknowledged and addressed promptly.

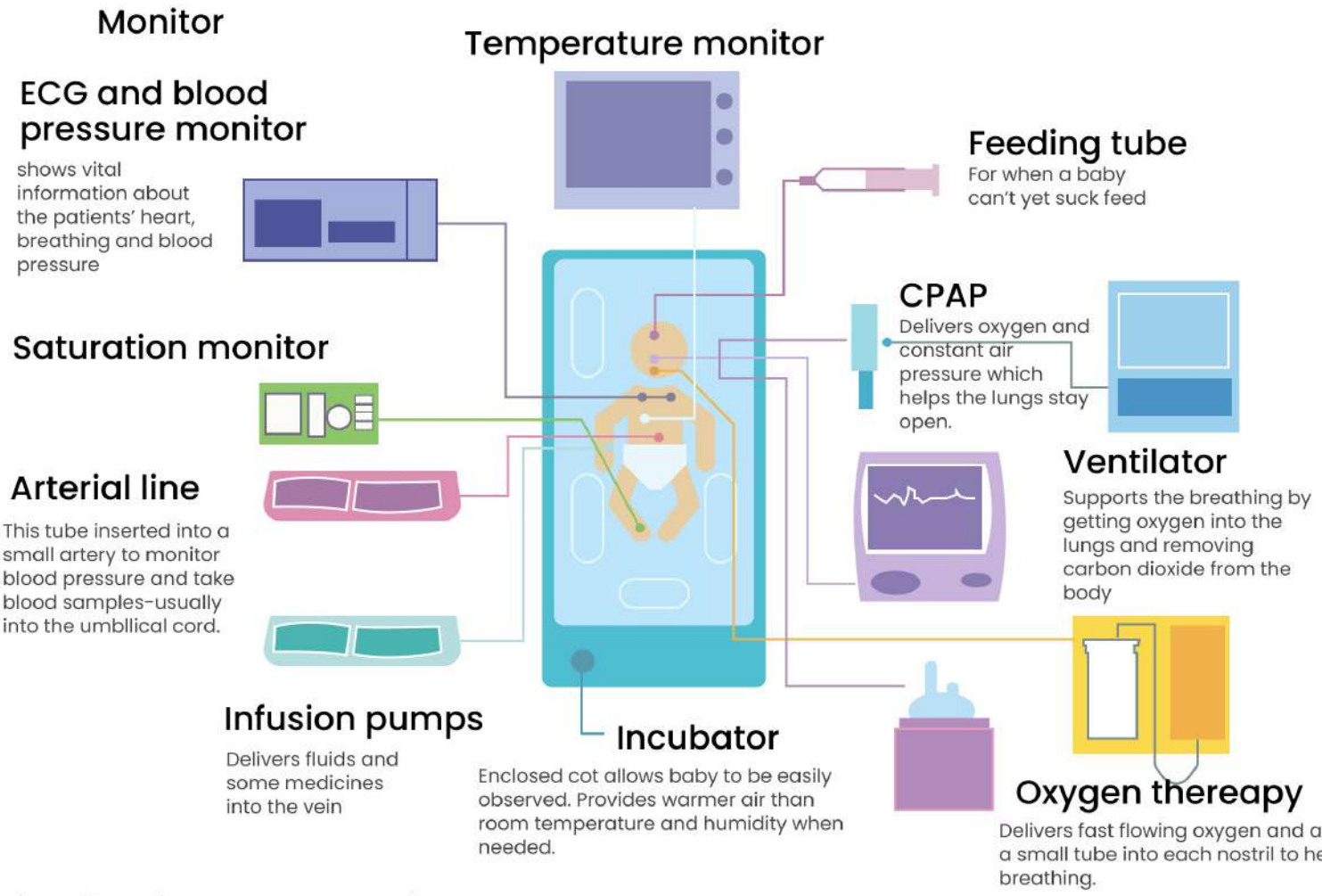



Figure 5. Equipment may see at the bedside in the NICU

# The team

A variety of specialized professionals collaborate in Neonatal Intensive Care Units to provide optimal care and support for newborns who are ill or born prematurely, as well as their parents. These professionals have undergone specific training in neonatology and related areas, enabling them to cater to the unique needs of each baby.

| | |
|---|---|
| **Patients**<br>The patients health status influences the actions of the entire team. | **Physicians**<br>They monitor the health of the babies, administer treatments, and make medical decisions. |
| **Nurses**<br>They monitor the baby, administer infusions and drugs, and take over the daily care of the child. Nurses are often the ones who spend the most time with patients and can quickly notice changes in their condition. | **Medical support**<br>There are several crucial members of the NICU team that provide medical support beyond the roles of nurses and physicians. These roles often include: Lactation Specialists, Dietitians/Nutritionists, Respiratory Therapists, Physical, Occupational, and Speech Therapists |
| **Family support**<br>They provide emotional, psychological, and social support for patients' family. Key roles that provide family support include: Psychologists, Social Workers,Chaplains or Spiritual Care Providers. | **Services**<br>The service team in a NICU plays an essential role in ensuring smooth operations and enhancing the comfort and experience of both the babies and their families. The roles of the services provided include: Technicians, Cleaning Staffs, ICT, ect. |

Table1. The NICU team

# Chapter 3

# Theoretical Research on alarms

## Chapter Overview

## 3.1 Alarm and Alarm Fatigue

Why alarm?
Alarm categorization
What is alarm fatigue
What are the causes of alarm fatigue in NICU?

## 3.2 Alarm Management

Components of an “alarm”
How to improve alarm management system
Alarm response in NICU
Nurses’ decision-making process related to alarms

## 3.3 Alarm Customization

Method
Case Study
Gap

# 3.1 Alarm and Alarm Fatigue

## Why alarm?

Firstly, the NICU represents a critical care environment where timely and accurate responses to alarms can have profound implications for patient outcomes. Given the fragile health of neonates, effective alarm management is of paramount importance to ensure the safety and well-being of these vulnerable patients.

Secondly, the NICU is a high-intensity setting with numerous monitoring devices, each generating its own set of alarms. This complexity presents a unique challenge in terms of alarm management. The substantial volume of alarms in this environment increases the risk of desensitization among healthcare providers, potentially compromising the quality of patient care.

Furthermore, optimizing alarm management in the NICU also has a broader impact on the healthcare delivery system. It can lead to improved efficiency, reduced healthcare costs, and enhanced patient and staff satisfaction(Varisco et al., 2021). Therefore, improvements in this area could have a ripple effect, leading to overall improvements in healthcare quality.

Finally, while much progress has been made in alarm management, there is still substantial room for improvement and innovation. My project aims to contribute to this ongoing effort by proposing the DFI's methods to optimize alarm management in the NICU. We believe that this focus aligns well with the evolving landscape of healthcare, where the integration of technology and patient care continues to be an area of significant interest and potential.

## Alarm categorization

The Neonatal Intensive Care Unit at Erasmus categorizes alarms into three tiers based on urgency(Spagnol et al., 2022):

1. High priority or 'red alarms': These are activated by potentially lethal physiological conditions demanding immediate intervention, like ventricular fibrillation. The acoustic alarm associated with these conditions is signified by a red alert.
2. Medium priority or 'yellow alarms': These indicate significant physiological conditions that warrant attention but are not immediately life-threatening, such as exceeding respiratory rate limits, or technical problems like hardware failures. The accompanying acoustic alarm is designated by a yellow alert.
3. Low priority or 'blue alarms': These warn about technical issues that could impair the functioning of the monitor, such as ECG waveform artifacts. The sound alarm associated with these issues is represented by a blue alert.

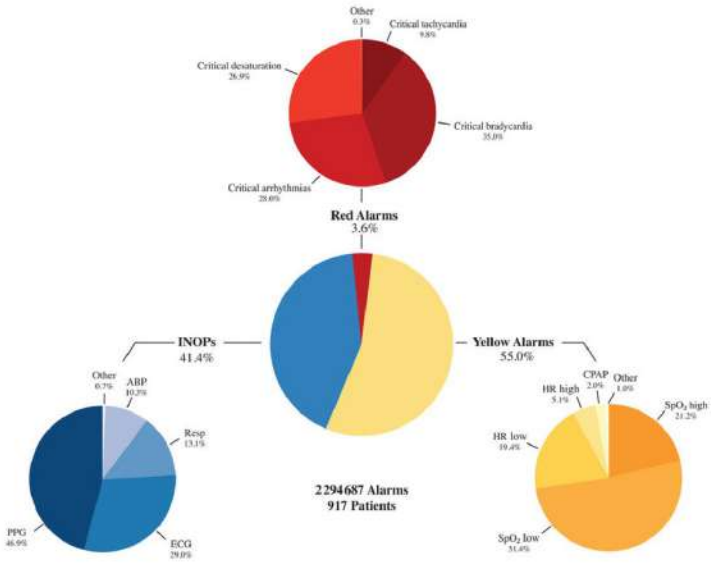



Figure 6. Distribution of NICU patient monitoring alarms(Li et al., 2018).

## NICU Alarm Environment

Cardiorespiratory monitors are widely used in neonatal intensive care units, providing a continuous assessment of numerous physiological parameters. The data can be viewed at the patient's bedside or from a central location. The alarms are set to notify healthcare professionals about potentially dangerous or ongoing harmful conditions, necessitating evaluation and possible intervention. Nonlatching audible alarms, which cease once the triggering condition is resolved without requiring manual silencing by a clinician, are beneficial in the NICU where transient conditions such as fluctuating SpO2 or heart rate frequently occur.

NICU monitors' alarm configurations typically include both preset and adjustable settings determined by manufacturers, hospitals, or operators. These settings can govern aspects like alarm thresholds, the delay before alarm generation, alarm latching, and alarm escalation protocols. Adjustments made by nurses, like those related to SpO2 or respiratory rate alarm thresholds, can enable more personalized care for specific patient groups, like those with very low birth weight or cyanotic heart disease.

### Default alarm setting in the Erasmus NICU

| Alarm | Default Setting |
|---|---|
| High heart rate limit | 200 |
| Low heart rate limit | 100 |
| High RESP limit | 80 |
| Low RESP limit | 20 |
| High SpO2 limit | 95 |
| Low SpO2 limit | 89 |
| High PLS limit | 200 |
| low PLS limit | 120 |
| Mean arterial blood pressure high | 35 |
| Mean arterial blood pressure low | 28 |
| Temperature high | 37.4 |
| Temperature low | 36.6 |

Table2. The Default alarm limits in the Erasmus NICU

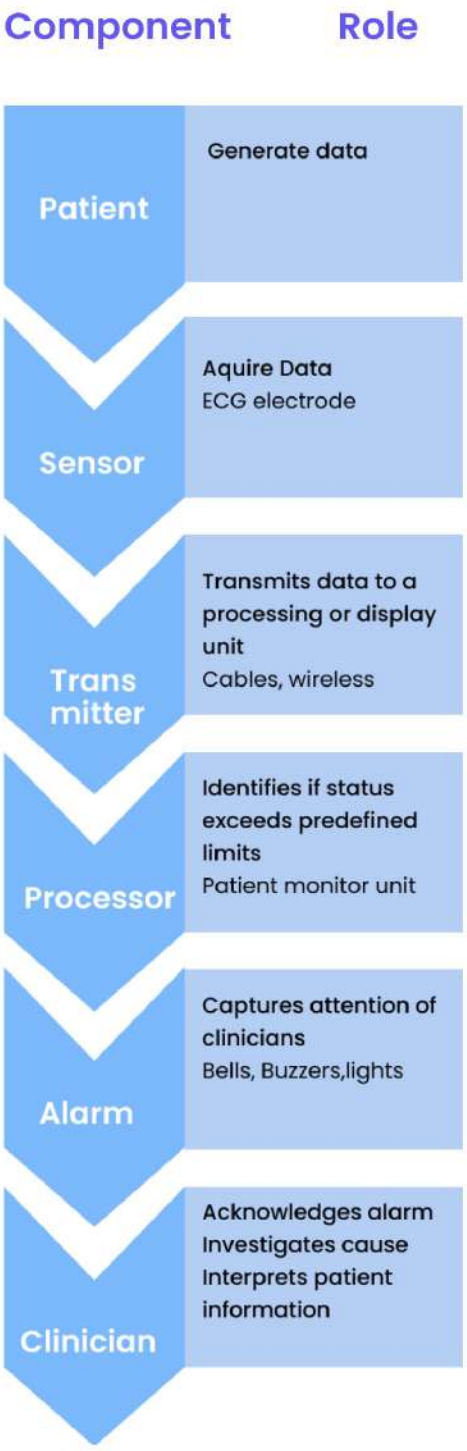



Figure 7. Component of an alarm.

## What is alarm fatigue

Alarm fatigue is a term commonly used to describe the effect of a high number of alarms on caregivers. Frequent alarms, many of which can be avoided, can lead to inadequate responses and severely impact patient safety. It is a significant concern in healthcare settings, especially in areas like intensive care units where alarm systems are prevalent.

**2595**
Mean number of alarms per day(Özcan, 2022).
In one NICU unit of Erasmus

**1460**
Median number of alarms one patient(Özcan, 2022).
In one NICU unit of Erasmus

**862**
Deaths
Number of alarm-related deaths reported in an FDA in 2005-2012

## What are the causes of alarm fatigue in NICU?

Alarm fatigue in NICU arises from several main causes. One of the most significant issues is the **high volume of false or non-actionable alarms**. NICUs use various monitoring systems, like those for heart rate, respiration, oxygen levels, and more, which can sometimes be too sensitive. These systems often alert for minor fluctuations that are not truly indicative of a threat to the neonate's health, causing staff to become desensitized over time due to the frequent non-urgent alarms.

**Poor differentiation** between alarms is another significant contributor to alarm fatigue in the NICU. When many alarms sound similar or when there are many types of alarms without clear distinctions, it becomes challenging for healthcare professionals to prioritize their responses. This can lead to slower reaction times or, in the worst cases, potentially life-threatening alarms being missed.

**Alarm overload** also plays a key role in the emergence of alarm fatigue. In an environment like the NICU, there are numerous devices, each with its own set of alarms. This can result in an overwhelming amount of noise and visual stimuli, confusing and overwhelming healthcare providers.

**Technical issues** with monitoring equipment can exacerbate the problem further. Equipment that is not well maintained or is malfunctioning can generate unnecessary alarms, contributing to the overall alarm burden and increasing the risk of alarm fatigue.

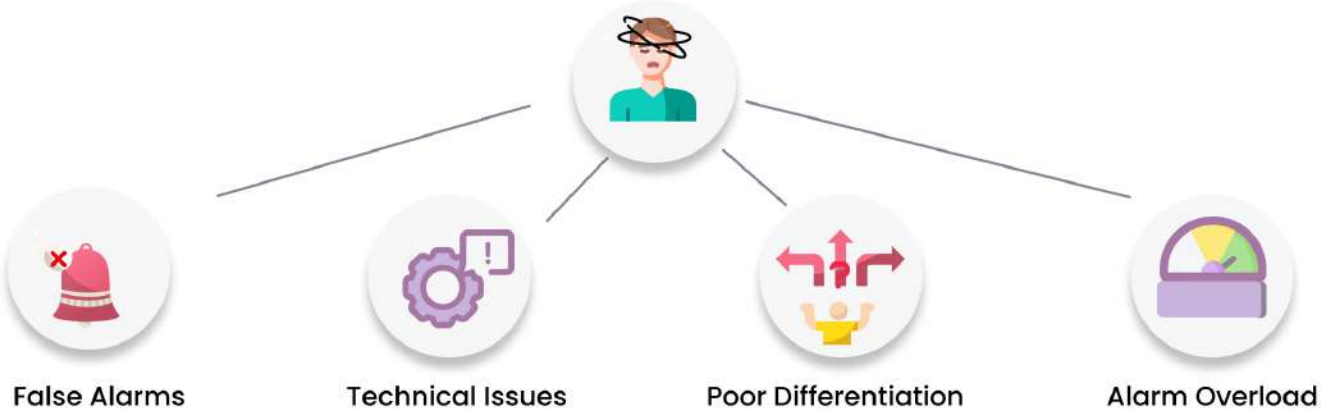



Figure 8. Causes of alarm fatigue.

## How to improve alarm management system

Several elements contribute to the overload of clinical alarms and the subsequent alarm fatigue. Improving these elements may optimize existing alarm management to reduce alarm burden(Fig. 8).

**Equipments**: Certain circumstances might involve the unnecessary use of alarm-triggering devices. Excessive use of oximetry monitoring in a lively infant may result in motion-related distortions and unwarranted alarms(Johnson et al., 2017). Devices that don't meet quality standards or have unreliable sensors could heighten the likelihood of false alarms due to signal interference(Johnson et al., 2017). Unsorted alarm signals from devices for less critical events may hinder nurses from properly prioritizing their responses. False alarms brought about by faulty heart rate monitor leads or oximetry probes, motion, or light interference with probes also significantly add to alarm fatigue(Cvach et al., 2013)

**Alarm Settings**: The settings on medical devices, such as alarm thresholds, delay times, and alarm persistence, can significantly influence the amount of alarm fatigue experienced by healthcare workers. However, definitive guidelines on the best alarm settings for newborns are scarce and typically originate from retrospective studies that associate the frequency and duration of cardiorespiratory events with outcomes(Cvach et al., 2013). Notwithstanding the scarcity of such guidelines, the nurses in the NICU, due to their extensive time spent with patients, are in a unique position to evaluate the current alarm settings. Drawing on their own clinical experience and understanding of the patient's specific condition, these nurses can make appropriate adjustments to the alarm settings, potentially reducing alarm fatigue and improving patient care.

This approach is contingent on the nurses' expertise, patient's condition, and institutional policies allowing such adjustments.

**Nurses**: The alarm management systems in NICUs are intricate, comprising numerous alarm settings, priorities, and escalation procedures. As the primary users of these systems, NICU nurses require comprehensive training and continuous support to properly configure and respond to device alarms. A survey found that 60% of ICU nurses felt they needed more training on monitors to manage alarms effectively(Sowan et al., 2016). Clinical decision support system aids, developed in collaboration with clinical engineering, could enhance compliance with alarm settings and potentially decrease the frequency of alarms(Brantley et al., 2016).

**Patients**: The frequency of alarms might increase in situations where patients' health deteriorates or their condition is undermanaged. Alarm settings specific to the patient's condition may be necessary to ensure that triggered alarms are relevant and require action.

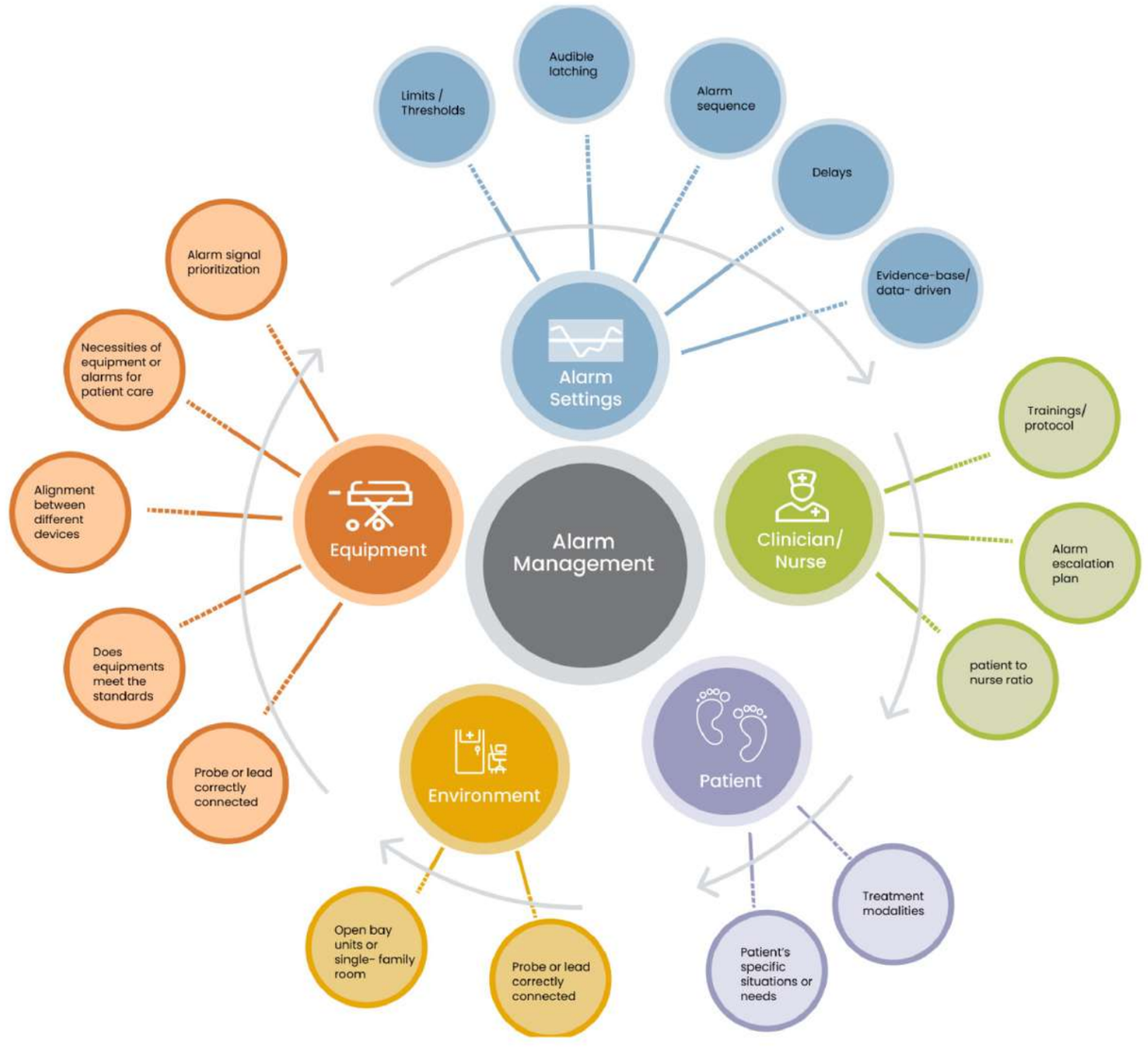



Figure 9. Key factors for optimizing existing alarm management to reduce alarm burden

## Alarm Response in NICU

NICUs often face a high volume of alarms, many of which have low validity. Studies in Pediatric Intensive Care Units discovered that less than 10% of clinical alarms led to a change in patient care(Lawless, 1994; Tsien, 1997).

This excessive alarm load can hinder the nurses' ability to respond to alarms and carry out their primary tasks, which include patient care, assessments, medication administration, feeding infants, documentation, among others.

## Response type

Based on literature studies, we summarised that nurses responded to monitor-generated alarm in one of 5 ways: waiting for self-correction response; partial response, it refers to a situation where nurses acknowledge an but do not take the necessary action to silence it; central station response; bedside silence response and no immediate response.

## Response time and alarm duration

Alarm fatigue is a complex issue to quantify directly, so a commonly used indirect measure is the response time to an alarm. A delayed response might indicate that the healthcare provider has become desensitized or is disregarding the alarm(Bitan et al., 2004). A rise in non-actionable alarms, whether false or nuisance, is linked to prolonged nurse response times.

One study findings indicate that the likelihood of nurses responding to an alarm within 15 seconds is 0.053, within 30 seconds is 0.067, and within 60 seconds is 0.098 from the start of the alarm. These probabilities are accumulative over time.

Since the initial reaction of nurses is usually to acknowledge and thereby silence the alarm, a longer alarm duration should generally correlate with response time. However, in situations where alarm conditions might resolve themselves, alarm duration would merely reflect the patient's condition and bear little relation to response time or alarm fatigue. In such instances, data on alarm duration might be useful in setting appropriate alarm delay times to prevent nuisance alarms(Gorges et al., 2009).

### Self-correction response

The monitor, without any nurse response, would stop sounding an alarm. The self-correction was caused by the patient values changing back to within allowed parameters. To be allotted to this category, an alarm must have self-corrected within 60 seconds of initial sounding.

### Partial response

A partial response refers to a situation where nurses acknowledge an but do not take the necessary action to silence it. This behavior may stem from factors such as multitasking, habituation, or prioritization of other tasks.

### Central station response

At the central nursing station, a nurse responded to the alarm by hitting a function key on the monitor touch screen or keyboard that would stop the alarm from sounding. To be allocated to this category, central station responses had to occur within 60 seconds from the start of the alarm.

### Bedside silence response

Within 60 seconds, nurse would press the "pause" button on the bedside monitor. If monitor values were not back within assigned parameters at the end of the countdown, the alarm resumed. If the alarm resumed after the 2-minute countdown, it was counted as a new instance of an alarm, and a new nurse response to the alarm was noted. If values were within assigned parameters at the end of the countdown, the alarm would end.

### No immediate response

The alarm **rang for longer than 60 seconds**, but there was no visible reaction by a nurse. Responses in this category include instances when nurses were present but overtly ignored the alarm or when potential nurse responders were present but otherwise occupied (eg, engaged in conversations with others, writing progress notes).

# Nurses' decision-making process

## Theoretic framework

After categorizing nurses' response to alarms, We start to explore what causes those response. As we all know, engaging with alarm systems can be viewed as a task involving decision-making.

The Situated Clinical Decision-Making Framework provides a systematic approach to examining nurses' decision-making processes in a clinical setting and to guide the choice of appropriate strategies to enhance clinical decision-making skills(Gillespie, 2010). This framework identifies four phases in the clinical decision-making process—cues, judgments, decisions, and evaluation(Fig. 1).

In this framework, the nurse's decisions are triggered by cues. Upon detecting this initial cues, the nurse gathers more signals to better understand the situation. Judgment, in this context, is considered the most suitable conclusion that can be reached at a given moment, based on the available information. Making a decision involves committing to a course of action, which could be attempting something.

Evaluating the outcome involves reflecting on the effectiveness of signal gathering, judgment, and decision-making, and determining if further action is needed.




| Foundational knowledge: Definitions | |
|---|---|
| Knowing the profession | Knowledge of standards of practice, competencies, skills and roles of nurses. |
| Knowing the self | Knowledge of individual strengths, limitations, skills, experience, assumptions, preconceptions, learning and other needs. |
| Knowing the case | Knowledge of pathophysiology, patterns that exist in typical cases, predicted trajectory and patient responses. |
| Knowing the patient/client | Knowledge of a patient's or client's baseline data, patterns that exist in laboratory or other data, or patterns in physiological responses to pathology and treatment. |
| Knowing the person | Knowledge of a patient's or client's past experience in relation to health and illness, patterns in relation to personal response to pathology and treatment, preferences, supports and resources. |

Fig. 10. The Situated Clinical Decision-Making framework (Gillespie and Paterson, 2009)

## Application to alarms

Based on the 4 phases provided by the situated clinical decision-making framework, we conducted literature research to investigate the decision making process related to alarms(Wung et al., 2018; Gazarian et al., 2015)

### Nurses decision making process related to alarms

**A CUES**

- Tone, duration, and type of alarm
- Other competing activities
- Patient status

**B JUDGEMENT**

**Alarm urgency**

- Tones of the alarm and
- knowledge of the patient's condition
- Immediate visualization of the patient.

**Alarm effectiveness**

- Through both visual and auditory means to decide if an alarm is authentic.

**C DECISION**

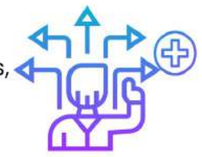
**Initial response to an alarm**

- Observe the patient
- Assess the alarm validity

→ whether the alarm warranted interventions.

**D EVALUATION**

**Resetting default alarm parameters**



- Providers' treatment orders,
- Observing the patient's baseline vital signs,
- A change in patient's clinical condition
- History alarm data.

**Decision on seeking consultation**

- Someone with whom they have a long and positive working experience.

**Barriers to response to alarms**

- Low staffing
- Multiple job responsibilities
- Competing priority tasks.

**Training received on monitors**

- Nurses have limited familiarity with monitors.

### 4 main reasons determine nurse-responsiveness to alarms

Therefore, after analyzing the nurses' decision making process in relation to alarms, four factors were found to determine their response to alarms, see Figure 11. The following design phase should focus on these factor.

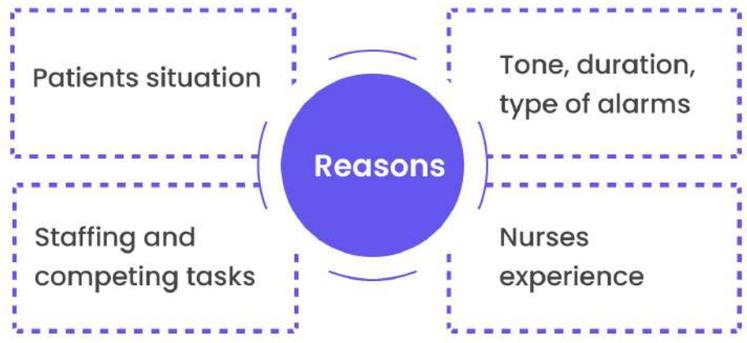



Figure 11. 4 main reasons determine nurse-responsiveness to alarms

# Alarm customization

As mentioned earlier in the discussion of key factors for optimal alarm management, alarm customization is one of the most effective measures to reduce alarm burden. Alarm customization means adjusting and configuring the alarm settings of medical monitoring systems to align with the specific clinical characteristics and needs of individual patients. Here are several aspects that alarm customization encompasses:

### Adjusting Thresholds

As we discussed earlier, adjusting the default alarm limits based on the patient's condition can be effective in reducing alarm fatigue, and a large number of literature has confirmed this experimentally(table1).

### Customizing Alarm Indicators

Changing the sounds or visual cues for different types of alarms helps clinicians quickly identify the nature of the alarm without having to look at a screen.

### Setting Alarm Delays

This involves setting a delay for the alarm to trigger, giving the system time to auto-correct or for transient changes to resolve themselves. This can reduce the number of false or nuisance alarms.

### Intelligent Alarm Algorithms

Use algorithms to evaluate a combination of parameters in real-time. For instance, for a patient with respiratory issues, the alarm can be customized to consider not only oxygen saturation but also respiratory rate and end-tidal CO2 levels.

### Adjusting Thresholds

As we discussed earlier, adjusting the default alarm limits based on the patient's condition can be effective in reducing alarm fatigue, and a large number of literature has confirmed this experimentally(table1).

### Customizing Visual Displays

Changing the sounds or visual cues for different types of alarms helps clinicians quickly identify the nature of the alarm without having to look at a screen.

# Alarm customization

These studies indicate that customization of alarm settings can significantly reduce the number of alarms. Some of the studies talk about the process of alarm customization involving clinical reasoning and decision making , and explore what factors play an important role in this process. We will base this part of the theoretical research to conduct field research on what information is valuable to support nurses in making adjustments to alarm limits. This is described in the next chapter.

| Study | Intervention | Results |
|---|---|---|
| Graham et al. | The nurses were trained in the valuable skill of adjusting alarm limits to meet the specific needs of each patient. | This reduction of 43% alarms can be attributed to the adjustment of monitor alarm defaults, the thorough evaluation and customization of monitor alarm limits and levels, and the effective implementation of a cross-disciplinary monitor policy |
| Ruppel et al. | Interviews on nurses' customization of clinical reasoning | A conceptual framework was developed to uncover the characteristics that influence the personalization of alarms. |
| Cho et al | | In only 18.8% of instances did nurses personally adjust the alarm range to accurately mirror the patients' condition. |
| Wung et al | A structured interview with data analysis | The physiological monitor alarms that are predominantly responsible for triggering sensory overload have been pinpointed. |
| Ruppel et al. | Interviews on nurses' customization of clinical reasoning | practices of customization varied significantly and were shaped by various factors such as clinical expertise, the absence of education on customization, and past negative experiences. |
| Honan et al. | Using the Krippendorff approach to analysis | Nurses at the bedside are advised to set appropriate alarm limits fit to the unique needs of each patient. |
| Bi et al | CEASE bundle | Alarms from auditory monitors saw a reduction ranging from 30 to 45% without any negative impact on patient outcomes. |

Table1. literatures about customization of alarm limits

A nurse is adjusting the thresholds of the alarm

# Chapter 4
# Field Research

# Background

As discussed in the preceding chapter, an effective means of optimizing the alarm management system is to adapt alarm limits according to the patient's specific conditions. This practice relies heavily on the nurses' extensive experience and intimate knowledge of their patients' health status, thus reinforcing their indispensable role in alarm management.

Recognizing the centrality of nurses in alarm customization, it is vital to closely examine their experiences and needs. As such, this chapter undertakes a thorough investigation into nurses' perspectives on alarm limits customization. To achieve this objective, we utilize a variety of user research methods, from surveys to observations and participatory design sessions, to get insights about nurses' day-to-day interactions with alarm systems, their needs and pain points, as well as their suggestions for improvement.

A deep dive into the lived experiences of nurses will provide valuable context and information, which may pave the way for novel design opportunities.

Firstly, we explore the existing process that nurses follow in responding to and managing alarms. This involves understanding the factors they consider when adjusting alarm limits, the challenges they face due to the current system limitations, and their coping mechanisms.

Next, we delve into their perceptions of the ideal alarm system. This encompasses identifying the desired features and functionalities of an alarm system that can support their workflow effectively, reduce alarm fatigue, and ultimately improve patient care.

Following this examination of nurses' perspectives, we analyze the collected data to identify common themes and patterns. These insights serve as a foundation for the design requirements and considerations that will inform the development of the interface for alarm customization.

**Research questions**

The main research question of this chapter are formulated as follows:

**What are NICU nurses' needs on adjustment of alarm limits and what are the design opportunities?**

- What factors do NICU nurses consider when adjusting alarm limits?
- What are the current challenges or difficulties NICU nurses face when adjusting alarm limits?
- What features or characteristics do NICU nurses desire in an alarm management system?
- How can ICU nurses be supported to adjusting alarm settings.

# Method

## Questionnaires

In order to know *What factors influence the nurse to adjust the alarm limit*, a list of questions were prepared based on conceptual model demonstrating the relationship between alarm adjustment clinical reasoning themes(Fig.XX).

By analyzing the results of the semi-structured interviews, the study found that nurses' customization of physiologic monitor alarms is influenced by several factors:

1. **Unit Alarm Culture and Context:** The culture of the clinical unit and the responses of colleagues and patients to alarms play a significant role in how nurses customize alarms.

2. **Nurse Attributes:** The level of clinical expertise and comfort of the nurse also affects how they customize alarms. Nurses tend to customize alarms based on their technical understanding of the physiologic monitors and their own level of comfort.

3. **Motivation to Customize:** Nurses are motivated to customize alarms to better monitor their patients and reduce the number of clinically irrelevant alarms. This also helps to address the problem of alarm fatigue.

4. **Customization "Know-How":** The technical knowledge and understanding of how to customize the alarms also play a role in alarm customization.

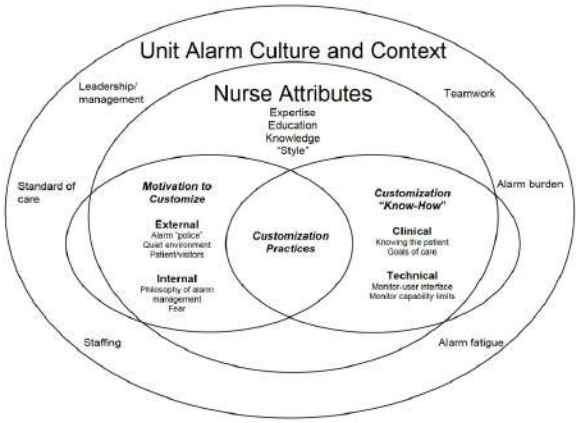
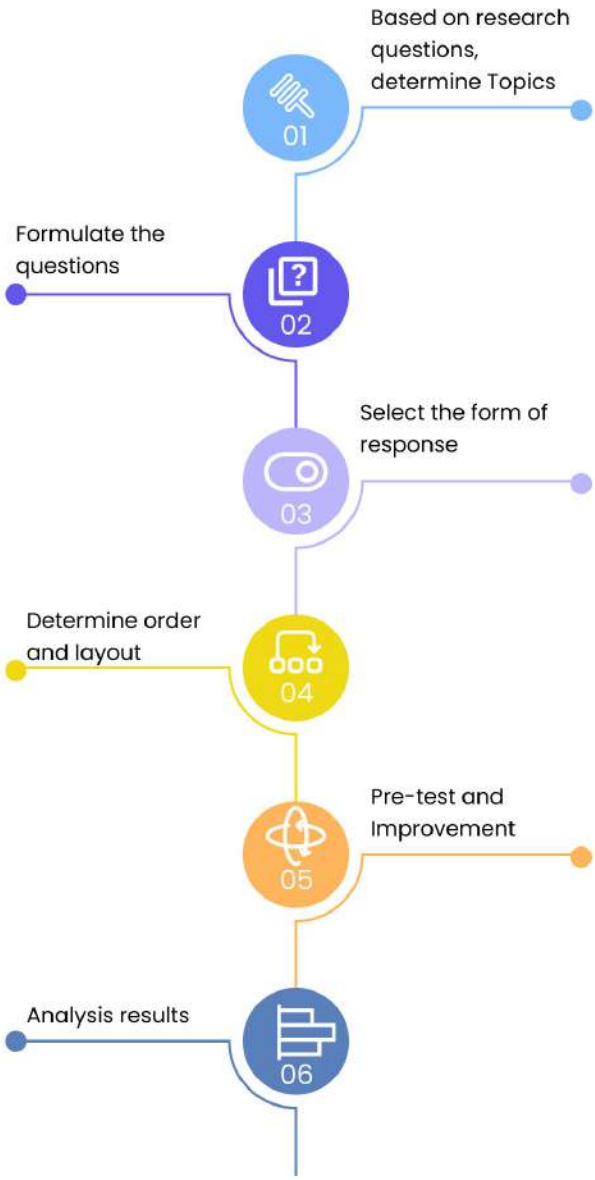



Figure.12 Conceptual model demonstrating the relationship between alarm adjustment clinical reasoning themes(Ruppelc et al., 2019)

## Procedure

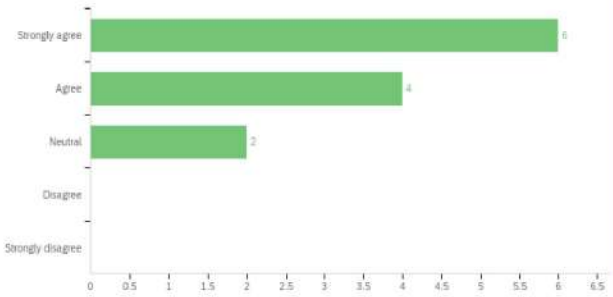


# Analysis

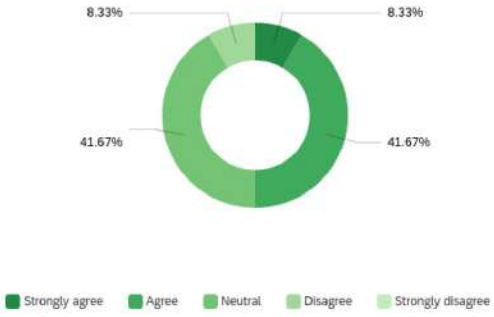
## Theme 1: Unit Alarm Culture and Context

**Information sharing and collective decision-making:** The majority of respondents (10 out of 12) agree or strongly agree that it's necessary to inform colleagues about alarm adjustments. This suggests a high level of collaboration and communication within the nursing team, reflecting a positive culture of information sharing and collective decision-making.

*You think it is necessary to inform colleagues about the adjustment*



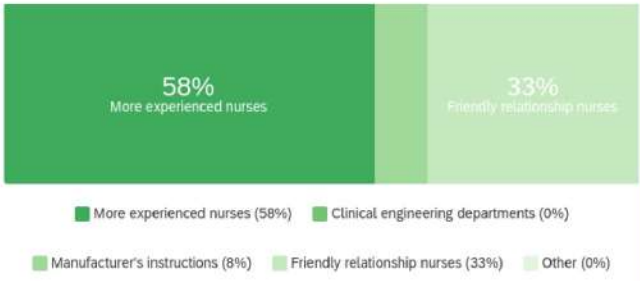

*You trust the response to alarms from other nurses*




**Trust in Colleagues:** Most respondents (6 out of 12) agree or strongly agree that they trust the response to alarms from other nurses. However, the fact that 5 respondents were neutral and one strongly disagreed indicates that there may be variability in trust levels among the team, possibly reflecting differences in experience, training, or individual relationships.

**Seeking Guidance:** Most nurses (7 out of 12) would seek a more experienced nurse when in doubt, suggesting that experience plays a significant role in alarm management. Interestingly, 4 respondents prefer to seek a more friendly nurse, hinting at the importance of interpersonal relationships and communication skills in the work environment.

*If you have any questions about alarm limits, who do you consult for help*

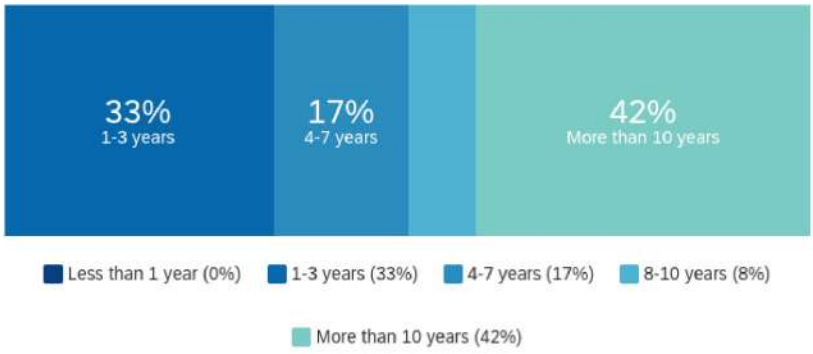



*Before each shift, what would you discuss with your colleagues about the alarm setting*


**Communication about Alarm Adjustment::** Most nurses (7 out of 12) Nurses appear to be open to explaining their reasoning behind alarm adjustments to their colleagues. However, communication seems to be contingent on the perceived importance of the adjustment, as respondents mentioned they would only inform colleagues about significant changes.

# Theme 2: Nurse Attribute

*How many years of experiences do you have working as a NICU nurse?*




Because this study finds that nurses' attribute related to alarm systems are strongly influenced by their years of experience, the analysis of these findings would be stratified by experience level.

## Training & Institutional Support:

- All groups have received some form of training, with the less experienced nurses (1-3 years) mentioning bedside teaching as an additional resource. This suggests an appreciation for a mix of structured and practical, hands-on learning.
- While nurses with more than 10 years of experience feel confident with the institutional support they receive, the less experienced groups (1-3 years, 4-7 years) have a more mixed perception.

## Knowledge & Confidence in Alarm Parameter Adjustments:

- Nurses with more than 10 years of experience feel most confident and knowledgeable about adjusting alarm parameters, which likely stems from their extensive experience in the field.
- The less experienced groups (1-3 years, 4-7 years) have a moderate level of knowledge about the alarm parameters, and some specific alarm parameters make them feel unconfident.

# Theme 3: Motivation to customize

## Basis for Alarm Adjustments & Confidence in Reducing Nuisance/False Alarms:

- Across all groups, nurses adopt a patient-centered, data-driven approach to alarm adjustments, with decisions based on patient symptoms and historical alarm data.
- Despite varying levels of experience, all nurses express confidence in adjusting and monitoring alarm parameters to reduce nuisance/false alarms.

# Results

**Concerns about alarm adjustment:** The analysis of the responses to this question underscores several key challenges nurses face when setting alarms in the NICU - namely concerns about patient safety, device complexity, incomplete understanding of patient conditions, and a lack of reference points for appropriate alarm limits. These challenges offer insightful design opportunities for an interface aimed at helping nurses manage alarms more effectively.

*You have difficulties in setting alarms properly because of*


## Theme 4: Customization"Know-How"

### Steps to Adjust Alarm Limits:

- The steps taken to adjust alarm limits differ slightly across the groups, reflecting their varying experience levels. More experienced nurses (more than 10 years) consider previous trends and specific patient illnesses, while the less experienced nurses (1-3 years) may consult a doctor for important adjustments.
- The mid-level experienced nurses (4-7 years) take an approach of validating alarms and making adjustments when frequent false alarms occur.

# Insights

The questionnaire responses have shed light on the crucial aspects impacting NICU nurses' experiences with alarm management.

It's clear that institutional support and training, along with an intuitive and patient-data integrated system, are key for enhancing their confidence and effectiveness in adjusting alarm parameters. Nurses expressed the necessity to inform their colleagues about adjustments they made, indicating **the need for effective and efficient communication channels**. They acknowledged the trust placed in their peers' responses to alarms, signifying the significance of teamwork in this setting. Most of the **nurses trusted their colleagues, especially the more experienced ones.**

While their approach to alarm adjustments and ways of reducing false alarms differ based on experience levels, **the need for a user-friendly and adaptable system stands out.**

Major challenges they face, like patient safety concerns, device complexity, understanding patient conditions, and lack of reference on suitable limits, also underscore the need for a system addressing these issues.

In essence, these findings underscore the importance of designing a tailored, user-friendly tools that **assists nurses in alarm management** while contributing to improved patient outcomes.

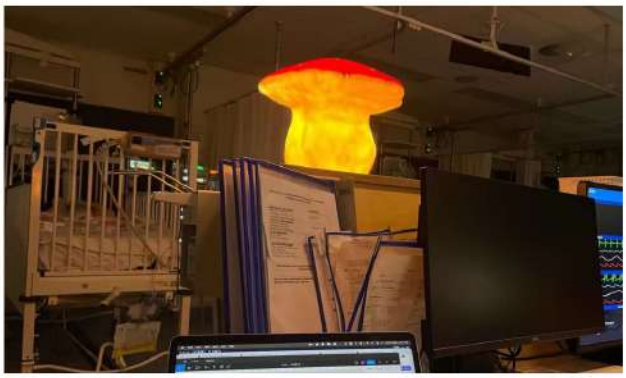
# Observations

In an effort to gain a practical understanding of how nurses interact with the existing alarm system, we undertook two observational studies. The first took place in units 3 and 4 of the Pediatric Intensive Care Unit (Figure.X). We draw the patients journey map While this environment is not precisely the NICU, it bears significant similarities. Given that the Erasmus is planning to merge the NICU and PICU into a single department in the future, insights gleaned from the PICU would undoubtedly be applicable to the NICU. This first observation enabled me to obtain a preliminary understanding of the frequency of alarms, the nurses' response rates, and their response methodologies.

Subsequent to the first observation, a brief interview with two nurses was conducted. This served to enrich the insights gleaned from the direct observation and added a subjective layer to our understanding, enabling a more comprehensive view of the real-life functioning of the alarm system.

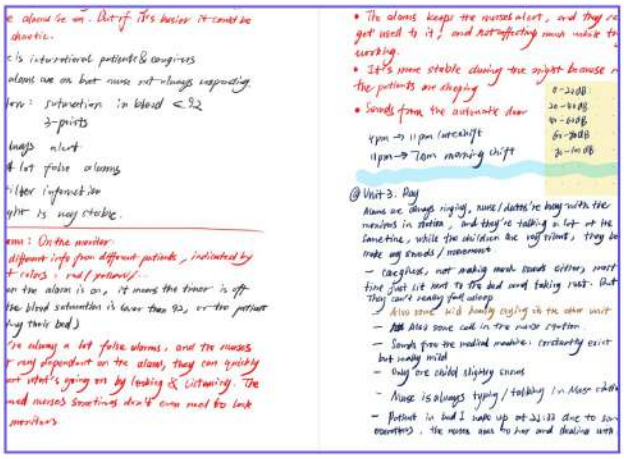
The second observational study was aimed primarily at gathering insights into the nurses' workflows. This study not only highlighted how the alarm system is embedded within their broader work processes but also revealed opportunities for system improvements that could streamline these processes.

Together, these observational studies have proven to be instrumental in providing a realistic understanding of the current alarm management practices, thereby informing future design decisions in an evidence-based manner.



Observation in PICU night shift

2nd observation in NICU



Manuscript of the first post-observation interview

## 2nd Observation

After conducting the second observation, an alarm events journey map was developed to provide insights into the interaction between nurses and alarms in the NICU. The journey map revealed two key findings. Firstly, nurses' assessments and responses to alarms exhibited a high degree of diversity and occurred frequently. Secondly, the type and timing of nurses' responses to alarms could provide indications of the urgency of the alarm.

Overall, the interaction between nurses and alarms is complex but highly valuable, and therefore a platform is needed to integrate this information and present it in a more intuitive and readable way.

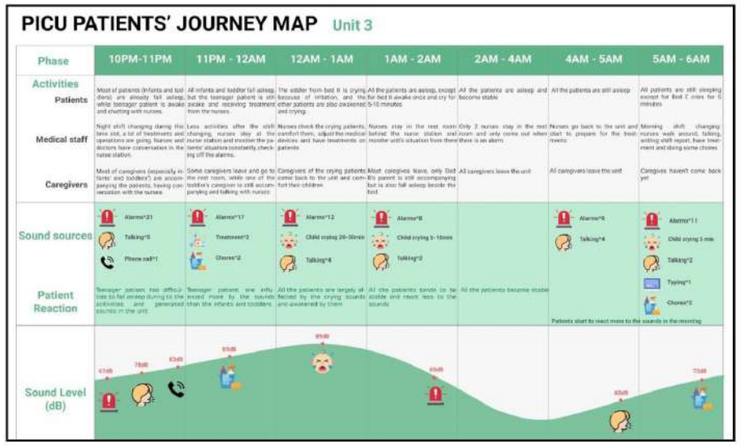



Figure 13.Patients' Journey Map-Results of 1st observation

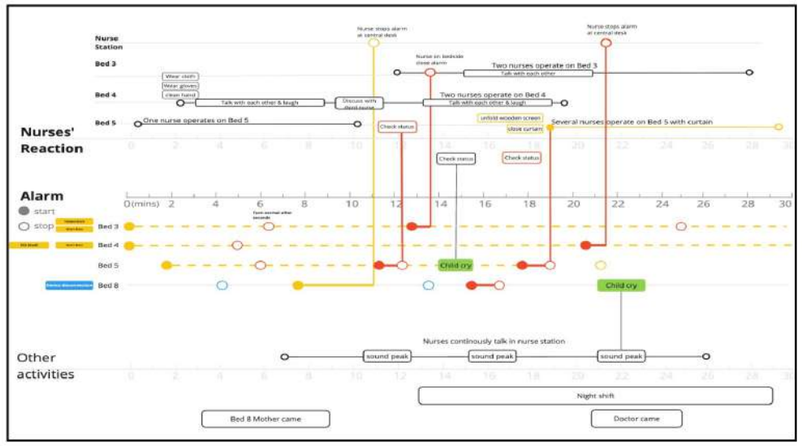



Figure 14.Alarm events journeymap - Results of 2nd observation

## Insights from 2 observations and interviews

### What we observe from the current workflow?

- Nurses will first respond to higher priority alarms, but for same priority alarm, they would first respond to alarms closer to their location.
- The current handover relies heavily on paper and pencil as well as verbal communication, which is less efficient.

### What do nurses find frustrating in current workflow?

- The same alarm could potentially prompt responses from multiple nurses.
- A nurse might have to respond to multiple alarms going off at the same time.
- Complex information retrieval

### How about the monitoring interface that nurses currently use

- The interface is complex and the visual cognitive burden is high.
- Apart from the actual number, color served as the sole visual cue for the nurses.
- No contextual information provided
- The blue/black background color is not visually appealing

## Our Design Should...

Facilitating team communication

Provides abundant and relevant contextual information to help nurses make decisions

Provides a simpler way to retrieve documents and information to help nurses complete shift handovers more efficiently

Some information display like the order of alarms for the same priority should be based on the nurse's preference

*#information need*

*#system design*

*#intuitive design*

*#data visualization*

# Sensitizing booklet

In the pursuit of understanding nurses' experiences and processes regarding alarm customization, a sensitizing booklet was developed. This tool not only enabled us to gain deeper insights into their daily practices and challenges but also served as a catalyst for sparking creativity among the nurses during the design evaluation phase. This method drew upon Sanders & Stappers' (2012) concept of "the path of expression." The booklet was structured to guide the participants through a journey spanning the present, the past, and the future.

Initially, the nurses were invited to write some background information and reflect on their current experiences in their NICU environment, particularly focusing on their interactions with the alarm systems. This helped in understanding the existing alarm settings, responses, and customization practices.

Subsequently, the tool facilitated a retrospective exploration of past experiences. This was instrumental in unearthing their underlying needs and challenges. Such reflections offered valuable context to the current situation and helped to identify any long-standing issues that need addressing.

Finally, the nurses were encouraged to envision future scenarios. They were prompted to imagine ideal experiences with the alarm systems, how they would like to interact with them, and what improvements they would desire. This forward-thinking perspective ignited creative thinking among the nurses and stimulated meaningful discussions about potential design opportunities.

All information and insights from the sensitizing booklet informed the creation of a journey map outlining the process of alarm limit adjustments by the nurses.

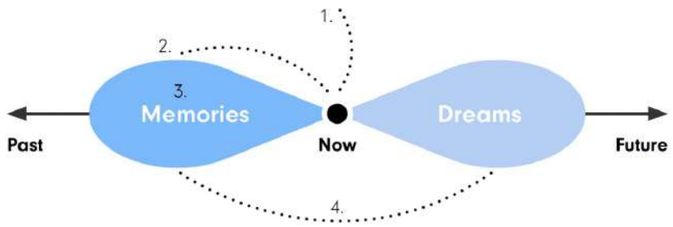
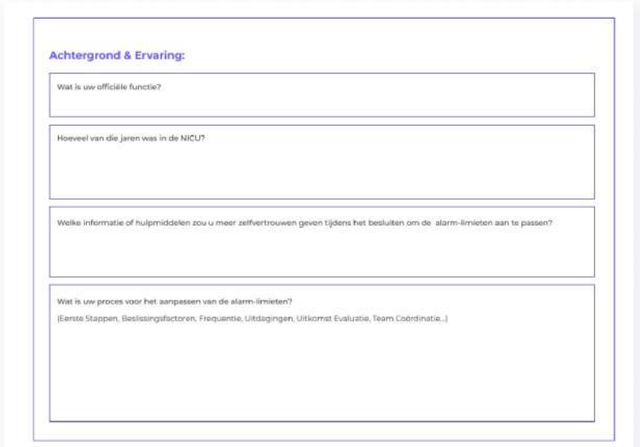
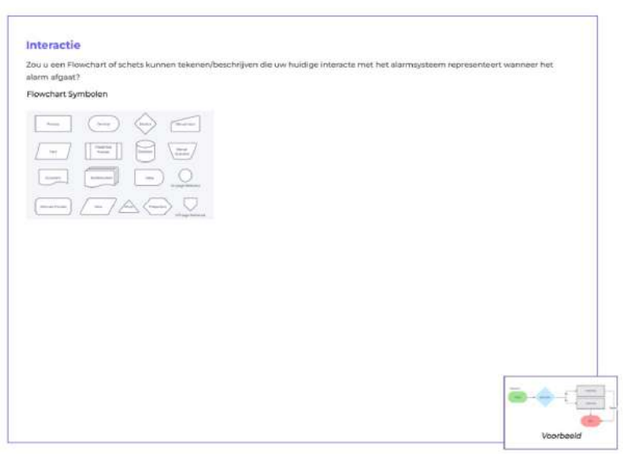



Figure 14. Path of expression

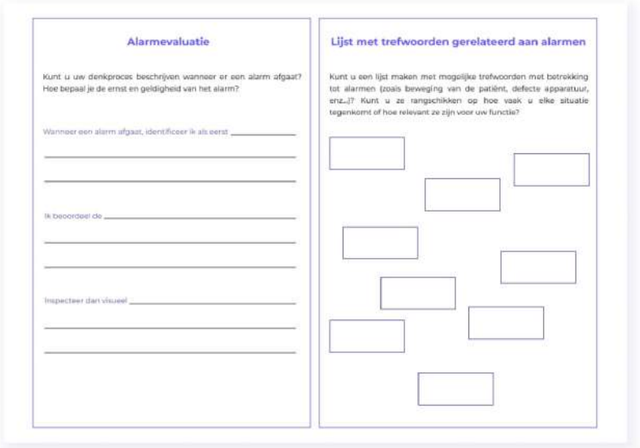

An introduction to the sensitizing booklet and project




Get information about the background and experience of the participants, ask them to recall some of their past experiences with the alarm adjustment process




Learn about their current interaction with the alarm system




How nurses assess the validity of alarms and what events are associated with them


What are the limitations of the existing alarm system as perceived by nurses and how they ideally respond to alarms

# Results

## Characteristics of the NICU nurses

### RESPONSIBILITIES

- Provide high-quality care to critically ill newborns in the NICU
- Monitor patients' vital signs
- Respond promptly and effectively to alarms to ensure patient safety
- Collaborate with the healthcare team to make informed decisions regarding alarm limits
- Maintain accurate documentation of alarm events and responses

### NEEDS

- Desire for a system that **integrates patient data and historical alarm information** to support decision-making
- Relevant **contextual information** to help nurses quickly respond and assess to alarms
-

### PATENT SAFETY

Patient safety is a paramount concern for nurses. Some key activities and practices that nurses engage in to promote patient safety, like Infection Control, Monitoring and Assessment, Medication Management, Continuous Learning and Improvement, Family Communication and so on.

### KNOWLEDGE

In order to adjust alarm limits appropriately, nurses need to have a understanding of the different **alarm parameters and their significance, patient profile and alarm tendency**.

### TECHNOLOGY

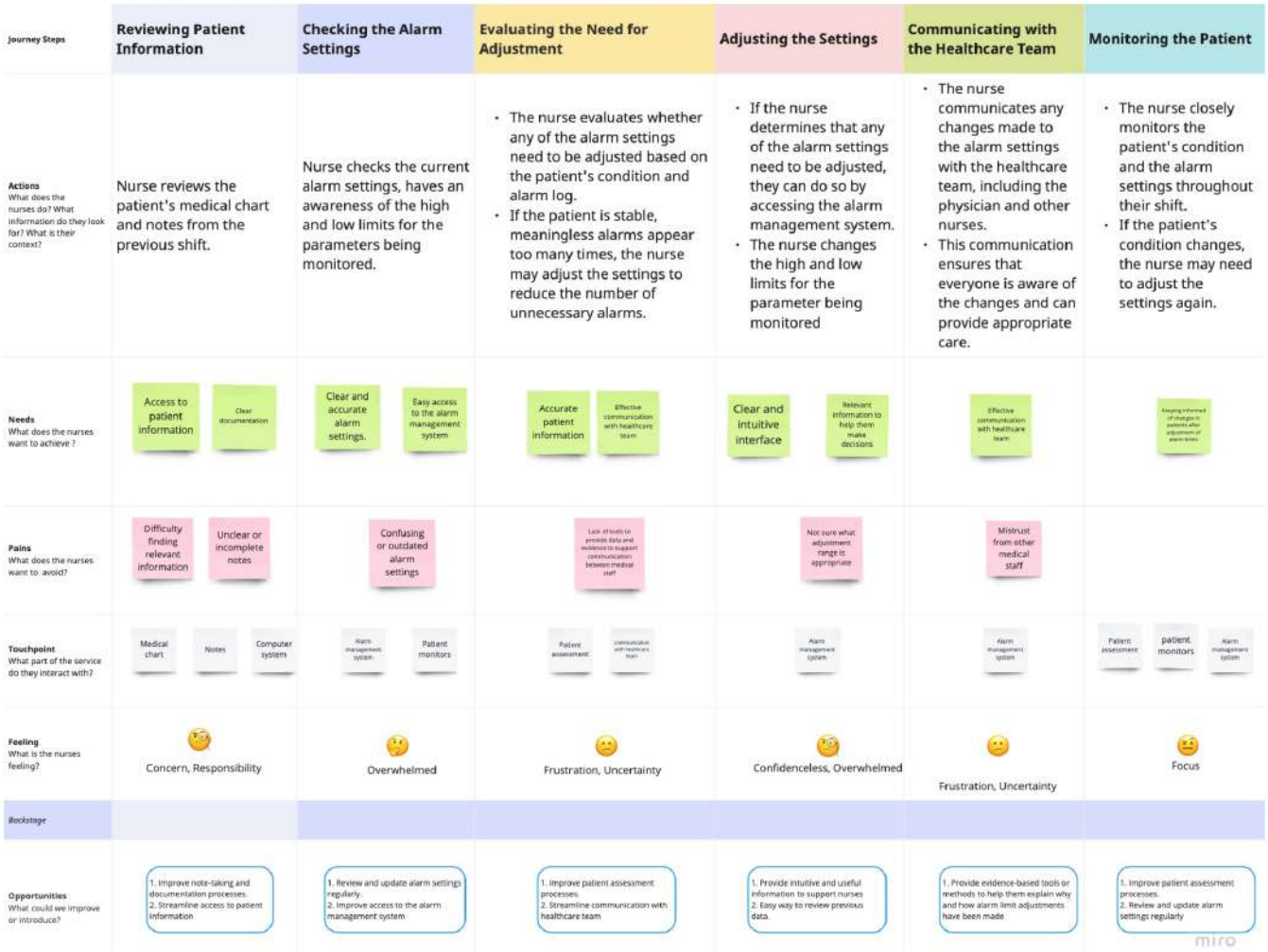
Nurses' use of remote alarm technology is expected to increase in the future, and it is crucial to design **visually appealing and user-friendly interfaces** for this technology in order to support their work in high-pressure environments. This technology should prioritize readability, usability, and overall user experience to ensure efficient and effective alarm management.

### TEAM & COLLABORATION

Nurses work together to provide comprehensive care to the same patient. They share critical information about the patient, including medical history, current condition, and specific alarm settings. They often use a combination of paper and verbal communication methods.

# Alarm limit adjustment journey map

Through a comprehensive analysis of observations, questionnaires, sensitizing booklets, and interviews with nurses, we have mapped out a detailed user journey that highlights the process of adjusting alarm limits by nurses. This approach has allowed us to identify crucial design opportunities and areas for improvement in the interface and workflow related to alarm customization. By gaining deep insights into the nurses' experiences and challenges, we can now focus on designing solutions that address their needs and enhance their efficiency in managing alarms effectively.




## Before adjustment

### Information review

1. Have an intuitive and comprehensive view about patient's alarm data.

## During adjustment

### Decision making

1. Be sure about what adjustment is appropriate
2. Knowing which range to adjust to will produce what results, such as a change in the number of alarms

## After adjustment

### Feedback

1. Continuous assessment of new alarm limits

### Communication

1. Efficient information and communication with other colleagues about adjustments to alarm limits

# Chapter 5

# Design conceptualization

## Chapter Overview

## 5.1 Design Brief

- Design Goal
- Interaction Vision
- Design characteristics

## 5.2 Lists of Reqiremens

- Content
- Interaction
- Layout
- Appearance

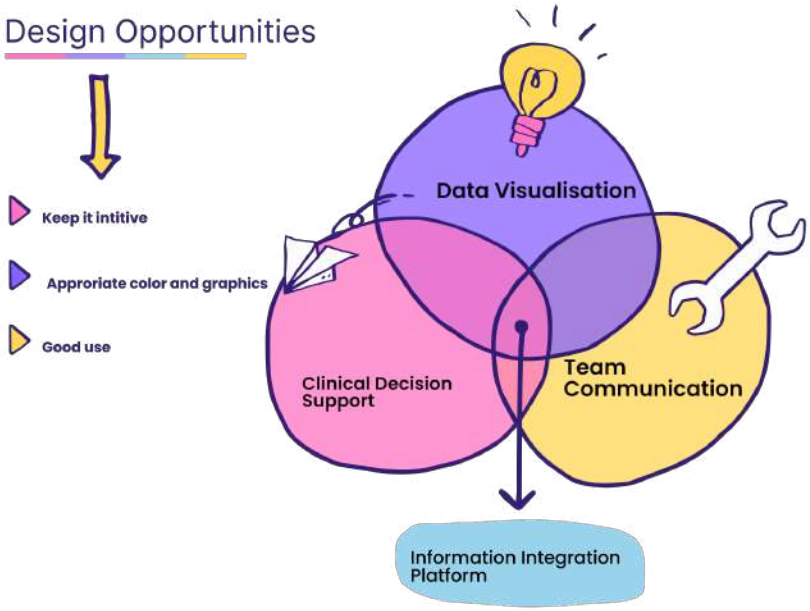
## 5.3 Ideation

- Brainstorming session
- Design Iteration

# Design Brief

## Design Opportunities

Drawing on the insights derived from extensive theoretical research and immersive fieldwork, including observations, interviews, and surveys, specific design opportunity areas have been identified and presented in Followings




## Design goal

Integrating these design opportunity areas, a comprehensive design goal is formulated:

***"I want to design interfaces that involves tracking, analyzing, and visualizing the data logged by the nurses in response to alarms and their evaluations, thus supports nurses in adjusting alarm limits for an individual patient."***

## Design characteristics

***Intuitiveness:*** The design should provide comprehensive and relevant information. It should integrate and visualize information in a straightforward and easy to understand manner that supports decision-making.

***Efficiency:*** Nurses are often required to make quick decisions under high-stress conditions. The design should streamline processes and reduce the amount of time required to perform tasks, helping nurses respond to alarms in a timely manner.

***Adaptive:*** The design should be able to adapt to different situations and contexts, whether it's for different shifts, different patient conditions, or different stages of a nurse's shift.

# List of requirements

Building on the design goal and insights gained from extensive research, we've outlined a series of design requirements that will serve as guidelines for our subsequent design and evaluation process. These requirements are organized under the broad categories of content, appearance, and interaction, which collectively constitute the fundamental pillars of our interface design.

## Content

- Standardize Terminology: The system should utilize standardized medical and nursing terminology to ensure clear and consistent communication across all users. This will also facilitate understanding between different members of the healthcare team.

- Justify Recommendations: The system should provide evidence-based rationales for its recommendations. This will help the nurses understand why a particular decision or action is suggested, fostering trust in the system and promoting adherence to recommendations.

- Universal Display: The system's basic clinical decision support system (CDSS) display should be the same for all members of the healthcare team. This will ensure that everyone has access to the same information, promoting collaborative decision-making and patient-centered care

## Layout

- Adaptive Layout: The layout should dynamically change based on the current task or situation, presenting the most relevant information to the nurse.

- Minimalist Design: The layout should avoid unnecessary elements that might clutter the screen and distract the user.

- Logical and consistent structure: Group related information together and use a consistent layout throughout the interface.

- Easy navigation: Nurses should be able to move around the interface easily and intuitively.

- Minimize scrolling and clicking: Important information should be visible without excessive scrolling or clicking.

- Use of white space: Avoid clutter and use white space effectively to separate different sections or elements.

## Interaction

- Timely Feedback: The system should provide immediate and clear feedback to the user's actions. This can be achieved by using visual indicators (like color changes, pop-up boxes, etc.), audio cues, or haptic feedback.

- Efficiency: The system should be designed to reduce the time needed to interact with the interface. This can be achieved by utilizing predictive text, pre-filled options, and shortcuts to common actions. The system should minimize steps and actions required to complete a task.

- Cognitive Load Minimization: The interface should be designed to minimize cognitive load. This can be achieved by reducing free-text typing and using selection tools such as drop-down boxes, toggle buttons, checkboxes, or radio buttons. Sorting options should be included to help organize information in a meaningful way. Automation of certain tasks and values can also help in reducing manual input and consequently the cognitive load.

- Flexibility: The system should offer flexibility to the user in terms of modifying orders. This can be achieved by allowing easy editing and inclusion of a clear 'reset' or 'undo' button. This feature would empower the user to correct or change their inputs when necessary.

- Ease of Use: The system should use selection tools (e.g., drop-down boxes, field types) and sort options to facilitate ease of use and reduce cognitive load and potential user error. Autocompletion features can be incorporated to suggest possible inputs.

## Appearance

These appearance requirements aim to create a visually pleasing and accessible interface that facilitates quick comprehension and easy navigation, supporting efficient and confident use by the nurses.

- Simplicity: The design of the interface should be simple and clean, reducing visual clutter and unnecessary elements. This means using clear, concise text and keeping decorative elements to a minimum.

- Contrast: There should be a high level of contrast between text and background colors to ensure readability under various lighting conditions. The colors chosen should also be accessible for those with color blindness or other visual impairments.

- Consistency: The presentation of information and the layout of the interface should be consistent across all sections of the system. This includes maintaining consistent placement of buttons, and maintaining similar styles for icons and other graphical elements.

- Use of Visuals: The use of text alone should be avoided. Incorporating relevant visuals such as icons, charts, graphs, or pictograms can greatly enhance the user experience, making the interface more intuitive and easier to comprehend at a glance.

- Color: Colors should be used carefully, for example, to distinguish critical information or indicate status, but not to the point where it's overwhelming or confusing.

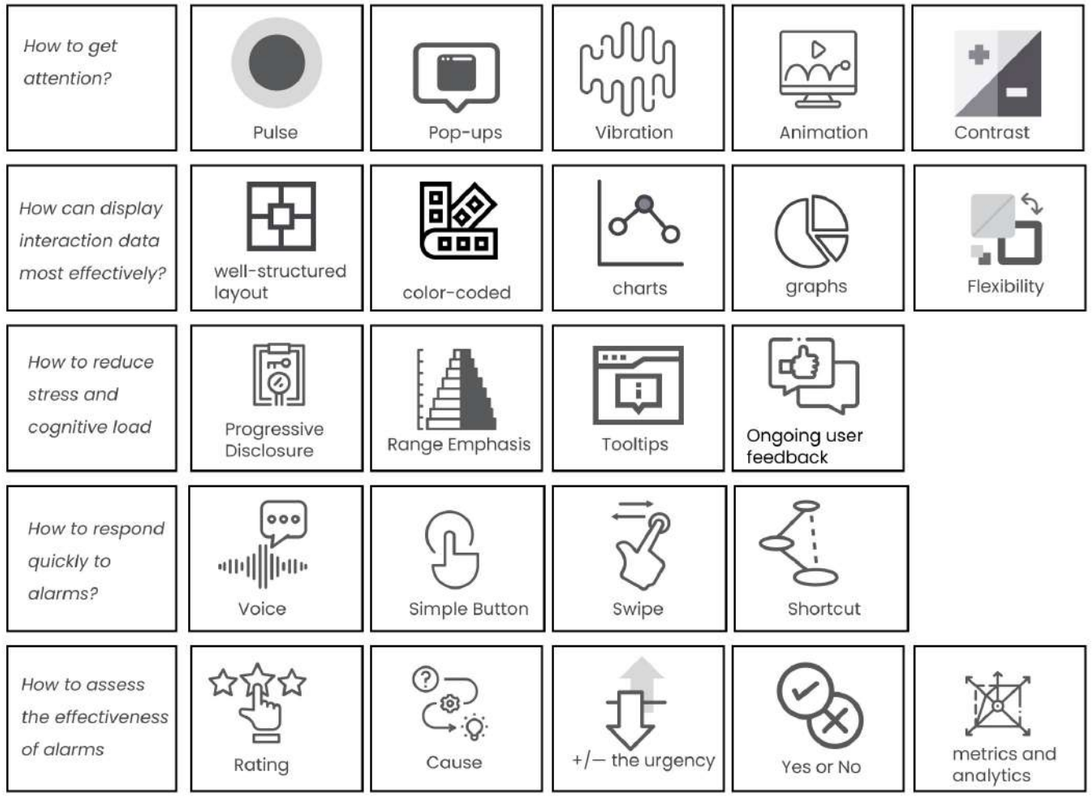
# Ideation

## Brainstorming session

After defining our design goals and requirements, we started brainstorming to come up with ideas. Before we began, I developed problem statements by formulating 'how-to' questions. This way, we had a clear direction for our brainstorming session.

I started the session by giving participants a brief overview of the project. This helped ensure them understood what we were working on.

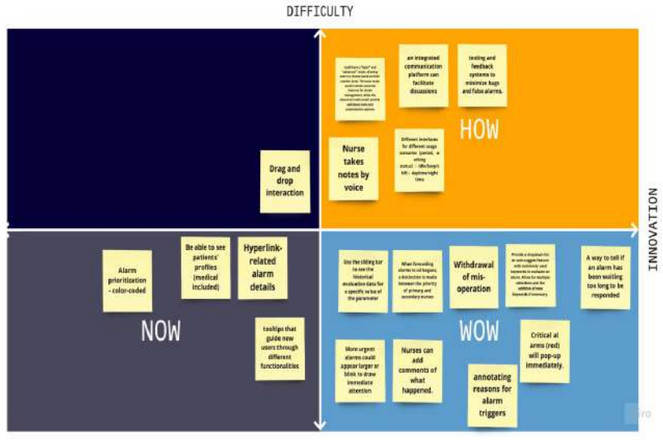
Next, I asked the 'how-to' questions and asked everyone to write down their ideas on sticky notes. This approach helped us gather a lot of diverse ideas from all participants, which was great for our brainstorming session.




## Diverge from the problem

Upon concluding the brainstorming session, we utilized the c-box technique, a structured method for idea selection, to determine which ideas would advance to the subsequent phase of the design process.

The c-box technique requires participants to assess each idea against a set of predefined criteria, namely innovativeness and feasibility. Participants then vote on ideas based on their assessment. By using the c-box technique, we were able to democratically choose the most innovative, feasible ideas.




### Insights

- Nurses can add comments of what happened.
- Withdrawal of mis-operation
- Alarm-related keywords from a pre-set library
- Critical arms (red) will pop-up immediately.
- A way to tell if an alarm has been waiting too long to be responded
- The nurse can save the alarm for later assessment
- Alarm adjustment history
- Heat map for analyzing the relation of frequency and hours.

After defining our design goals and requirements, we started brainstorming to come up with ideas. Before we began, I developed problem statements by formulating 'how-to' questions. This way, we had a clear direction for our brainstorming session.

I started the session by giving participants a brief overview of the project. This helped ensure them understood what we were working on.

Next, I asked the 'how-to' questions and asked everyone to write down their ideas on sticky notes. This approach helped us gather a lot of diverse ideas from all participants, which was great for our brainstorming session.

## Design Iteration

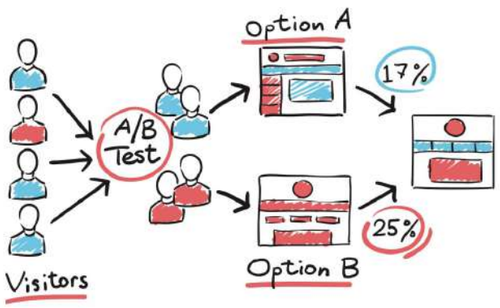
## A/B Testing

In order to evaluate the effectiveness and usability of my design, I employed the A/B testing methodology. A/B testing allows for a systematic comparison between two or more design variations, helping me gather valuable insights and make data-driven decisions.

**Participants:** At this early design stage, it's important to focus on the fundamental usability and design principles of the interface. Designers, with their expertise in user interface design and usability, are well-equipped to identify potential design improvements and usability issues.

**Process:** The A/B testing process consisted of four main steps. In the first three steps, participants were tasked with completing specific design-related tasks. They were asked to complete the tasks using both versions of the design, allowing for a direct comparison. In the fourth step, participants were asked to provide their ratings and comments using a scale and open-ended questions.

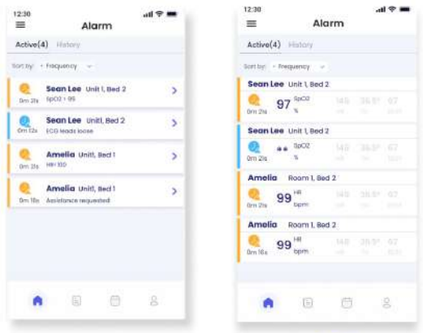
**Data collection:** Including task completion times, participant feedback, and ratings, were analyzed to determine which version of the design performed better. These findings were instrumental in making informed decisions for design improvements and enhancements.




## Testing 1: Silence Alarm

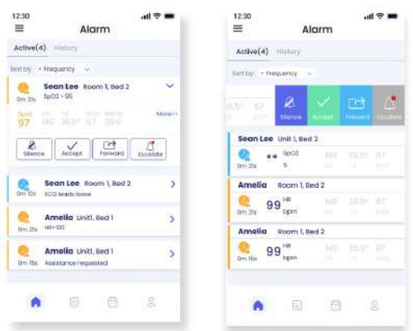
Locate the 'silence' function in the interface. Take note of how intuitive the process is and how quickly they can complete the task.

### group 1




- The information hierarchy is well-structured. Key information is visually emphasized, enabling they to quickly identify. The interface also provides relevant auxiliary information that supports decision-making without the need for additional clicks.

### group 2

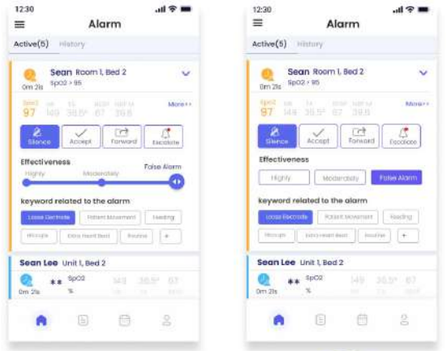



- It ensures that crucial information remains visible throughout the user's interactions. Users have the opportunity to review and confirm the information multiple times, reducing the likelihood of errors.
- This version of the interface aligns with the professions and seriousness of medical use. It provides clear indicators and visual cues, so the user knows what to do next.

## Testing 2: Evaluate Alarm

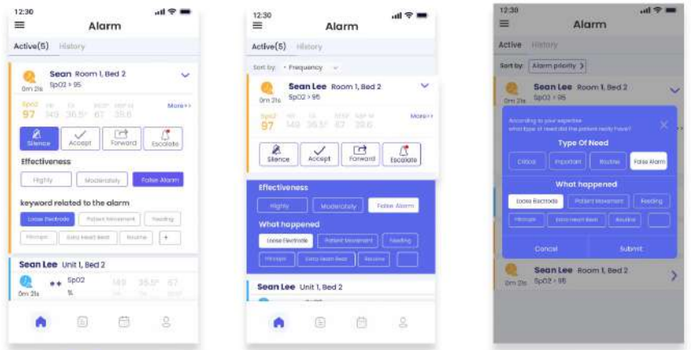
locate the 'evaluate' function in the interface and use it to assess the situation. This evaluation should include identifying potential keywords related to this alarm.

### group 3




- The click action provides a more intuitive and direct way for users to access information, offering a natural interaction that aligns with their expectations.In contrast, the sliding bar provides information and feedback that is too abstract for the user.
- it is advisable to incorporate visual indicators such as icons.

### group 4




- In the selected version, the background information that provides decision support remains prominently visible, ensuring that users have access to the necessary context while making decisions. The use of stronger contextual links enhances the connectivity between different pieces of information.
- Additionally, the visual color contrast is appropriate to ensure optimal readability and clarity of information.

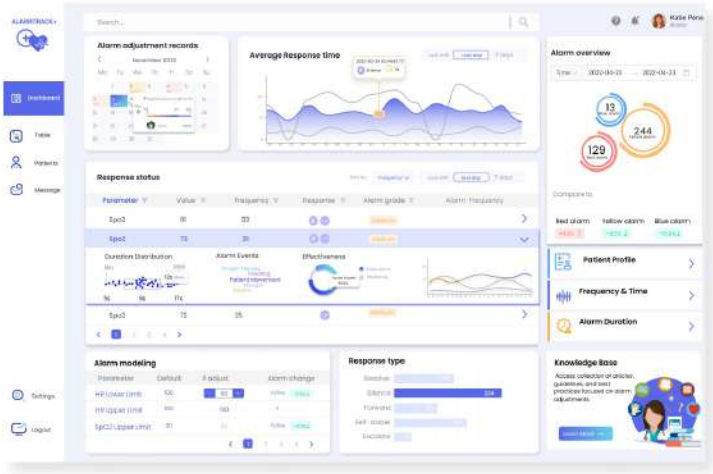
### group 5


- Consistency of content for the same operation reduces the learning and cognitive burden on the user.

## Testing 3: Alarm Data Review

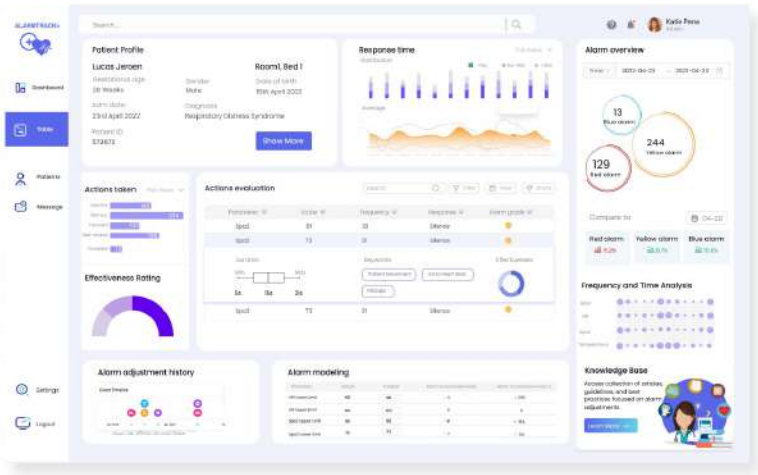
Navigate to the dashboard to access the alarm data. Take a moment to review the patient's alarm data, your responses, and the assessments you made. Look for patterns or anything that stands out to you.

### group 6



- The current visual design exhibits some challenges, including an overload of information at the center of the screen, a lack of size hierarchy, and an overcrowded layout. Some of the presented information is not essential to the user's primary purpose, and it should be minimized or relocated away from the core area. The information presented to the user lacks intuitiveness and requires further refinement to enhance user comprehension. Additionally, the expanded diagram information is not adequately visible and would benefit from more space allocation to improve visibility and clarity.

- In comparison to the previous page, the current design appears cleaner, but it lacks a clear visual center point and fails to effectively translate and visualize the data. There is a need for a stronger focal point that draws the user's attention and facilitates better comprehension of the displayed information. Additionally, there is a lack of interface maneuverability cues, which may lead to confusion or difficulty for the testers in navigating through the interface.



- The logic of the information layout in the current design aligns more closely with the mental model of nurses when making decisions about alarm adjustment limits. The interactive slider on the page allows nurses to easily visualize how the alarm changes and their tendency based on the adjustment limit they set, providing a clear indication of the validity of the selected range or value.

# Chapter 6
# Final Concept

## Chapter Overview

### 6.1 System Architecture

### 5.2 Design Detail

Content

Interaction

Layout

Appearance

### 5.3 User senarios

**Brainstorming session**

Design Iteration

# Final Design

As depicted in the following illustration, the system, comprising the application and dashboard, will encompass five key components:

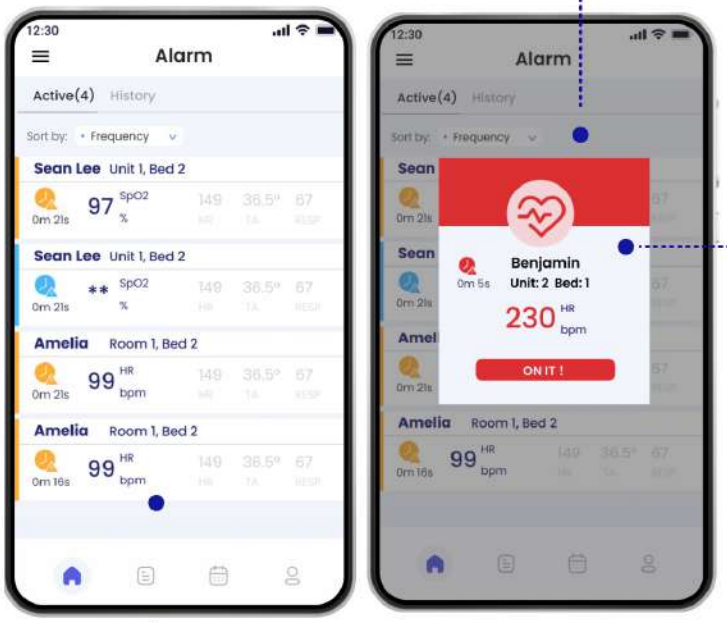
1. Alarm Lists Page.
2. Nurse Response Page.
3. Alarm Evaluation Page.
4. Vital Signs Graph Page
5. Data Dashboard Page

## Alarm Lists Page

This page will display a comprehensive list of active alarms, providing nurses with an overview of the ongoing alarm events. It will allow them to quickly identify and prioritize alarms based on nurses' preference.

Nurses can choose the sorting order of alarms based on their preferences and specific needs, such as the time of occurrence or the type of parameter being monitored.
Interface empowers nurses to organize and prioritize alarms in a way that aligns with their workflow and enhances their efficiency

When a red alarm is triggered, it will immediately generate a pop-up window on the screen, capturing the attention of the nurse and drawing their focus to the urgent situation.




The pop-up window will display details of the red alarm, such as the patient's name and location, the specific parameter being monitored, and the alarm duration.

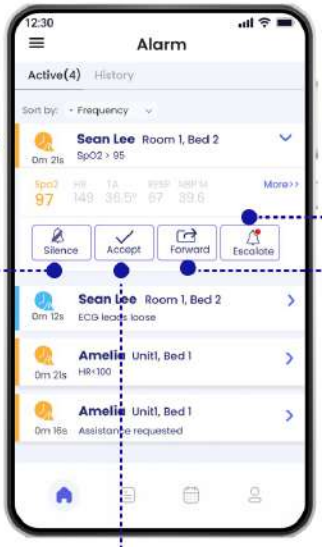
Each alarm in the interface will be represented by a card. The card will display the patient's name, location, and the number of parameter values that triggered the alarm. This information helps nurses identify the specific patient and the severity of the alarm at a glance.
Furthermore, the card will also include additional vital signs values, providing a comprehensive overview of the patient's current condition. This enables nurses to make informed decisions based on a broader set of patient data. The alarm duration will be clearly displayed, serving as a reminder for the nurse to respond promptly and ensure timely interventions.
To enhance visual clarity and differentiation, color coding will be implemented to represent the different urgency levels of alarms

## Nurse Response Page

This dedicated page will enable nurses to promptly respond to active alarms by providing them with intuitive and efficient interaction options.

The four options for nurses to respond to alarms - silence, accept, forward, and escalate - have been designed based on a combination of theoretical research and field research conducted with nurses.

The escalate option is reserved for critical situations where immediate and urgent action is required. It allows nurses to escalate the alarm to a rapid response team or an emergency team. This option is typically used for alarms indicating life-threatening or severe conditions that demand immediate attention and intervention from specialized caregivers.




The silence option allows nurses to temporarily mute or deactivate non-critical alarms that may not require immediate action. It can be applied when the alarm is not relevant to the current situation or when the nurse is already attending to the underlying cause of the alarm.

The forward option enables nurses to direct the alarm to another medical staff like nurses for further evaluation or intervention. It is used when the nurse receiving the alarm has higher level tasks to attend to at the moment and the nurse is unable to reach the patient's bedside to check the situation and then respond to the alarm.

The accept option signifies that the nurse acknowledges and takes ownership of the alarm. It indicates that the nurse will actively respond to and address the alarm promptly.

## Vital Signs Graph Page

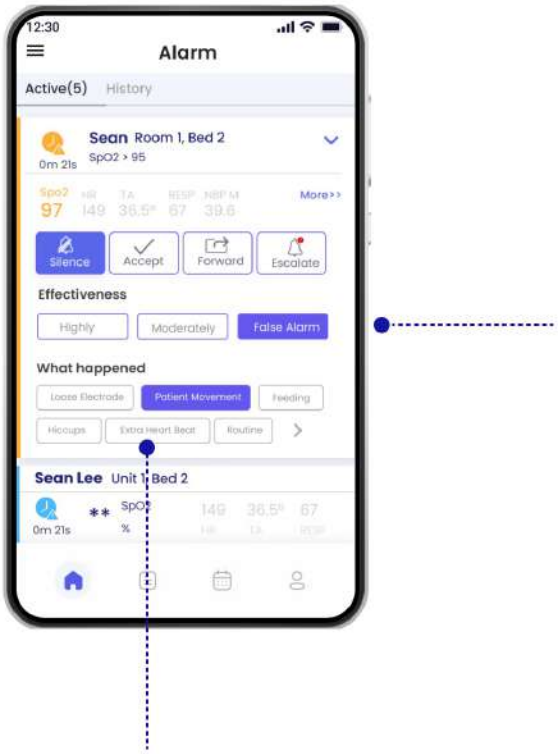
The Vital Signs Graph Page serves as a supplementary resource for nurses when they need to access more detailed information about a specific patient. By clicking on the "more" option within the Nurse Response Page, nurses can navigate to the Vital Signs Graph Page.

Nurses could view visual representations, such as graphs or charts, that display the vital signs data of the patient. This includes parameters such as heart rate (HR), respiratory rate (RR), and oxygen saturation (SpO2). The graphs provide a visual timeline of the patient's vital signs over a specific period, allowing nurses to observe trends, fluctuations, and any noteworthy patterns.


By including response options on the vital signs graph page, nurses can conveniently select their response without back to the nurse response page. This reduces the number of steps required for the nurse. The response buttons on the page maintain consistency with the design and functionality of the nurse response page, reducing the cognitive and learning burden of nurses.

# Alarm Evaluation Page.

After responding to alarms, nurses will access this page to provide feedback, assessment, and categorize the alarms based on their observations and clinical judgment. The section consists of two main parts.




The second part allows the nurse to select predefined keywords or enter their own keywords related to the alarm. This enables the nurse to provide additional context and details about the events or patients situation associated with the alarm. For example, they can select keywords like Patient Movement, Feeding, or Equipment Malfunction to indicate the specific factors contributing to the alarm. By capturing this information, the system can gather valuable insights into the causes and patterns of alarms, facilitating further analysis and optimization of the alarm management process.

Based on the insights gained from both research and design activities, the three options were formulated to capture the varying perceptions of nurses regarding the effectiveness of alarms.Based on the insights gained from both research and design activities, the three options were formulated to capture the varying perceptions of nurses regarding the effectiveness of alarms.

1. Highly Effective: This option indicates that the alarm accurately detected a significant event or condition requiring attention. The nurse believes that the alarm is reliable and trustworthy in alerting them to a genuine issue related to the patient's health or safety.
2. Moderately Effective: The nurse considers the alarm to be reasonably valid, but there might be occasional instances where it triggers unnecessarily or fails to detect relevant events.
3. False Alarm: The alarm is invalid or false, meaning it does not correspond to an actual critical event or condition. Such alarms may be caused by technical problems, false triggers or other factors.

## Data dashboard Page.

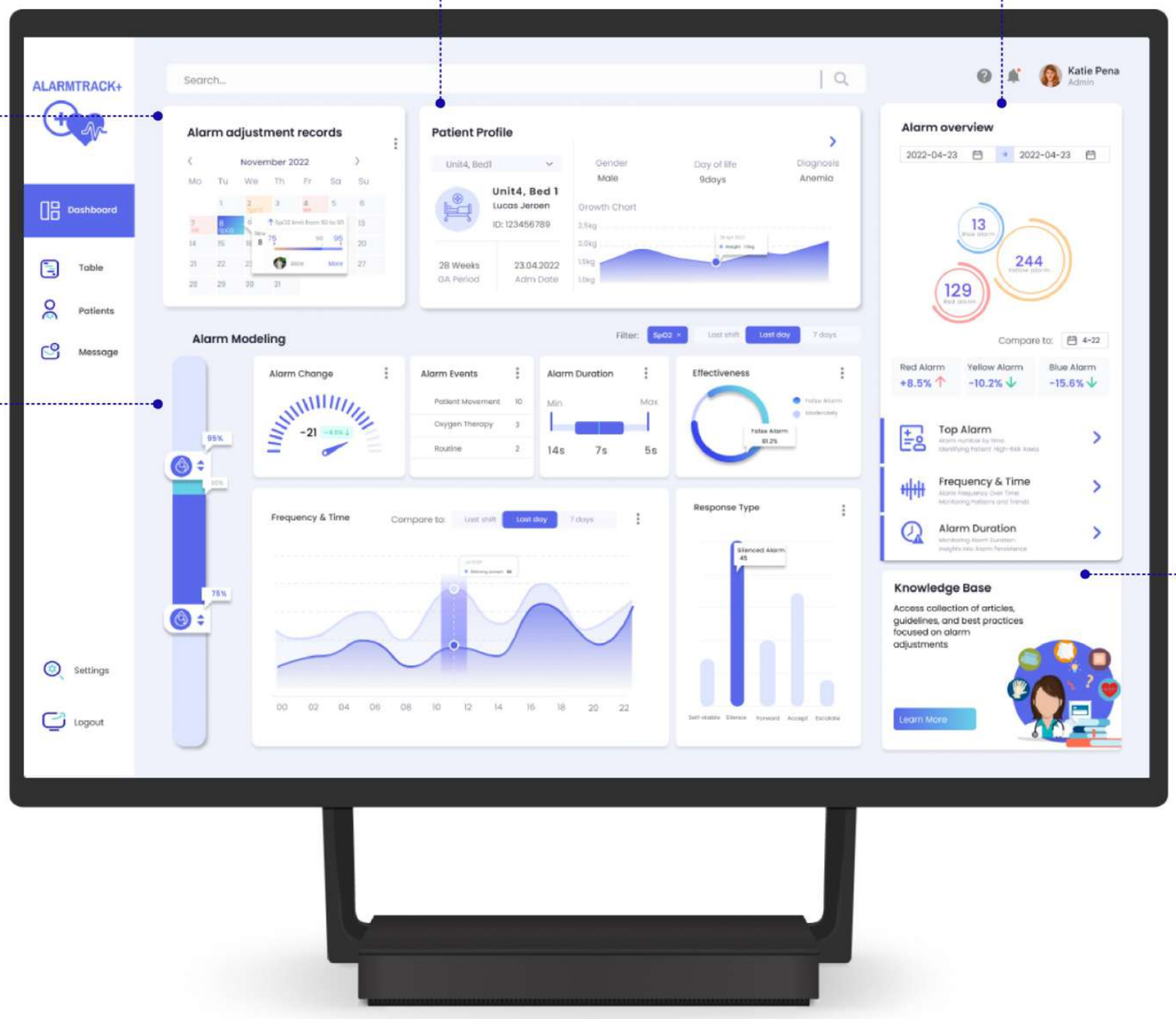
The data dashboard will offer a holistic view of the alarm data, nurse responses, and assessment outcomes. It will present visualizations, trends, and analytics to facilitate data-driven decision-making and support nurses in adjusting alarm limits for individual patients. The layout and content of this dashboard is based on the nurse's decision model for adjusting alarm limits.

## Alarm adjustment records

The first section, the Alarm Adjustment History, presents a visual representation of parameter modifications using an intuitive calendar format. By hovering over a specific day, nurses can access detailed information about each adjustment, including the responsible nurse, the extent of limit adjustments, and the duration of the new limits.

## Alarm Modeling

At the heart of the dashboard lies the Alarm Modeling section, a pivotal area that empowers nurses to fine-tune alarm parameters with real-time visual feedback. Through the seamless interaction of sliding the bar on the left, nurses see dynamic changes in the alarm landscape on the graphical area to the right. This live representation showcases the immediate impact of the nurse's selected limits compared to the default thresholds, ensuring valuable insights into alarm frequencies and related metrics. Furthermore, historical data associated with the new thresholds, such as the nurse's response type, assessment of effectiveness, alarm duration and the events linked to alarms, provide an enriched context for decision-making and analysis about alarm adjustments.




## Patient Profile

Adjacent to alarm adjustment records lies the Patient Profile, which leverages insights from prior user research to highlight essential factors such as gestational age (ga) weeks, symptoms, and stability. These critical indicators inform the nurse's decision-making process regarding whether and how to customize the alert settings, ensuring a tailored and patient-centered approach.

## Alarm Overview

The Alarm Overview section presents a comprehensive view of alarm statistics, categorizing alarms by type ( red alarm, blue alarm, yellow alarm) for a specific date or time period. This intuitive display empowers nurses to gain quick insights into the frequency of alarms, facilitating their ability to identify patterns and trends. By visualizing changes over time, nurses can effectively assess the impact of alarm adjustments and interventions on alarm occurrences.

## Knowledge Base

In previous studies, it has been recognized that nurses require continuous learning and training to enhance their knowledge of alarm adjustment and improve their professional practice. Therefore, the knowledge base section of the interface aims to address this need by providing a comprehensive repository of protocols, articles, and practical insights from experienced professionals.

# System Architecture

## Alarm Display and Notification

Patients Vital Signs

Detects abnormal conditions

Medical equipments

Triggers alarms

Alarm management system

Categorizes and prioritizes the alarms

Notify alarms to nurses

Nurses access the alarm lists page on the user interface to view active alarms.

They can quickly view the alarm details, including patient information, vital signs, and alarm duration, in the alarm cards.

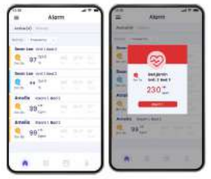
## Nurse Response and Interaction

***More information***

Nurses can also click on the alarm card to access additional information and details

***Response options***


Choose one of the response options



## Alarm Evaluation

Nurses can evaluate the alarm's effectiveness and select the appropriate option

They can enter relevant keywords or select predefined options to document events associated with the alarm

The nurse's response, evaluation, and associated events are recorded and stored in the system for future reference and analysis.

## Data Visualization and Analysis

Nurses can review historical alarm adjustment records, providing a comprehensive overview of past adjustments made by nurses.

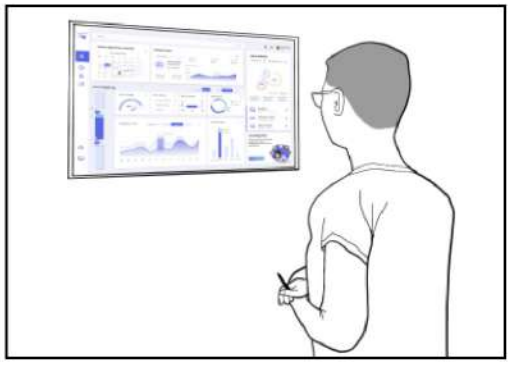
Nurses have the option to aware alarm changes after adjustments of alarm limits using the slider bar.

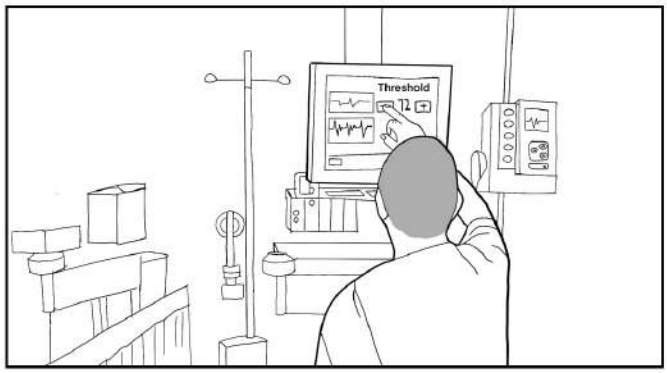
The dashboard provides key insights and analytics, such as alarm frequency and duration, nurse response types, and the effectiveness of alarms.

Integrate decision support tools such as clinical guidelines, protocols or reference materials into the interface. These resources can provide additional guidance and assistance to nurses

# User scenario

## Alarm Review and Decision Support





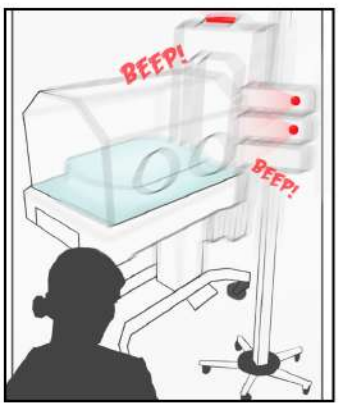

Before starting shift, nurse uses it to familiarize himself with patient's alarm history. The dashboard provides visual representations of this data, making it easy for nurses to identify trends and patterns.

Based on this information and the decision support provided by the dashboard, nurse can confidently make decisions about adjusting alarm limits for patient during his shift, optimizing patient care.

## Communication alarm limit adjustment

Nurse Alice uses the dashboard to explain her adjustment and the reasons behind them. This allows for seamless communication and collaboration between nurses and ensures that they are on the same page regarding the patient's condition and alarm settings.

## Alarm Evaluation and Feedback




Alice rates the alarm on the interface, providing feedback on its relevance and urgency. This information can be used to analyze the effectiveness of alarm settings and guide future adjustments.

After an alarm sound, nurse Alice goes to patient's bedside, checks on situations, and determines that the alarm was not critical.

# Chapter 7
# Evaluation

## Chapter Overview

### 7.1 Materials

### 7.2 System Usability Testing

- Purpose
- Participant
- Procure
- Results

### 7.2 Design Goal

- Purpose
- Participant
- Procure
- Results

### 7.2 Conclusion

# SYSTEM USABILITY TESTING *Is my interface usable?*

## Purpose

In order to evaluate the system usability, we choose the SUS (System Usability Scale). The scale was developed by John Brooke in 1986 as a rapid and efficient scale for evaluating the usability of virtually any system.

*The System Usability Scale helps measure*

- Efficiency
- Intuitiveness
- Ease
- Satisifaction

## Participants:

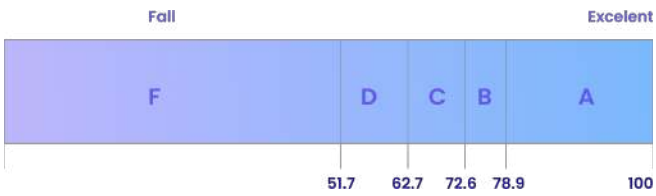
- Target participants: Registered nurses with experience working in the NICU setting.
- Sample size: Aim for a diverse group of participants, preferably between 5-7 participants to ensure a range of perspectives.
- Recruitment: Recruit participants through professional networks, nursing associations, or directly from NICU departments.

## Procedure:

- **Context Introduction:** Initially, participants were shown a storyboard that depicted key user interactions and their contexts. This was intended to aid them in comprehending the purpose of using the interface and the situations in which it might be employed. The storyboard could further enable participants to visualize their possible interaction with the design, which is particularly beneficial for evaluating online concepts.
- **Experience the interfaces with tasks:** Assign specific tasks to participants that reflect real-world scenarios related to adjusting alarm limits and managing alarms. Observe participants as they interact with the system, taking note of their actions, challenges, and feedback. Encourage participants to think aloud, expressing their thoughts, impressions, and difficulties encountered during the tasks.
- **SUS Questionnaire:** After participants have completed the tasks, administer the SUS questionnaire to gather quantitative feedback on usability.
- **Data Analysis:**

**SUS Questionnaire**

- Scoring 80.3 or higher earns an A, showcasing top-notch performance and user admiration.
- A score close to 68 lands a C, suggesting areas to refine.
- However, anything below 51 is an F, emphasizing the immediate need to boost site usability.



# DESIGN GOAL EVALUATION *Is my design goal achieved?*

## Purpose

The evaluation aims to determine whether the interfaces successfully provide the necessary functionalities and support for nurses in their alarm management tasks.

*What I want to test is*

Content

Visualization

Function

## Procedure:

- Step 123 of the procedure for this part of the test is the same as system usability testing, but the 4th step completes the questionnaire and scales designed according to the design goal

## Questionnaire and scales:

### Section 1: Content of Information

- How satisfied are you with the provided information related to alarms and their evaluations? (Scale: 1-5)
- Do you find the information provided relevant to your decision-making process for adjusting alert limits? (Scale: Yes/No)
- Are there any specific types of information that you feel are missing or should be included? (Open-ended)

### Section 2: Clarity of Data Visualization

- How clear and understandable are the visual representations of alarm data and evaluations? (Scale: 1-5)
- Are the visualizations helpful in quickly grasping the key insights and trends related to alarms and evaluations? (Scale: Yes/No)
- Is there any specific aspect of the data visualization that you find unclear or could be improved? (Open-ended)

### Section 3: Support in Adjusting alarm Limits

- To what extent do you feel supported by the interfaces in adjusting alert limits for individual patients? (Scale: 1-5)
- Do you find the available features and functions helpful in customizing alert limits according to patient needs? (Scale: Yes/No)
- Are there any additional features or tools you would like to see in the interfaces to further support the adjustment of alert limits? (Open-ended)

# EVALUATION RESULTS

There were seven participants in this section, three of whom participated in the usability testing. Two of the participants were engineers in the NICU units.

## Section 1: Content of Information

his part of the question set was designed to examine whether the content of the interface met the needs of the process of the nurse adjusting the alarm limits. Most nurses recognised that the content was highly relevant to the information they needed.

| Assessment Criteria | Questions | Mean | Media | Min. | Max. |
|---|---|---|---|---|---|
| Relevant | Do you find the information provided relevant to your decision-making process for adjusting alert limits | 4.1 | 4.2 | 3 | 5 |
| Satisfaction | How satisfied are you with the provided information related to alarms and their evaluations? | 3.9 | 4 | 2 | 4 |

*"There is some information that would be useful to me, such as the frequency of occurrence of a certain alarm value"*

## Section 2: Clarity of Data Visualization

| Assessment Criteria | Questions | Mean | Media | Min. | Max. |
|---|---|---|---|---|---|
| Intuitiveness | How clear and understandable are the visual representations of alarm data and evaluations? | 4.5 | 4.4 | 4 | 5 |
| Effectiveness | Are the visualizations helpful in quickly grasping the key insights and trends related to alarms and evaluations? | 3.8 | 4.2 | 3 | 5 |

Because in an emergency situation, nurses need to make decisions quickly and accurately, and the interface needs to reduce the cognitive load on nurses. So these questions were set up to test whether the data visualisation of the interface was intuitive and clear.

## Section 3: Support in Adjusting alarm Limits

Most participants very much agreed that the interface and dashboard provided features that were very useful in helping them to know how to adjust alarm limits to be appropriate. However, some participants also felt that the existing method of assessing the effectiveness of the alarms could be made more interesting as a way of motivating nurses to participate.


| Assessment Criteria | Questions | Mean | Media | Min. | Max. |
|---|---|---|---|---|---|
| Intuitiveness | How clear and understandable are the visual representations of alarm data and evaluations? | 4.5 | 4.4 | 4 | 5 |
| Effectiveness | Are the visualizations helpful in quickly grasping the key insights and trends related to alarms and evaluations? | 3.8 | 4.2 | 3 | 5 |


*"I like the alarm modelling part, it lets me clearly see the changes after I adjust the alarm limits!"*

# Chapter 8

# Conclusion and Discussion

## Chapter Overview

### 8.1 Summary of the outcome

### 8.2 Reflect

### 8.3 Limitation

### 8.4 Future Opportunities

## Summary of the outcomes

We delved into this subject by studying relevant literature, observing real-world scenarios, conducting interviews, and gathering valuable insights through questionnaires. Our primary focus was to thoroughly understand the existing alarm system in the Neonatal Intensive Care Unit (NICU). Specifically, we concentrated on the customization of alarms, aiming to reduce unnecessary alarms. Our efforts centered around creating user-friendly interfaces for nurses to quickly respond and evaluate alarms. We also developed a comprehensive dashboard that seamlessly integrates data gained from interfaces. This dashboard is designed to assist nurses in effectively adjusting alarm settings.

## Limitation

While this project has brought forth valuable insights and advancements, it's essential to acknowledge certain limitations that influenced its scope and outcomes. One notable constraint was time. Due to time restrictions inherent to academic projects, there might have been areas that couldn't be explored in as much depth as desired. This could potentially impact the comprehensiveness of the solutions presented.

Another crucial limitation is my lack of a professional medical background. While I collaborated extensively with nurses and healthcare professionals, my inherent understanding of medical intricacies might be limited. This could have implications on the precision and depth of medical contexts embedded within the design. I strived to bridge this gap through thorough research and collaboration, yet this constraint is worth noting.

Furthermore, the absence of firsthand medical experience may have impacted the extent of empathy embedded in the design. While I aimed to envision solutions from a user-centric perspective, the absence of personal experience in medical contexts might have introduced certain gaps in understanding the nuanced needs and challenges faced by nurses and patients.

## Recommendation for future

**Machine Learning for Alarm Customization:** Leverage machine learning algorithms to continuously learn from nurse interactions and improve the system's ability to suggest optimal alarm limits based on patient-specific conditions.

**Customization Options:** Offering a level of customization in the interface could address the concerns raised by very experienced nurses who found certain information unnecessary. Allowing users to personalize the interface to suit their preferences and workflows can lead to a more satisfactory user experience.

**Collaboration and Communication Enhancements:** As teamwork and communication among nurses play a pivotal role in patient care, consider integrating features that allow nurses to share their observations and alarm adjustments with their peers for collaborative insights and decision-making.

**Gamification Elements:** Incorporate gamification elements into the interface to make the experience of adjusting alarm limits more engaging and rewarding. This could encourage nurses to interact with the system more frequently.

## Personal Reflection

Embarking on the journey of designing an improved alarm management system for the NICU has been an illuminating experience. From the outset, I was captivated by the potential to blend design with healthcare, aiming to create something impactful and user-friendly.

As the project unfolded, the significance of staying closely attuned to the needs of the end-users became vividly clear. Collaborating with nurses and integrating their insights into the design process not only refined the solutions but also reinforced the essential role of user-centered design in healthcare technology.

Witnessing the convergence of evidence-based practices and technological innovation was a revelation. Integrating data-driven decision-making not only fortified the project's underpinnings but also ensured that the design resonated with the practical needs of nurses and the patients they care for. This synergy underscored the potential of technology to empower and assist healthcare providers in their crucial roles.

Reflecting on this journey, I find myself contemplating the delicate balance between innovation and functionality. The interfaces and the broader system had to be sophisticated enough to handle complex data while remaining accessible and intuitive for the users. Achieving this equilibrium necessitated a deep comprehension of both technological capabilities and the daily challenges encountered by nurses.

Peering ahead, I am enthusiastic about the project's potential ripple effects. Observing how the new system enhances user experience and aids in more informed decision-making among nurses fills me with a sense of pride and accomplishment.

It solidifies my belief that at the intersection of technology and healthcare, there lies a profound opportunity to make a tangible difference.

In summation, this project has reaffirmed my conviction in the transformative power of design. It serves as a reminder that even in the realm of technology, a human-centric approach remains paramount to crafting solutions that are not only effective but also compassionate. As I chart my course forward, I carry with me the realization that each design choice has the ability to shape lives, an understanding that is both humbling and invigorating.

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# Appendix

# Appendix

DESIGN FOR our future

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: Chen
initials: _____ given name: Gongyu
student number: 5590795
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: dr. Elif Özcan Vieira — dept. / section: Critical Alarms Lab
** mentor: Tom Goos — dept. / section: _____
2nd mentor: _____
organisation: _____
city: _____ country: _____

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.

## APPROVAL PROJECT BRIEF

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

chair dr. Elif Özcan Vieira date - - signature

## 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: _____ EC

Of which, taking the conditional requirements into account, can be part of the exam programme _____ 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 date - - signature

## 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: APPROVED NOT APPROVED

Procedure: APPROVED NOT APPROVED

comments

name date - - signature



Initials & Name Chen Student number 5590795

Title of Project New alarm strategies for adjustable alarm parameter thresholds

New alarm strategies for adjustable alarm parameter thresholds

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 17 - 02 - 2023

07 - 07 - 2023 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 priority of a neonatal intensive care unit is to provide appropriate care for critically ill newborns, including the provision of a quiet acoustic environment. However, when stay inside the NICU, you will hear a lot of sound: Hum and alarm from bedside's equipment, conversations between caregivers, operation sounds for routine care. One area in particular that presents a great challenge in is in the use of alarms and alarm fatigue. As defined by the American Association of Critical Care Nurses, alarm fatigue occurs when clinicians (especially nurses) become insensitive to alarms due to the excessive number of alarm signals[1]. Due to patients in critical condition, alarms are everywhere in NICU. Nurses, are particularly susceptible to the alarm fatigue which can lead to missed alarms or delayed responses. With the future tendency to design NICU units as single-patient room, alarm fatigue will become more prominent. This is because the healthcare team will choose conservative alarm thresholds that may lead to an excessive number of alarms.

Studies show that the majority of alarms are false or unrelated to emergencies, accounting for over 85% of all auditory signals[2]. Nurses view the existing alarm system as too frequent and disruptive to patient care so that they often do not respond directly and immediately to alarms[3]. Yuval et al. found that overall likelihood of a nurse responding to an alarm was very small, and, for more than 90% of alarms, the nurse did not attend to the patients during the minute following the alarm. When they analyzed only the longer alarms (that lasted for more than 5 s), they found a greater tendency of nurses to attend to the patients[4]. This tendency differed for different types of alarms. Nurses were more likely to intervene after a relatively rare alarm (respiration) than after the frequent saturation alarm. Their response to these alarms can be categorised according to emergency from low to high: Nothing/Proceed, Log, Log&Monitor closely, Run procedure, Call engineer[5].

There is no doubt that the existing alarm system gives nurses a certain degree of working instructions, but over general and conservative thresholds cause alarm fatigue. Therefore, we can adjust the parameter thresholds to reduce the presence of unnecessary auditory signals and alarm fatigue. At the same time, through observation and literature review we speculate that the behaviour and duration of nurses' responses to alarms can also be a reference for adjusting patients' individual alarm thresholds. As a further deduction, with this adjustable and dynamic thresholds, we can adopt different signal notification strategies in place of a single high frequency acoustic signal.

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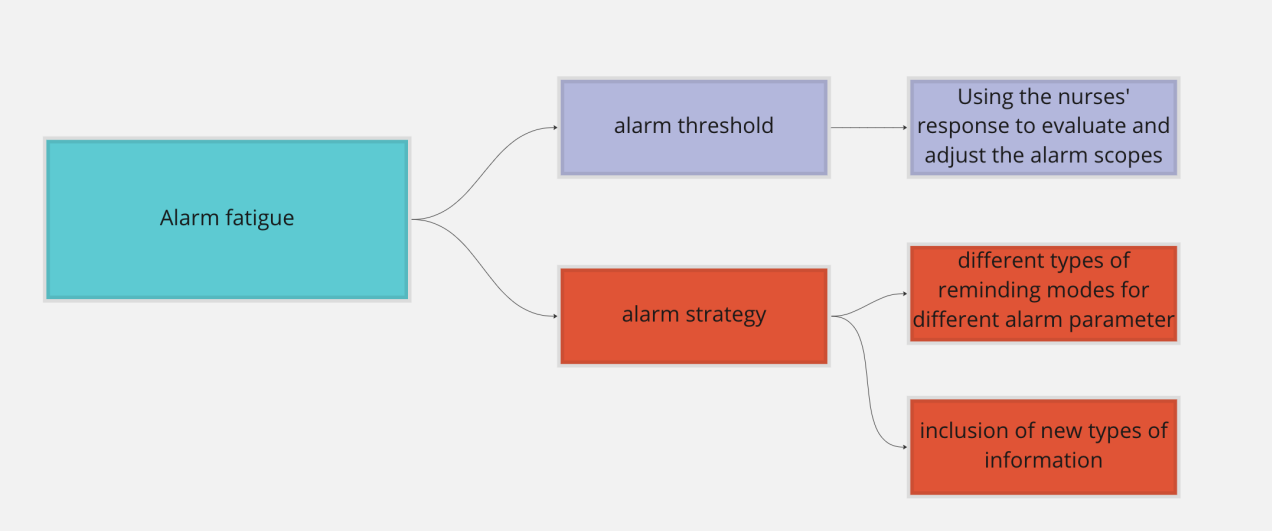



image / figure 1: Mindmap for problem definition and solution scope

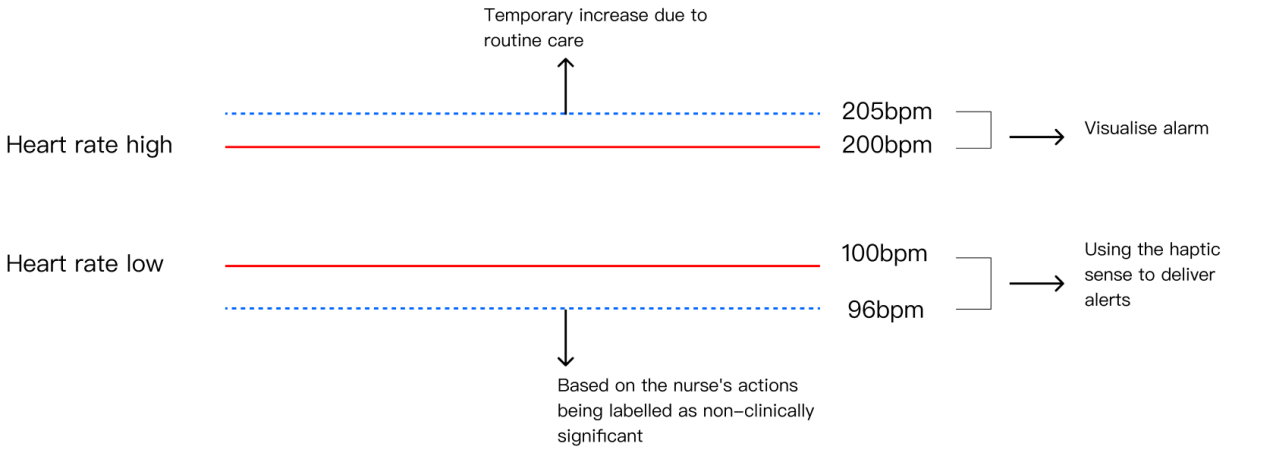



image / figure 2: potential solution for this project

## 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.

As mentioned before, fixed and general alarm parameter thresholds can generate a large amount of clinically insignificant alarm and alarm fatigue. That' because they are set at a standard level for all patients and do not account for individual variations in vital signs and patient conditions. This can result in a high volume of false or non-critical alarms that do not accurately reflect the patient's condition. Fixed alarm parameter thresholds also do not allow for changes in the patient's condition to be taken into account. For example, a patient's heart rate may increase due to daily care from nurses, which can trigger an alarm even if the patient is not in danger. In contrast, dynamic alarm parameter thresholds allow for real-time adjustments based on patient data and nurse response, providing a more customized approach to alarm management and reducing the number of false or non-critical alarms. This helps to improve patient safety and reduce the risk of alarm fatigue. Therefore, I will create evaluable and adjustable alarm parameters to ensure that they are set at appropriate levels.

In addition, the constant noise of the alarms can also disrupt the peaceful environment of the NICU, making it difficult for medical staff to concentrate and making it more difficult for patients to get the rest they need to recover. This can contribute to the problem of alarm fatigue and make it even more difficult for medical staff to effectively respond to changes in a patient's condition. To address this single continuous acoustic stimulus, we considered setting different alarm patterns at different scopes, and transform the single acoustic signals into diverse visual or haptic information Based on the above problems, the main focus of this project is to create dynamic and adjustable alarm parameter thresholds based on nurses' response, as well as converting existing audible-based notifications into multi-sensory information delivery.

## 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.

I want to create new notification strategies for dynamic and adjustable alarm parameter thresholds based on nurses' response. This new notification strategy will be based on a more intelligent alarm parameter scope and the inclusion of new types of information delivery such as visuals or vibrations. And the strategy illustrated through products that users are nurses.

Research and design process
1. During the discovery and research phase:
1.1 Conduct a thorough review of the existing alarm systems used in NICU/PICU and their strengths and weaknesses. Know about how alarms are set up, managed, responded to, and used in everyday clinical activities.
1.2 Explore the methods and equipment used to record the nurse's response to the alarm. Interviews with nurses to understand their decision making process.
1.3 Explore and select algorithm which is appropriate to analyze the patients' data and nurses' responses.
2. For the Ideation and concept development：
In this phase, I will focus on exploring diverse alarms other than acoustics. I will find suitable medium to deliver the information for different alarm parameters. Meanwhile, I will start trying to train my algorithmic model.
3. Prototyping and usability testing
I will build a low-fidelity prototype to test the feasibility of the selected concept. Conduct usability testing sessions with healthcare providers and patients in NICU/PICU to gather feedback and evaluate the effectiveness of the prototype in reducing alarm fatigue. Then, based on the qualitative and quantitative analysis of the test results, I will iterate the prototype's interactive forms and patterns
4. Evaluation
Selecting the proper experience metrics to evaluate the entire design concept and final product. Reflect on the



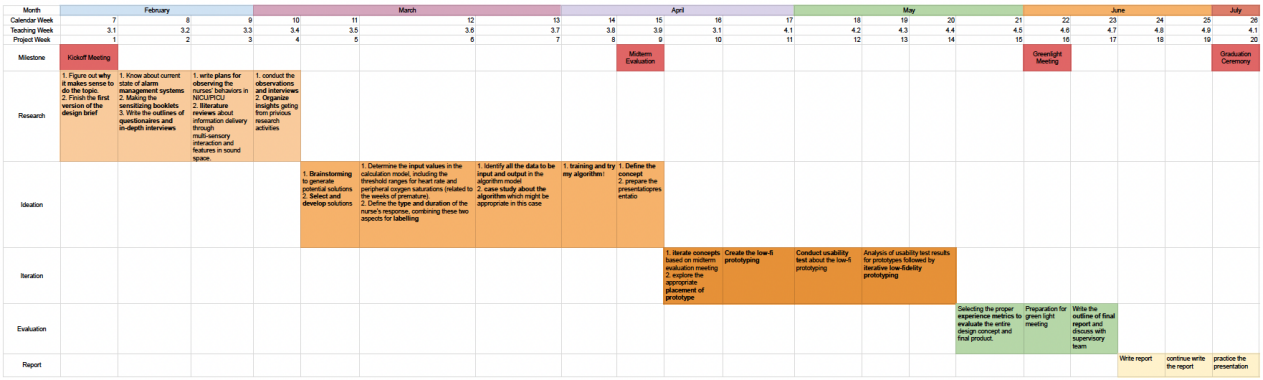
Initials & Name Chen Student number 5590795

Title of Project New alarm strategies for adjustable alarm parameter thresholds

## 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 17 - 2 - 2023 7 - 7 - 2023 end date




As a DFI student, I will employ several design methodologies including user-centered design, agile design and design think. Those methodologies are involved in conducting user research, prototyping, usability testing and continually iterating based on user feedback.
My plan will span 20weeks
Week 1-2: Develop a clear understanding of the problem of alarm fatigue in healthcare settings and the current state of alarm management systems. Conduct a literature review to gather information on existing alarm management strategies and their effectiveness. Some preparatory work for observations and interviews, such as making sensitizing booklets, determining the tool used to record the nurse's response, writing interview outline and questionnaires.
Week 3-4: Conduct interviews and surveys, their needs and requirements for a new system. Continue to conduct literature reviews about information delivery regarding multi-sensory interaction and features in sound space.
Week 5-9: Develop a set of requirements and specifications for the new notification strategy, taking into account the perspectives gathered from the stakeholders. Explore the algorithms and data structures needed to implement the real-time adjustments.
Week 9-11: Begin the implementation of the new notification strategy, starting with the development of a prototype. Conduct testing and debugging of the concept to ensure it meets the requirements and specifications.
Week 12-15: Refine the concept based on feedback from stakeholders and any issues identified during testing. Integrate the concept with medical equipment to build prototypes. Conduct the usability testing for the prototype.
Week 16-17Analysis of usability test results for prototypes followed by iterative low-fidelity prototyping. And then, higher-fidelity prototypes will be developed.
Week 18-20: Write the final report for the project and prepare for presentation.



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## 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.

last semester in my course-research methodology, my team's project about the night routines of patients in Paediatric Intensive Care Units and description of the acoustic environment helped me establish the fundamental research methodology and knowledge related to sound design in the healthcare field, and also aroused my curiosity and interest in this field. Therefore, in my graduation project, I dedicate to creating a suitably acoustic environment for NICU/PICU.

By designing the project, I would hope to demonstrate and learn several key competencies, including:

1. Artificial intelligence and machine learning skills: I want to discover how artificial intelligence can be used in design and machine learning techniques to generate related algorithm models.
2. Data analysis skills: The project requires the ability to collect and analyze large amounts of data related to patient monitoring and alarm events to train AI algorithms and evaluate the effectiveness of the new notification strategies.
3. Prototyping Capabilities: I hope I can improve my ability to create and refine a functional and physical prototype.
4. Problem-solving skills: I want to develop my problem-solving and critical thinking skills through the process of defining, prototyping, and testing new solutions.

## FINAL COMMENTS

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



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# Plan for observation

| Purpose | Time | Participants |
| --- | --- | --- |
| Connection<br>Effectiveness | Daytime<br>Night<br>Day- night shift | 2 |

| Position of observation point | Contents |
| --- | --- |
| Next to the equipments that emits the alarm | Causes of alarms<br>Response time of the nurse<br>Type of response<br>Whether the nurse is alone or with other staff members |

**1. Patient and Nurse Demographic Characteristics**

- Patient's Age:
- Weeks of gestation:
- Gender:
- Diagnosis:
- Nurse's years of experience:

**2. Pre-Observation Notes**

- Threshold values of alarm parameters:
  - Heart rate:
  - Blood pressure:
  - Oxygen saturation:
  - Respiratory rate:
  - Other:

**3. Observation Checklist**

**3.1 Causes of Alarms**

- Contact and transmission problems
- Routine treatment and care
- Inappropriate device settings
- Patients clinical condition
- Patients movement in bed

**3.2 Response Time and Response Type**

- Response time:
  - Within 15 seconds
  - Within 30 seconds
  - More than 60 seconds
- Response type:
  - Nothing
  - turning off the alarm（pause/silence）
  - Physical check on patient
  - Phone call to physician
  - Other (please specify):

**3.3 Nurse Alone or with Other Staff Members**

- Was the nurse alone or with other staff members when the alarm occurred?
- If with other staff members, who were they?

*Introduction.* Welcome to our survey! The purpose of this survey is to explore the interaction between nurses and alarms. We are interested in understanding how nurses respond to different types of alarms in their work environment. The survey consists of 20 questions and should take approximately 10-15 minutes to complete. Please note that all responses will be kept confidential and anonymous. Your participation in this survey is entirely voluntary, and you may choose to withdraw at any time. Thank you for taking the time to complete this survey. Your valuable insights will help us gain a better understanding of the relationship between nurses and alarms.

*1.* How many years of experiences do you have working as a NICU nurse?

- ○ Less than 1 year
- ◉ 1-3 years
- ○ 4-7 years
- ○ 8-10 years
- ○ More than 10 years

*2.* Have your institution provided you with any training, protocols, workshops or other information about adjusting alarm limits

- ☐ Not at all
- ☑ Trainings
- ☐ Protocols
- ☐ Workshops
- ☑ Other I learned this from bedsite teaching

*3.* Information provided by your institution can surpport you adjust alarm limits confidently

- ☐ Strongly disagree
- ☐ Agree
- ☑ Neutral
- ☐ Disagree
- ☐ Strongly agree

*4.* You are knowledgeable about the type of alarm parameter limits in your working unit

- ☐ None at all
- ☐ A little

- [ ] A moderate amount
- [x] A lot
- [ ] All

*5.* Rank the following statements on issues which inhibit effective alarm management (Most important = 1 to Least important = 5)

| | |
|---|---|
| Frequent false alarms, which lead to reduced attention or response to alarms when they occur | 1 |
| Inadequate staff to respond to alarms as they occur | 2 |
| Lack of training on alarm systems. | 3 |
| Difficulty in hearing alarms when they occur | 4 |
| Difficulty in setting alarms properly | 5 |

*6.* How often do you adjust alarm limits for one of your patients?

- [x] Several times during one shift
- [ ] Every time before starting shift
- [ ] Once or twice a week
- [ ] Once or twice a month
- [ ] Never

*7.* Which parameter makes you feel unconfident when adjusting the limits of the alarm

- [ ] ART D
- [x] ART M
- [ ] ART S
- [ ] SpO2
- [ ] CVP
- [ ] NBP M
- [ ] RESP
- [ ] STaVF
- [ ] STaVL
- [ ] STaVR
- [ ] STI
- [ ] STII
- [ ] STIII

- [ ] Other

*8.* You adjust the alarm limits based on

- [x] Patiens‘ symptoms
- [ ] Patient's historical alarm data
- [ ] Prescribed by doctors
- [ ] Discussion with colleagues
- [ ] Other

*9.* You feel confident in adjusting and monitoring alarm parameters in order to reduce nuisance/false alarms

- [x] Strongly agree
- [ ] Agree
- [ ] Neutral
- [ ] Disagree
- [ ] Strongly disagree

*10.* You have difficulties in setting alarms properly because of

| | Strongly disagree | Somewhat disagree | Neither agree nor disagree | Somewhat agree | Strongly agree | #Conjoint, Total# |
|---|---|---|---|---|---|---|
| Concerns about patient safety | 0 | 1 | 0 | 0 | 0 | 1 |
| Device complexity | 1 | 0 | 0 | 0 | 0 | 1 |
| Lack of complete understanding about patient condition | 0 | 1 | 0 | 0 | 0 | 1 |
| Lack of reference on the appropriate limits for patient condition | 0 | 0 | 1 | 0 | 0 | 1 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 |

*11.* You think it is necessary to inform colleagues about the adjustment

- [ ] Strongly agree
- [x] Agree
- [ ] Neutral
- [ ] Disagree
- [ ] Strongly disagree

*12.* You trust the response to alarms from other nurses

- [ ] Strongly agree
- [ ] Agree
- [ ] Neutral
- [x] Disagree
- [ ] Strongly disagree

*13.* If you have any questions about alarm limits, who do you consult for help

- [ ] More experienced nurses
- [x] Friendly relationship nurses
- [ ] Clinical engineering departments
- [ ] Manufacturer's instructions
- [ ] Other

*14.* Before each shift, what would you discuss with your colleagues about the alarm setting

If it is very divergent I will ask/explain why it is different

*15.* What steps do you take to adjust alarm limit?

I do not understand this question. I adjust the alarm limit, and sometimes I ask the docter if it is something important.

*16.* How do you feel telling your colleagues about your adjustments of the alarm limit?

If it is important i will tell, and otherwise not. Example: When the arterial line is not working properly I have a less strict alarm settings and I will tell this because they might react to a very low blood pressure.

*17.* You always silence alarms before starting nursing care.

- [ ] Never
- [x] Sometimes
- [ ] About half the time
- [ ] Most of the time
- [ ] Always

*18.* You silence alarms because

- [ ] Prepare nursing care
- [ ] Perception overload for alarms
- [x] Know the alarm is not clinically significant
- [ ] Patient moving
- [ ] Other procedure being performed
- [ ] Other

*19.* The place where you most often silence alarms

- [ ] Central station
- [x] Bedside monitoring
- [ ] Others

*20.* You do not respond immediately to an alarm because you are

- [ ] Waiting for alarms to self-correct
- [x] Handling higher priority tasks
- [ ] Not hearing the alarm
- [ ] Others

| | |
|---|---|
| Introduction (10min)<br><br>1. Welcome the nurse and express gratitude for their time.<br><br>2. Explain the purpose of the session: to improve the usability of a new application aimed at helping nurses in the NICU respond to and assess alarms more effectively.<br><br>3. Briefly outline the session structure. | Mindmap |
| Sensitizing Booklet (20 minutes)<br><br>1. Introduction:<br>Brief description of the booklet<br>How to fill the booklet.<br><br>2.Background & Experience:<br>Questions about their role, years of experience, their responsibilities, etc.<br>A description of a typical day in their role.<br><br>3.Understanding Alarms:<br>A section where they can write about what different alarms signify and how they usually respond to each.<br>Space for them to describe the most common issues with the current alarm system.<br><br>4.Interface Interactions:<br>They can describe their ideal process for silencing, forwarding, calling etc., in response to alarms.<br><br>5.Alarm Assessment:<br>They can describe how they currently assess the validity and seriousness of an alarm.<br>Include a list of possible alarm related keywords (like patient movement, equipment malfunction etc.) and ask them to rank them by relevance or frequency of use.<br><br>6.Dashboard Needs:<br>Ask for specifics about what they would like to see on a dashboard and how it can support their decision-making.<br>Invite them to sketch or describe their ideal dashboard.<br><br>7.Adjusting Alarm Limits:<br>Ask for their thoughts and concerns about adjusting alarm limits for individual patients.<br>Provide space for them to describe any specific experiences they've had with this. | Sensitizing-booklet |
| **Evaluation and Redesign of Interface (15 minutes)**<br><br>1.Introduce the app interface design. Discuss the reasoning behind your design decisions.<br>2.Encourage the nurse to explore the app, focusing on their ease of use, intuitive navigation, and relevance of information.<br>3.Ask for their feedback, what they liked and disliked. Do they think anything is missing or unnecessary?<br>Invite them to suggest changes. Use open-ended questions to inspire creative thinking, "How might you rearrange these elements?" "What could make this easier to use during your routine?" | Interface prototype |
| Evaluation and Redesign of Dashboard (20 minutes)<br><br>1.Introduce the dashboard design. Highlight the purpose of each feature.<br>2.Allow the nurse to interact with the dashboard, observing their initial reactions.<br>3.Ask for their feedback, focusing on readability, data clarity, and relevance. | Dashboard prototype |

## Important to know:

- This booklet is your personal tool. Therefore, there are no right or wrong answers. I am most interested in understanding your personal experiences and perspectives.
- Use any pens or stickers you like, and feel free to draw.
- Please rest assured that any information you provide in this booklet will be processed confidentially. Your anonymity is guaranteed.
- If you have questions, call me at 611270520 or email at G.CHEN-7@student.tudelft.nl.

# *Nurses & Alarms: Your Insights Matter*

Thank you for participating in my research! My name is Gongyu. I am working on my graduation project at Delft University of Technology. I study Design for Interaction at the Faculty of Industrial Design.

In this project, I am focusing on the creation of a comprehensive interface and dashboard for nurses in the Neonatal Intensive Care Unit (NICU). The primary aim is to provide an intuitive, evidence-based overview of patient alarms and other critical data, ultimately enhancing the efficiency and effectiveness of your work.

But for this design to truly be beneficial and meet your needs, it's absolutely essential that I understand your unique challenges, experiences, and perspectives as a NICU nurse. This booklet contains several exercises related to your work in the NICU.
Thank you once again for your invaluable contribution to this project.

I look forward to delving deeper into your insights during our co-creation session!

## Background & Experience:

What is your official role?

How many of those years have been in the NICU?

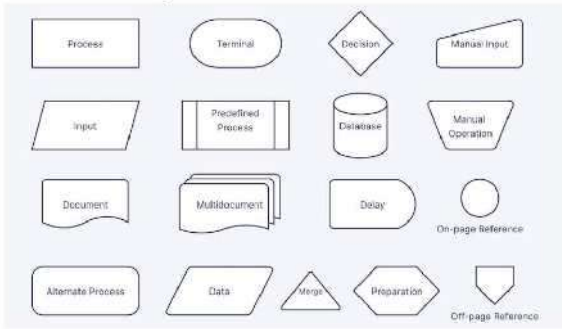
What information or tools would give you more confidence when deciding to adjust alarm limits?

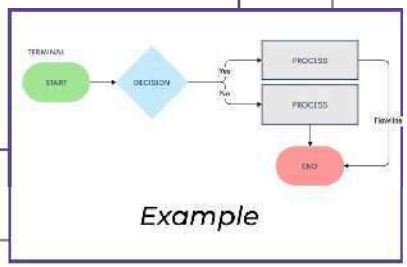
What is your process for adjusting alarm limits?

(Initial Steps, Decision-making Factors, Frequency, Challenges, Outcome Evaluation, Team Coordination.....)

Could you draw out a flowchart or sketch that represents your current interaction with the alarm system when an alarm occurs?

Flowchart Symbols




*Example*

## Alarm Evaluation

Could you describe your thought process when an alarm goes off? How do you determine the seriousness and validity of the alarm?

When an alarm sounds, I first identify the _____

_____

_____

I assess the _____

_____

_____

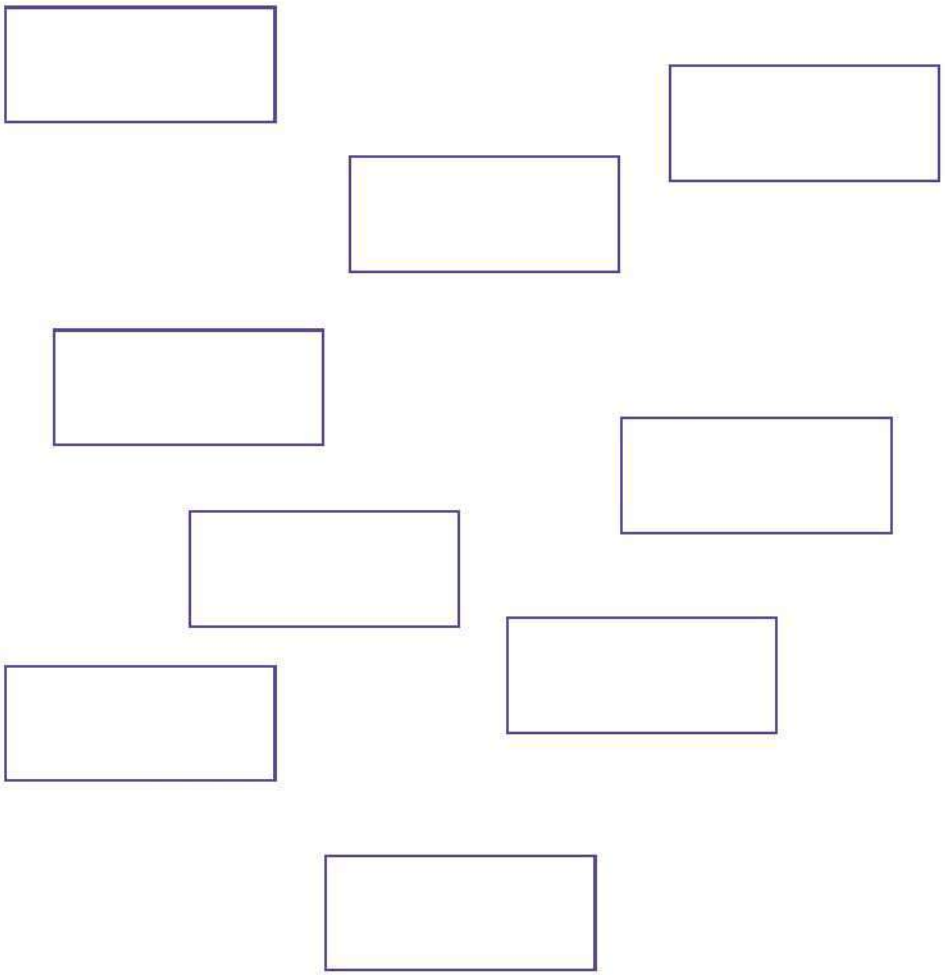
then visually inspect _____

_____

_____

## list of keywords related to alarms

Could you list of possible keywords related to alarms (such as patient movement, equipment malfunction, etc.). Could you rank them in terms of how frequently you encounter each situation or how relevant they are to your role?



## Current Limitations

Are there any instances where the current interface has hindered your actions or caused inconvenience while responding to alarms?

## Ideal Process

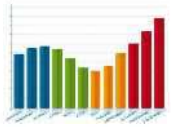
How would you ideally like to silence, forward, and respond to alarms?

## Dashboard Needs

In this section, we aim to understand your needs and preferences for an ideal dashboard that could support your decision-making process. Your insights will directly inform the design of the new system.

What specific information would you like to see on the dashboard?

How should this information be displayed to best support your decision-making?



bar graph

pie chart


word cloud

timeline

tabular format

card

## Creating Your Ideal Dashboard:

Can you sketch or describe your ideal dashboard?

When designing your ideal dashboard, you might want to consider:

- What information is essential for you to see at a glance?
- In what order or layout would that information be most useful?
- How would you like to be informed when alarm limits need to be adjusted?
- What additional features or tools would help you make these decisions more confidently?