Master thesis

Overcome

Reducing ICU patients anxiety through medical alarms feedback provision

Salvatore Luca Cucinella

MSc Design for Interaction | Specialisation Medisign | Delft University of Technology | 2020

Master thesis

Overcome

Reducing ICU patients anxiety
through medical alarms feedback provision

Salvatore Luca Cucinella

Colophon

Master thesis

Overcome

Reducing ICU patients anxiety through medical alarms feedback provision

Defended on March 13th 2020

Written and designed by **Salvatore Luca Cucinella**

Dr Elif Özcan Vieira

TU Delft supervision by **Dr Jos Kraal**

Eramsus MC supervision by **Dr Diederik Gommers**

Ai miei nonni.

Executive summary

In the Intensive Care Units (ICU) patients are exposed to many, continuous and highly stressors, such as medical alarms, which contribute to the development of psychological issues, such as delirium, anxiety disorders and post-traumatic stress disorders (PTSD). These psychological issues have a negative influence on the patients' healing process and dramatically reduce the quality of life during and after ICU.

Medical alarms are meaningful signals that inform nurses and lead them to properly act to attend patients' basic needs and medical treatments.

However, medical alarms are not meant for patients who lack resources to cope with them. Due to their ambiguity, alarms are perceived as a threat, and appraised as dangerous by patients.

Nurses are the main resource for patients to cope with such a threat. Nurses have the information needed by patients to reduce their uncertainty and stress provoked by such a stressor; therefore, lack of support contributes to the risks of developing psychological issues.

Designing solutions that aim to reduce the risks of developing psychological disorders during the period of hospitalization in the ICU is necessary to facilitate the people healing process and to guarantee them an improved quality of life during and after such an experience.

Overcome is a feedback interface designed to enable nurses to communicate by a distance with patients to reduce the risks of developing a state of anxiety when a medical alarm goes off.

Through the provision of feedback, *Overcome* informs patients about the nurses' decisions over medical alarms while they are approaching the room thus restoring the perceived sense of safety.

This report reveals insights into the experience of ICU nurse and (former) patients with medical alarms in the ICU and focuses on the patients' cognitive process, as well as on the nurse-patient interactions.

Contents

Chapter 1

A basic introduction to the topics treated in this report will be given in this chapter. The outcomes from the research conducted at the Erasmus MC as student-intern will be briefly introduced to guide the reader into the process that led to the definition of the problem investigated in this Graduation Project.

A brief presentation of the concept of Patient-centered care will be provided, including an introduction to the top 20 research priorities of adult intensive care nurses in Europe.

In addition, to understand more about the relationship between stress, anxiety and ICU patients, a theory based on Coping and Stress will be explained. Finally, the topic of Social Support will be treated with a focus on the interpersonal relationship between nurses and patients.

Figure 0. Patient's room at the *Department of Intensive Care of the Erasmus Mc*. Photo by TU Delft.nl.

introduction

Since my bachelor, I have been always interested in the topic of Ergonomics and how to design solutions that improve users' experience when interacting with everyday products. Apply ergonomics principles into my projects taught me that Design is a discipline that requires a balance between creativity and technical knowledge. During that journey, I have strictly focused on people's physiological well-being, such as understanding how to improve the position people hold their bodies when sit or read.

This interest has led me to want to know more about the aforementioned topic with the intent to become a Designer for Health.

The Master of Science in Design for Interaction gave me that opportunity. What I have learned during this journey went over my expectations, especially when I decided to take the specialization in Medisign. In the last two years, I had the opportunity to explore the topics related to psychological well-being and learning how to approach a problem starting from the study of users' needs in a specific context to design products that are relevant to them.

At the end of my first Master year in TU Delft, I started to collaborate as a student intern in a project cooperated by the Critical Alarms Lab (Tu Delft) and the Department of Intensive Care of the Erasmus MC (Rotterdam). During that experience, I studied the problem of sleep disruption in ICU patients and its relationship with the sound-producing events (SPEs). That study put me inside the intensive care, a challenging environment where people fight, with the support of professionals and loved ones, to survive.

What I have seen inside that rooms is something that it is difficult to describe because what a person can become in a matter of seconds after an accident or a disease is profoundly touching and it is truly comprehensible

only by those that live such an experience, such as patients, family members, friends or healthcare professionals.

Being an ICU patient means becoming dependent by others, it is like being a working mind inside a broken body: you can see what's happening, but you cannot do anything to help yourself except submit to the events and hope that one day you will return back to your life as you used to be.

Being in close contact with the patients and observing them in their everyday life inside the ICU led me to want to know more about how they feel, especially when exposed to those stressors, such as medical alarms, that make their experience even more miserable.

Thus, I started to develop an interest in the study of the ICU patients emotional reactions to the SPEs, and, with my tutors, we redefined my assignment:

Monitoring emotional well-being in the Intensive Care Unit (ICU): Emotional implications of sound-producing events (SPEs) on non-sedated patients.

A first investigation into the emotional experience of non-sedated ICU patients elicited by sound-producing events with a focus on patient sleep.

I concluded my internship showing that medical alarms, the way how professionals respond to them and the way how they interact with patients are factors that contribute to the development of high levels of stress and they can facilitate the development of psychological issues, such as anxiety disorders.

With this conclusion, I decided to dedicate my Graduation Project in the study of this problem with the aim to develop a solution that could prevent the development of a state of anxiety when a medical alarm goes off.

1.1 | Problem definition

In the Intensive Care Units (ICUs), medical alarms can act as stressors. Stressors are potential threats that only result in stress if people cognitively appraise them as threats that exceed their resources [1]. The stress that medical alarms cause can lead to a range of psychological discomfort raging from anxiety and delirium in the ICU or post-traumatic stress disorders (PTSD) after discharge.

To reduce the risks of developing these psychological issues, is it necessary to provide patients with proper and timely support when stressful events occur.

The "unpredictable transition between silence and disturbing sounds do not create a healing environment for the critically ill patient but create stress" [2]. When they occur, medical alarms startle patients who make a transition from a state of quiet to an unpredictable state of stress.

Patients are not educated to interpret alarms nor they can control them, but only submit. Lack of control, understanding, and support lead them to perceive all the alarms as threats and appraise them as dangerous. Allowing patients to positively reframe the medical alarms calm them down and restore comfort.

Interactions with nurses, which implies verbal and non-verbal communication, help patients to cope with the alarms and reduce stress levels and anxiety. Nurses are the main resource for patients to cope with such a threat because they have the information needed by patients to reduce their uncertainty and stress provoked by such a stressor [3]. However, such human-human interactions are not always possible due to obstacles in alarm management or nurses' difficulties in recognition of and fatigue in relation to medical alarms [4]. As a result, nurses can delay their responses leaving patients exposed to medical alarms longer than expected.

Lack of control, understanding, and support can lead patients to the uncertainty of surviving especially when waiting for the arrival of a nurse. Waiting time increases uncertainty on patients regarding their safety: the more a patient wait for the arrival of a nurse, the less they perceive themselves safe. When waiting is longer than expected, patients can start to doubt whether nurses are aware of the alarm and if they are monitoring them.
To restore the perceived sense of safety, patients need to know what is happening. While waiting, patients wonder if the alarm is indicating a life-threatening situation and whether a nurse will arrive to check. Being oblivious of such a situation adds stress and facilitates the development of anxiety.

Patients can experience such situations many times, especially if considered that false alarms, which are more frequent in the ICUs, "lead to reduced attention or response to alarms in nurses" [4].

Timely acknowledging patients when a medical alarm goes off could calm patients down. It might benefit their healing process, as well as mental health.

Overcome gives nurses the opportunity to support timely and continuously their patients by a distance. Through the provision of feedback, patients are passively involved in the nurses' decision-making process when a medical alarm goes off, thus nurses can calm them down while waiting for their arrival.

1.2 | Previously at the EMC

Figure 1. Erasmus Mc, Rotterdam.

During my internship at the Erasmus Medical Center - EMC (Figure 1) an observational study was performed to record the actions and behaviours of ICU pantients and nurses in relation to Sounds Producing Events (SPEs), alarms, human-human interactions and human-environment interactions.

During this study, I determined the prevalence of emotions and behaviours, measured the typology of SPEs and detect the changes of three ICU patients vitals signs. The observations were made being 'a fly on the wall' without disturbing, influencing or altering the environment or the patients and nurses in any way.

Three non-sedated ICU patients were continuously observed for an 8-hour period each in three different work shift (morning, afternoon and night). Through a window placed in the nurse monitoring workstation, I was observing the patient and collecting the data. Attention was put on the study of the psychological stress provoked by sounds producing events (SPEs) with a focus on patients emotional reactions and sleep/ wake cycles.

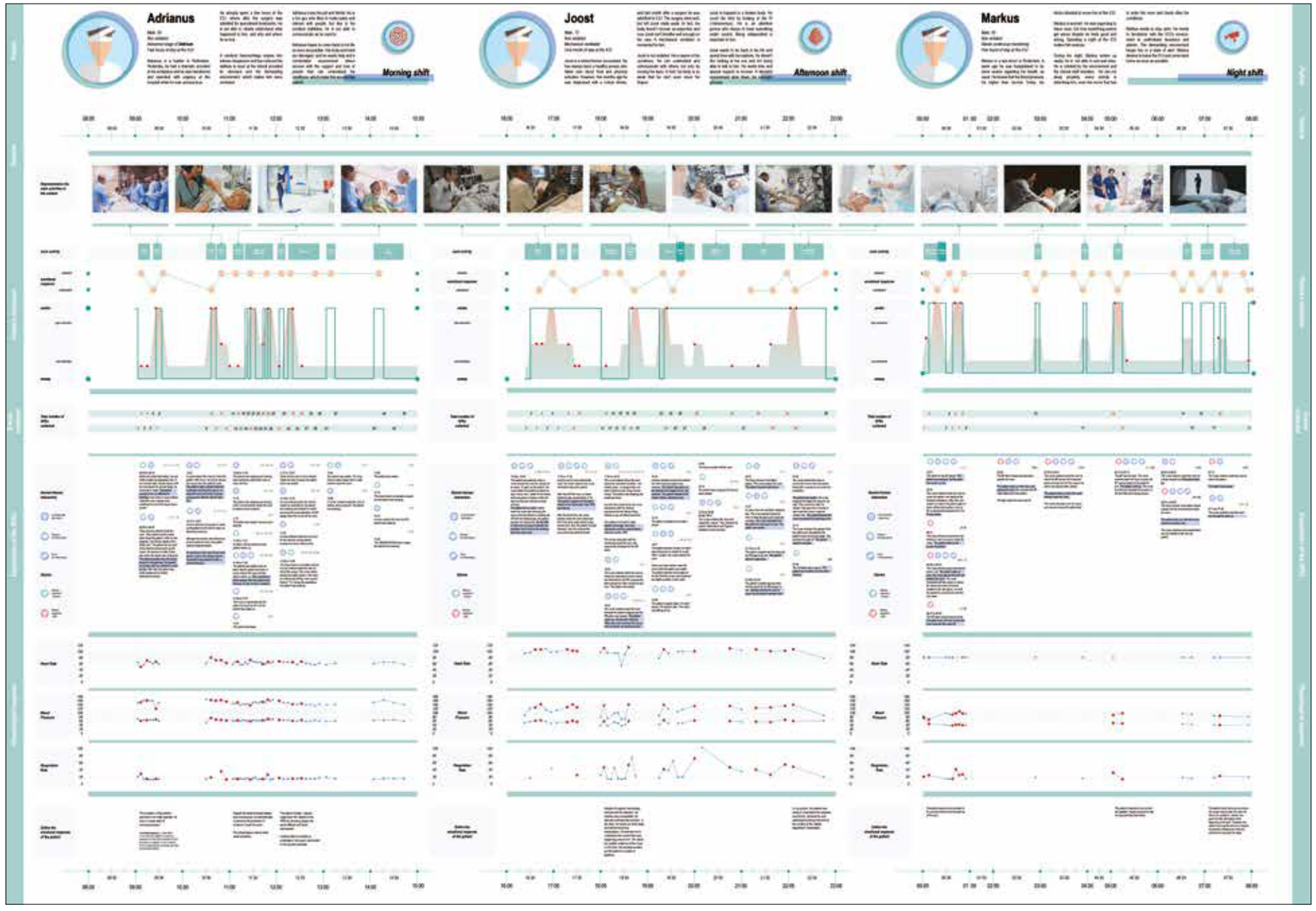
Based on the top 5 anxiety indicators [11] (agitation, increased blood pressure, increased heart rate, patients' verbalization of anxiety, and restlessness), to estimate patients emotional responses to the SPEs, patients' vital signs (blood pressure - BP, heart rate - HR and respiration rate - RR) were collected, as well as facial expressions, to assess psychological well-being.

As shown in Figure 2, in most of the cases, especially when a medical alarm went off, arousals in vital signs and changes in facial expressions were captured. In addition, if asleep, patients woke up. Then, arousals corresponding to SPEs were viewed as a representation of a state of anxiety, considered as a result of a reaction to stress.

It was concluded that ICU patients respond to SPEs with negative emotional reactions and long exposure to such unpleasant emotions might contribute to low psychological well-being. As a result, SPEs were defined as a cause of sleep disruption and considered as a source of stress and anxiety as their occurrence interferes with patient well-being.

Figure 2.
Patient Emotional Experience Map: *causes and effects of sudden SPEs.*

A patient's framework where the main sudden SPEs and the respective emotional reactions are shown. This document provide an overview of the patient's emotional reactions and a categorization of the more common and influencing sudden SPEs that contribute to the onset of psychological disorders in a case of prolonged and constant exposure.



1.3 | EFCCNa research priorities

The importance of effective communication has been acknowledged as essential to reduce stress and anxiety, especially with ICU patients.
The topic has arisen interest on an international level and it was presented in a study conducted by *The European Federation of Critical Care Nurses Associations* (EfCCNa).

The EfCCNa is a formal network of critical care nursing associations in Europe, and has presented a list of the top 20 research priorities of adult intensive care nurses in 20 European countries, including the Netherlands. These priorities serve as a guide for conducting research on the most relevant issues related to ICU care [10].

In the study, five different areas of interventions have been identified: *(1) patient safety issues; (2) impact of evidence based practice on outcomes; (3) impact of nursing workforce (numbers and qualifications) on patient outcomes; (4) wellbeing of patients and relatives; (5) impact of end-of-life care on nursing staff and practice.*

One of the four topics, related to patients and relatives wellbeing, was scored in the top 5 intensive care nursing priorities (3rd position):

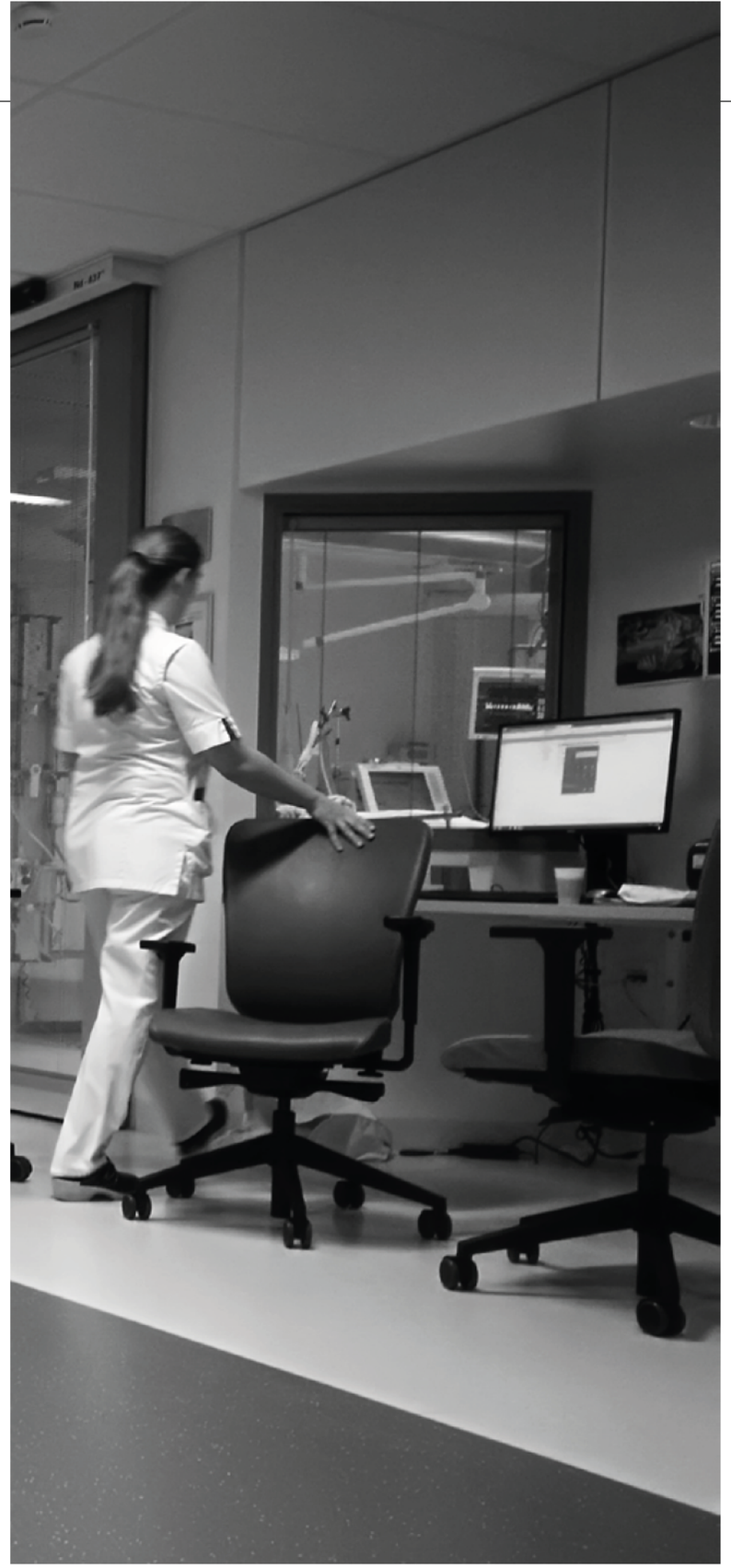
“Exploration of the extent of, and strategies to reduce anxiety, fear and stress of ICU patients”

The area of wellbeing of patients and relatives is one of the more dominant and includes topics like psychological care (including anxiety, fear and stress) and communication (patients and relatives).

In light of these considerations, it seems that the topic related to anxiety and stress on ICU patients needs more research and attention by healthcare professionals.

In this discussion, designers can also participate with research that improve the understanding of the factors (contextual and individual) that influence patients wellbeing, such as the medical alarms.

As a result, and in line with the third priority proposed by the EfCCNa, with my research, I want to give my contribution on the topic of the *wellbeing of patients and relatives* by understanding the relationship between anxiety and medical alarms and developing a strategy/solution that could help to reduce the anxiety of ICU patient.



1.4 | Research areas

Person-centered care

In *Person-centered care* patients and members of their family are seen as partners of healthcare professionals. Clinicians are encouraged to keep patients informed during the entire process of care involving them in decisions about their own care [7].
Patients involved in the decision-making process are empowered because are giving them more opportunities to understand their problems and gain control over their own situation. Collaboration and communication between patients and clinicians is essential and considered key concepts in person-centered care.

According to [8], “ the importance of clear communication in a timely and understandable manner to the person being treated and their relatives, might support the coping mechanism managing the stressful surroundings and critically unstable situation”.
Also, “ineffective communication and lack of information further contribute to distress patients” [9].

As a result, communication and the provision of information help patients to make sense of their situation and to cope with the stressful and demanding experience they have to live with during hospitalization.

Indeed, being able to understand the reasons behind an event can reduce stress, fear, and anxiety, because people can cognitively and emotionally process all the possible outcomes in advance [8].

In this project, the person-centered care approach served to understand the importance of communication for patients’ psychological well-being and to develop a tool that, by a distance, could improve the nurse-patient communication when a medical alarm goes off.

Human-centered alarms

In the field of Audible Alarm Design attention is put on designing more human-centered alarms for “monitoring health data and warning users regarding out-of-limit values and other conditions for which alarms might be appropriated” [6].

A collaborative approach in Critical Alarm Design is proposed in [6] where the “individual and collaborative roles of the different users in, and their role in contributing to, the future development of audible alarms is fundamental”.

The framework illustrates a non-linear collaborative approach that aims to “being inclusive in decision making by taking a holistic view of the alarm issues and emerging technologies” [6].

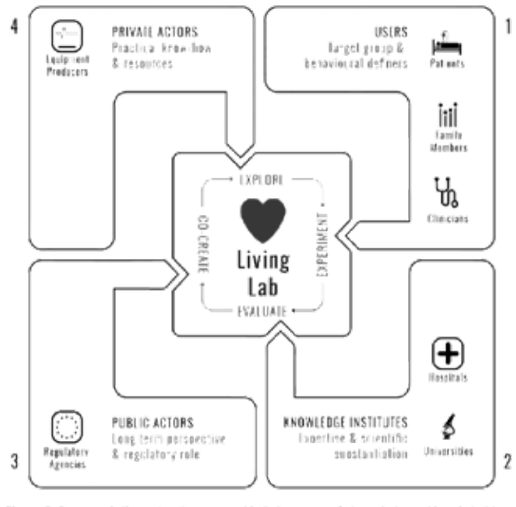


Figure 3. *Framework illustrating the holistic context of alarm design, with stakeholders equally and simultaneously contributing to the development of future alarms and medical equipment in living labs designated for critical alarms (Ozcan, Birdja and Edworthy, 2018).*

In this project, the collaboration of the knowledge institutes (TU Delft and Erasmus MC) and users (ICU nurses and former ICU Patients) was considered to understand how alarms are managed by clinical staff and perceived by users, and to design a solution that satisfies their needs.

Medical alarms

While in 1983 about 6 types of alarms from one patient were reported, in 2011 about 40 types of clinical alarms were recorded [4], and between 85% and 99% of alarms do not warrant clinical intervention; but only an average of 10% of alarms are seen reliable by nurses [18].

According to [15], “ambient noise, including alarms, in ICUs were estimated to be more than 80 dB, which is close to the noise level generated by a pneumatic drill in an operating room”.

Noise levels, resulting from more than 40 different alarms of different monitoring systems [16], can negatively impact the working conditions of the medical staff and causing stress to patients hospitalized in the ICU [17].

Alarm categorization

Although medical alarms are intended to protect patients and used as tool that help clinicians to improve “the safety of patients” by communicating information that “requires a response or awareness by the operator”[20], they have instead led to many issues, such as increased unit noise, alarm fatigue, etc.

Medical alarms may follow a hierarchical order in some medical devices (e.g. physiological monitor), such as *crisis alarm* (detection of life-threatening situations), *system failure* (detection of life/threatening device malfunction), *warning alarm* (detection of imminent danger), *system warning* (detection of potential device malfunction), and *advisory alarm* (detection of unsafe situation), thus for clinicians recognise them can be easier; however, other devices (e.g. IV infusion pump) do not follow such an hierarchy, thus sounds can be the same regardless of the situation that triggers an alarm [20].

According to the *Association Francaise de Normalisation* (AFNOR) alarms can be classified into three categories [60]:

•*Les alarmes de priorite’ haute - high priority alarms*: which indicate an emergency situation: an immediate response from the nursing staff is necessary to resolve an immediately vital problem for the patient;
• *Les alarmes de priorite moyenne - medium priority alarms:* which indicate a danger; prompt response from caregivers is required;
• *Les alarmse de priorite basse - low priority alarms:* which indicate an alert level; the attention of the nursing staff is necessary.

False alarms

Studies have shown that the rate of *false alarms* is higher than those who are clinically relevant [24,19]. Up to 90% of all alarms in critical care are false and, in many

cases, they result from measurement and movement artefacts [23, 24].
False alarms are the most problematic factor in the ICUs that lead clinicians to develop alarm fatigue and which, as a consequence, induce patients to experience long waiting time when a medical alarm goes off.
They are defined in [20] as *false-positive alarms and/or clinically irrelevant* alarms that can compromise patients safety. They do not represent a danger to the patient but they may interfere with patient care; these alarms typically do not result from an adverse patient condition, but they come from medical devices that cannot differently configured to stop an alarm sounds when the situation is neither important nor urgent.

Nurses' reaction time
The probability of a nurse to respond directly to an alarm depends on different factors (*causes of an alarm, its duration and the characteristics of the patient*) which are take into consideration when nurses decide which action to take or whether is necessary their intervention [20].
In a study conducted by [22] the reaction time of the health care team was measured, and from the 82 alarms with responses, on average, clinicians spend *from a minimum of 20 seconds to a maximum of 5 minutes* before reacting to an alarm. In addition, it was shown that the most common procedures performed by clinicians in responding to an alarm were pause the alarms (36.84% during the morning shift and 54.55% during night shift), adjust the electrodes (28.95% during the morning shift and 6.82% during the night shift) and repositioning of the pulse oximetry sensor (5.26% during the morning shift and 22.73% during the night shift).

Alarm fatigue
Medical staff overexposed to alarms may experience a decrease in concentration, become careless, and commits mistakes [21].
Overexposure may lead to desensitization to alarms and may cause nurses to improperly cope with significant alarms that affect patient's safety [21].
According to [20], "alarm fatigue occur when the number of alarms causes clinical staff to become desensitized such that a real event may be unrecognized or ignored, or the speed with which the caregiver reacts to an alarm is hampered".

Patients and alarms
Patients are exposed to many alarms during a day (an average of 1 alarm every 37 minutes - [23]).
Medical alarms overwhelm and surround patients whose position is central in relation to the sources of these alarms.

Patients' wellbeing is affected by the alarms in two ways: (1) *directly*, by increasing the number of arousals, which may result in sleep disruption and in high levels of stress; (2) *indirectly*, by reducing the degree of alertness of the ICU staff whose exposure to high number of clinically irrelevant alarms may result in a reduction of their clinical sensitivity of the alarm system (alarm fatigue), inducing patients in critical or even life-threatening situations [19].
Therefore, patients are powerless to the alarms and at the mercy of the clinical staff.

Alarm ambiguity
For patients all the alarms are important, and there are no differences between a true or a false alarm.
Medical alarms ambiguity is a serious issues for ICU patients well-being. Alarms have more than one interpretation, explanation or meaning for patients who lack of the knowledge to properly distinguish and interpret them.
The lack of understanding can contribute to fear, stress and anxiety as patients are unable to properly appraise these auditory stimuli.

Anxiety

In [26], anxiety is defined as "fear of the unknown, as disproportionate to the threat involved, related to the future". At the Delft Institute of Positive Design (DIoPD), anxiety is described as a negative emotion experienced by individuals as a response to an ambiguous threat and defined as the feeling when "You think about bad things that could happen to you. You are on guard, because you don't know what the threat is" [27].

Anxiety can be described as a negative emotion that people experience in response to a potential threat in an unfamiliar situation which presents unclear outcomes. These unclear outcomes are, for instance, due to lack of experience and resources which reduce an individual's capability to properly appraise and react to a threat. Indeed, feeling that something is wrong and not knowing where the threat comes from make people uncertain which, as a result, adversely affects their wellbeing (e.g. increased stress levels).
In such emotional conditions, people start to become vigilant and scan their surroundings for more information [27].

Trait Anxiety and State of Anxiety
The way how people emotionally and physiologically react to a medical alarm can vary between individuals. Noise sensitivity, as well as the personality can influence the way how patients look at an alarm and how they approache the problems.

About anxiety, it is necessary to understand the differences between *trait anxiety* and *state of anxiety*.

Trait anxiety is the "tendency of a person to experience anxiety" and this depends on his/her personality, or the tendency to "perceive the world in a certain way and in dispositions to react or behave in a specific manner with predictable regularity" [50].

With *state of anxiety*, we are referring to the emotional and physiological manifestations of anxiety that a person shows when he/she is subjected to a stressor.
An emotional state exists at "a given moment in time and at a particular level of intensity"[50].
In addition, anxiety states are characterized by "subjective feelings of tension, apprehension, nervousness, and worry, and by activation or arousal of the autonomic nervous system" [50].

In this research, I did not take into consideration the personality (anxiety trait) of patients into account, but I focused on the emotional and physiological manifestation of anxiety (state of anxiety) in relation to medical alarms.

Delirium
Delirium is a psychological issues that limits the mental abilities of patients and resulting in confused thinking and reduced awareness of the environment. Delirium can take hours or a few days before starting, and takes place during the period of ICU stay.
This mental disorder can be caused by many factors, such as

chronic illness, infection, surgery, drug intoxication, as well as the exposure to medical alarms [28].

For a patient with delirium is difficult to stay focused on a topic or responding to questions or to conversate. They usually have poor memory and have difficulties in understanding.

Consequences of anxiety and stress
"Impairment in physical, cognitive or mental health status following treatment on an ICU" is known as *Post-intensive care syndrome* (PICS). Psychological issues such as anxiety disorders[1], depression and post-traumatic stress disorder[2] (PTSD) [31], are the major psychological conditions former patients experience after ICU discharge. Unfortunately, these issues have usually long-term effects and they can make difficult any activity, such as sleeping, social interactions, finding a job, etc.

Research suggests that acute stress in the ICU may be "one of the strongest patient risk factors for poor psychological and cognitive outcomes after intensive care" [30]; therefore, it is important to detect and minimise acute stress where possible.
In general, depressive symptoms occur in around 29% of survivors at 3, 6 and 12 months post ICU discharge, and it has been shown that there is no correlation with ICU length of stay or illness severity [31].

Interventions in the ICUs
To improve mental health and facilitate rehabilitation, several strategies are employed in the ICUs, as well as by external organizations that support former patients and their families.

Here, few examples: *reduction of pharmacological interventions* that instead keep patients unconscious and facilitate the development of psychological disorders; *ICU diary*, which enables patients to reconstruct a chronological timeline from a fragmented memory [62]; *psychological services*, such as follow-up care where psychotherapists, counsellors and follow-up nurses specialists psychology support patients to reduce the incidence of PTSD [30, 33]; *protocols and guidelines* to improve healthcare staff performance and skills in the interaction with their patients [34].

Such interventions can improve the overall patients experience [9] and help in minimizing symptoms of cognitive and mental disorders [62]; indeed, according to [35], state of anxiety management during ICU treatment might contribute to reduce subsequent PTSD.

[1] Anxiety disorders
People with anxiety disorders frequently is worried and scared. Anxiety disorders involve feelings of intense anxiety, fear or panic attacks [62].

[2] PTSD
Post-traumatic stress disorder is a mental health condition and it is caused by a traumatic event which, usually, have been experienced in the past. Symptoms may include flashbacks, nightmares and severe anxiety, as well as uncontrollable thoughts about the event [62].

Coping with medical alarms

The *Transactional Model of Stress and Coping* proposed by Lazarous and Folkman (Fig. 4) was used as a framework to describe the ICU patient's experience with medical alarms.

According to [36], "psychological stress is a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being".

The *Model of Stress and Coping* shows the cognitive process people follow after being exposed to an environmental stimuli, also called stressors.

After sensing and filtering a stimulus, people try to interpret it (*primary appraisal*) and, based on their perception, appraise the stressor as positive, dangerous or irrelevant. If the stressor is unknown is usually perceived as

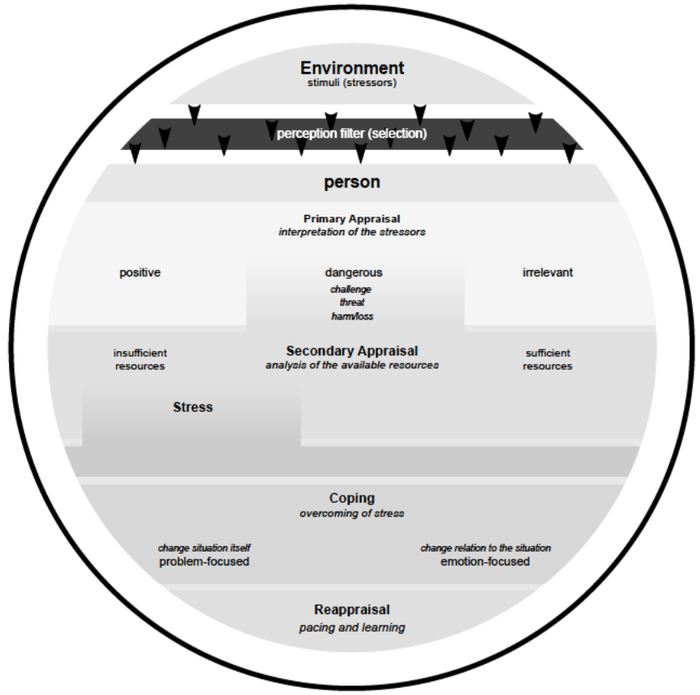


Figure 4. *The Transactional Model of Stress and Coping describes how stimuli can be perceived by people. Depending on a person's appraisal of the stressor and their available recourses to respond, they can experience stress.*

a threat and appraised as dangerous. Not being able to interpret the stressor nor identifying its source are the reasons that can lead people to such an evaluation.

During *secondary appraisal*, people start to analyse their available resources and, if the resources to cope with the threat are sufficient, the person will suddenly overcome the stress, but if the resources are insufficient, people develop stress.

To cope, people use two different strategies: *Emotion-focused strategies*, in which a person decide to change the relation to the stressor (e.g. self-controlling, escape-avoidance, distracting, etc.); and *Problem-focused strategies*, in which people change the situation itself (e.g. social support, problem-solving skills).

Resources provide people with the abilities to regulate their emotional and physiological response towards a stressor. Resources help people to properly *reappraising* the stimuli and, finally, calm down.

"Adequate coping resources are necessary to assist the patient with adapting to stressors in order to minimize stress levels in the present situation" [1].

Coping with a medical alarm is critical to safeguard patients psychological well-being, and good strategies can lead a patient exposed to a medical alarm, in a physiological and emotional response-regulation.

In the ICUs, patients are constantly exposed to many sensory stimuli which aggravate the feeling of anxiety and affect or even induce new health complications (e.g. *intensive care syndrome*) prolonging the recovery process, and which alters individuals' mental functions (e.g. confusion, disorientation, hallucinations) [7].

Noise-induced stress is a condition that physically and emotionally occurs when a person is "unable to ignore, block out or otherwise cope with the unwanted sound" [29].

Normally, events induce people to a physiological reaction called the *fight-or-flight response*[3] which describes how human beings, as well as animals, react to stress. Unfortunately, the critical conditions reduce the patients' fight-or-flight response.

Medical alarms, considered as negative sources of influence, are an example of sensory stimuli that patients cannot solve or escape from. The imbalance between external demands and the individual's capability to cope with such stressors leads to reduced well-being, but can also result in adverse stress reactions that affect patients both physically and mentally, for instance, resulting in delirium [28].

[3] ***Fight-or-flight response***
When feeling threatened, our nervous system physiologically prepares our body to respond to the events by producing hormones (e.g. testosterone, estrogens and cortisol) which effect the way how we react. People can have two types of threat-responses: fight with the threat or escape from the threat. The way how a person reacts depends also on the resources he/she has to cope with the threat; thus, the more are the resources, the higher are the possibilities to succeed.

Social support

Social support can enhance patients' ability to access new information and to identify and solve problems. The provision of information might help to reduce uncertainty and help to produce desired outcomes.

"When people experience stressors, having enhanced individual or community resources increases the likelihood that stressors will be handled or coped with in a way that reduces both short-term and long-term adverse health consequences" [61].

Social support can be provided by many types of people and in two different kind of helping networks: *informal*, such as the support provided by family, friends, co-workers or supervisors; *formal*, such as health care professionals.

"The effectiveness of the support provided may depend on the source of the support" [38]. In medical care settings, "patients often need emotional support from family and friends and informational support from health care professionals" [39].

The social network of ICU patient is composed by many social relationships including different professionals, family members and friends.

Patients' social relationships are characterized by different functions, such as social support and companionship. In the case of this project, we focused on the social relationship between ICU nurses and patients.

Nurses are the main resources for patients to cope with stressors, including medical alarms; indeed, they have the knowledge a patient needs to cope with. The nurse-patient relationship is characterized by many interactions and types of supportive behaviours.

According to [38] social support can be categorized into four types of supportive behaviours:

1. *Emotional support*, or the provision of empathy, love, trust, and caring.
2. *Instrumental support*, or the provision of tangible aid and services that directly assist a person in need.
3. *Informational support*, or the provision of advice, suggestions, and information that a person can use to address problems.
4. *Appraisal support*, or the provision of information that is useful

for self-evaluation purposes - such as constructive feedback and affirmation.

In this project, I analysed the nurses supportive behaviours towards a patients to understand how they help patients coping with an alarm. I focused on verbal and non-verbal communication considering the content and the way how nurses convey to patients the information needed to cope.

ICU Patients' social network

At the ICUs, many professionals are involved in the care of patients providing the needed support to help in the recovering process. Family members, as well as friends, also are included in this network providing o their loved ones with emotional support (Fig. 5).

Nurses, who principal role is to execute the treatments, are the caregivers that spend more time in contact with patients; *physicians* (intensivists, specialists, etc.) are those that visit patients and determine their medical treatment; *physiotherapists, dietician, pharmacist*, etc., are the professionals that support nurses and physician with specific treatments; *cleaning staff, technicians*, etc. are those who, instead, support the treatment logistically. The team is led by an *operational manager* or *team leader*.

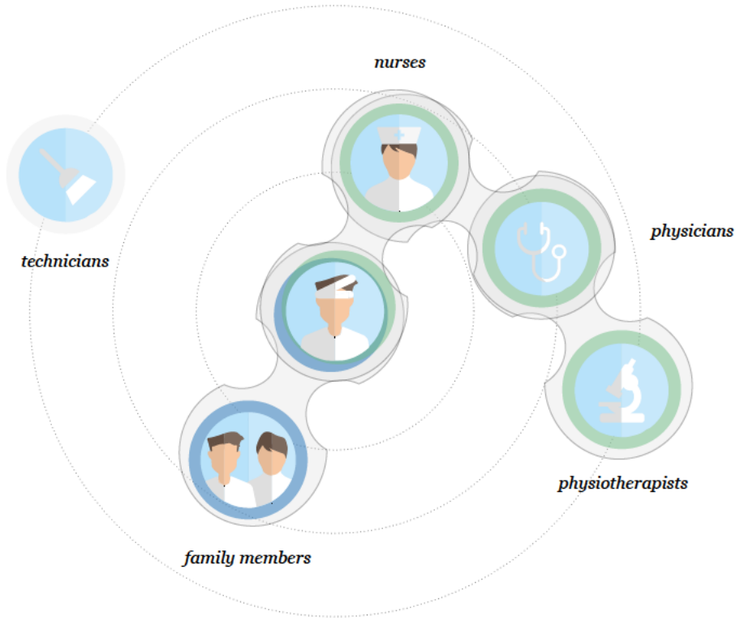


Figure 5. ***Patients' social network.*** *The figure shows the people patients the most interact with during the period of hospitalization. Nurses and family members, as well as friends, are the people closest to patients and who the most provide support in the case of medical alarms. The links between the different users inside the social network are also shown; for instance, physicians' decisions affect both nurses and physiotherapists interactions with patients. Finally, between these users, such as family members and physicians, there are other levels of interactions which are not shown here.*

The type and amount of professionals (as well as medical devices) required and involved for the treatments of a patient depends on his/her diagnosis.

In addition, it is expected that the r*atio nurse-patient* is a nurse each two patients, but during the less busy shift, such as evening and night, this ratio can change and nurses can have the responsibility to take care of more than one or two patients because the number of professionals required during that work shift is reduced compared to the morning one.

Theory of interpersonal relationship

The theory of *Interpersonal relationship* is a representation of how the interaction between the nurse and the patient should occur.

The model describes how "the nurse-patient relationship can facilitate the identification and accomplishment of therapeutic goals to enhance patients well-being" [3].

According to this model, the achievement of these goals is achieved through the use of "a series of steps following a series of patterns" [3].

The four sequential phases (Fig. 6) are:
(1) *orientation*, the phase directed by the nurse and involves engaging the patient in treatment, providing explanations and information, and answering questions;
(2) *identification* phase that begins when the patient works interdependently with the nurse, expresses feelings, and begins to feel stronger;
(3) *exploitation*, is the phase when the patient makes full use of the services offered;
(4) *resolution*, or the phase when the relationship ends because the patient no longer needs professional services and gives up dependent behaviour.
Through this phases, the nurse and the patient should work together so both become "mature and knowledgeable in the process" [3].

Nurses are a fundamental resource for the patient since their presence contributes to reducing potential stress factors and coping constraints, maximizing coping resources and facilitating coping strategies to limit the physiological and psychological deleterious effects of the stress in critically ill patients [1].

Nurses are resource persons who have the information to convey to patients. Patients need this information especially in an unfamiliar environment, where such information reduces uncertainty and stress [3].

The interactions between these users occur through verbal and non-verbl communication. Differences in interactions, how the nurses are responding on the

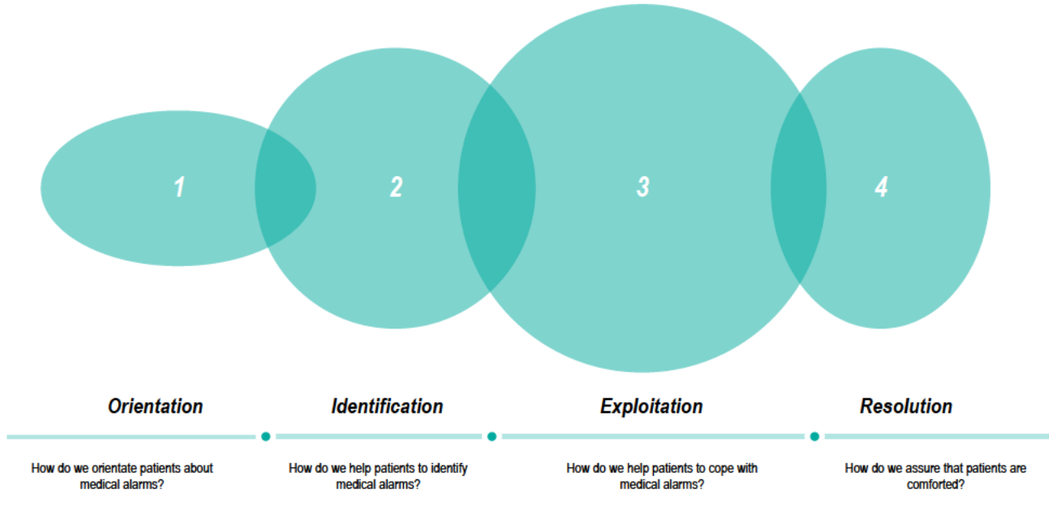


Figure 6. ***Peplau's model of interpersonal relationship.*** *The figure is a representation of the Peplau's model. This model was adopted during the design phase as a framework for investigating the interactions between nurses and patients when a medical alarm goes off. The four phases are shown with the respective questions asked to nurses in the investigation.*

alarms and how nurses communicate with the patients have an influence on patients psychological well-being.

Studying how nurses communicate with patients by considering the verbal and non-verbal levels of communication is considered fundamental, because is through this interaction that patients learn how to interpret and cope with medical alarms.

Levels of communication

Patients' learning process regard the medical alarms is based on observing the nurses in action and listening to their explanations. Communication between nurses and patients can be referred as *interpersonal communication*, or a face-to-face communication. Interpersonal communication describes a communication among two or more people which implies verbal and non-verbal modes of communication. Such communication is important especially because gives nurses the opportunities to gather information from patients , teach patients about their health issues, and to explain care and to provide comfort and support [3].

Communication (Fig. 7) can happen in a *verbal level*, which consist of the content of the message or what users say; and on a *physical level* which represent how users convey a message. These levels of communication are interdependent, as each level affects the other.

Verbal communication includes the person's selection of words which can evoke different images, memories, and meaning for different people and their selection is critical to provide people a defined understanding of the content of a message. Physical communication includes eyes contact, gestures, movements, posture, facial expressions, etc.

Communication includes also other levels, such as the *auditory level* which refers to the sound of people voice, the tone, volume and speed. *Emotional level* includes the emotional states of the person who is delivering a message and it affects what people communicate and how the message is interpreted by the recipient. *Energetic level* includes unseen factors, such as a person's level of consciousness, the frequency of the message, etc. Nurses must consider all the levels of communication in a way that benefit their patients. For instance, to be more effective, nurses should introduce an element of *empathy* to assess and modify their behaviour and providing information.
Different techniques can be employed to facilitate communication, such as touching, repeating and paraphrasing a message, acknowledging a patient, giving information, clarifying time or sequences of a procedure, summarizing and planning, etc.

1.5 | Research questions

How do medical alarms contribute to the development of a state of anxiety?

What do ICU patients think about medical alarms?

How do ICU patients and nurses experience medical alarms when they go off?

How do nurses support patients when a medical alarm goes off?

How can design contribute to reducing the risks to develop a state of anxiety on ICU patients when a medical alarm goes off?

1.6 | Project approach

Figure 8. The project approach. *Inspired by the the "Double Diamond Design Process", the figure shows how the research was executed and with attention to the different phases and research questions. Numbers on pictures are related to the number of users involved in each respective activity.*

For this project, the design brief has been formulated as:

"Develop a preventive measure that calms ICU patients when they are exposed to medical alarms. Design an interactive tool as an interface between nurses and patients to complement nurses' need for communication and patients' need for understanding the meanings of medical alarms".

To reach this goal, the context of use was researched by using a *User-Centered Design approach*.

Contextmapping was employed as a method to gather information about the ICU nurses and (former) patients' experience with medical alarms.

Outcomes from the fieldwork research and literature research led to a clear understanding of the problem and the definition of the design concept.

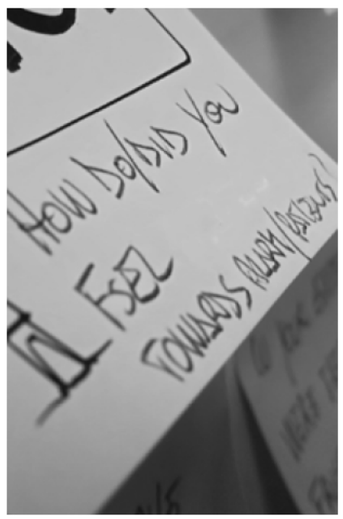
In the design phase, co-creative sessions with ICU nurses helped to define the content and qualities of the design leading to the creation of a prototype.

Finally, the design was evaluated with potential users in two steps and recommendations for further development formulated.

Researching the problem
This phase was focused on understanding the impact of medical alarms on ICU patients' psychological well-being.

Knowledge was gathered by a previous observational study conducted at the Erasmus MC as a student intern and by literature research. The research helped to identify a model that was used to analyze the cognitive process of patients in coping with medical alarms.

In addition, in this phase, research on the interactions between nurses and patients was conducted to understand how nurses' support influences patients' reactions to a medical alarm.



Discovering users' needs
By applying the contextmapping method, an understanding of the contextual factors that influence the behaviours and opinions on medical alarms in ICU nurses and (former) patients was reached and by involving real users.
The meanings users attribute to medical alarms and the emotions they arouse were investigated, as well as the interactions between nurses and patients in coping with medical alarms.

Insights into the experience of ICU nurses and (former) patients provided an understanding of the factors that cause a state of anxiety in patients when exposed to medical alarms, and an understanding of the factors that affect nurses' response time to medical alarms.
Outcomes from this research-phase led to the definition of the design goal and design directions.

Designing the Overcome's feedback interface
The outcomes were presented and discussed with ICU nurses in two different co-creation sessions.
In one session, the more effective strategies used to reduce the anxiety evoked by medical alarms on patients were discussed with a group of 24 ICU nurses at the EMC. In another session, I participated as a nurse to the activities of ICU nurses at the EMC where a role-playing activity was performed to test a concept.

Outcomes from these activities helped me to establish a design direction and define the concept, as well as the design qualities of Overcome.

This phase guided me to the development of a first prototype which was tested over the Internet with two different groups of users, former ICU patients, and the general population.

Evaluating the design
In this phase, the Overcome concept was improved and digitally implemented into a Virtual Reality (VR) environment reproducing the ICU patients' room.
A Between-Groups experiment design was then performed where participants were divided into two groups to test the prototype on usability and in anxiety reduction.
Outcomes led to recommendations for further research.

1.7 | Involved parties

The project was developed in collaboration with different parties that served as support and facilitators.

The *Critical Alarms Lab* (CAL) is a *Delft Design Lab* of the faculty in Industrial Design Engineering (IDE), *Tu Delft*.

The aim of the lab is to "shape the future of alarms and soundscapes in socio-technonlogical environments".

At the CAL, and within the *Silent ICU project* in collaboration with the *Department of Intensive care at the Erasmus MC (EMC)*, researchers and healthcare professionals are trying to figure out how to reduce the amount of sounds inside the ICU to make it a calm environment for the patients and clinical staff.

With this project, the contribution to the CAL and the EMC is to develop a preventive measure that helps to mitigate the detrimental impact that medical alarms have during the ICU experience in patients' psychological well-being.

The IC connect is a patients' organization for (former) IC patients and family members. The aim of the organization is to help patients and loved ones during and after the period of hospitalization in ICU. Former patients, as well as family members, friends and healthcare professionals monthly meet to help people through the intense time during or after an intensive care admission.

Collaborating with the organization was fundamental for the development of this project. Former patients provided their support through all the process discussing the problems under study and providing me the knowledge I needed to understand and empathise with the patients in the ICU.

The *VR Zone Lab* is a Virtual Reality lab located at the *TU Delft Library*. The aim of the VR Zone is to help students, lecturers and researches in using, building and exploring VR in education and research. In this project, the support of the VR Zone Lab was important for the develoment of a virtual ICU room which I used to evaluate my design.

Chapter 2

In this chapter, a description of the ICU environment is provided and with attention to the Department of Adult Intensive Care at the Erasmus MC.

Ab overview of the patients' room, medical devices is given. In addition, an understanding of the ICU patients popilation is offered.

In an attempt to help the reader better empathize with an ICU patient, at the end of this chapter, a detailed description of what being critically ill means will be offered. The description is based on research conducted about the experience of ICU patients reported in the literature, my own observations and on what nurses and patients have taught me during this journey. You will be invited to imagine yourself as being in critically ill conditions inside an ICU.

intensive care

2.1 The ICU environment

The intensive care is a department in the hospitals where patients are in critically ill conditions and more vulnerable than other hospitalized patients.
The physical environment in the ICUs is not designed or built to protect the patients from the disturbing sounds, but to meet the needs of the staff and hygienic requirements. As a result, noise becomes the norm for patient care in the ICU while quiet remains the exception [2].
ICUs provide critically ill patients with continuous care over a 24-hour time span. Close monitoring, equipment and medications in order to ensure normal bodily functions are major parts of critical care, as well as specialists and family members who provide social support.
ICUs are stressful environment because patients are not only critically ill, but also exposed to a wide range of stressors, including invasive treatments, pain, threat of death, insufficient sleep, noise, loss of interaction with family and friends.

Erasmus MC
The *Erasmus Medical Center* (EMC) in Rotterdam has two ICUs placed in two different floors, the general Adult ICU (4th floor) and an optional independent Cardiac ICU (6th floor), called Intensive Cardiac Care Unit (ICCU). In addition, while the general Adult ICU provides rooms for a total of 38 beds, the ICCU has a total number of 18 beds.

Nurses' stations
The ICUs at the EMC are equipped with *decentralized nurse stations* (DNSs) where two nurses can monitor two single bed units/boxes together. The stations are adjacent to each patient room. In every nursing desk, each nurse can make

use of two different monitors: a *monitor*, placed on the wall, which shows all the vital signs of the patients recovered in the unit, and from it nurses can pause an alarm; and a *monitor* that provides access to the *patient data management system* (PDMS).

Through the PDMS clinicians can document important measurement of the patient's bodily functions, treatment goals, planning and checklists.

Figure 9. *Decentralized nurse station. Erasmus MC.*

Patients' room

At the EMC patients are hosted in single-bed rooms, also called boxes. These rooms can be visually closed from the corridor and the outside through curtains that help to provide patients with more privacy.
The rooms are equipped with sliding doors that contribute to make the room soundproof to provide patients with a more silent environment where to rest and recover.

Figure 10. *Patient's single-bed room or box. Erasmus MC.*

2.2 Medical equipment

Every box or unit at the ICU is equipped with different kinds of medical devices which categorization can be made according to the intended usage in patient care.

These devices may be used for various purposed such as: monitoring clinical parameters, *Monitoring devices* (such as patient monitoring system); *Therapeutic devices* (such as Ventilator system, syringe pump, defibrillator and suction pump) used during therapies; *Diagnostic devices* (such as ECG, Mobile X-ray machine) used in diagnosis; and to help with various support services: *Supplementary devices* (ETO Sterilizer) [12].

Medical equipment is an important part of the ICU to monitor and support patients. Additionally, most of these devices are manufactured with one or more functioning alarms that clinicians must be able to distinguish to properly react based on the perceived importance of the sound emitted.

Figure 11. *Monitoring device. Patient monitoring system.*

Figure 12. *Therapeutic devices. Syringe pump.*

Figure 13. *Diagnostic device. Mobile X-ray machine. (Photo:siemens-healthineers.com)*

2.3 | ICU patients

In general, patients in the ICU are treated for dysfunction of vital signs, or life-threatening issues. In such conditions, patients are usually under sedation or induced coma. However, nowadays, less or no sedations are administered to patients due to their negative effects on individuals health. An awake patient might have more vivid memories of their stay in the ICU, increasing the need and demand for care after discharge [13].

Sedated patients are people usually on mechanical ventilators which require sedation and analgesia in order to tolerate the invasive treatment and to lie down in the same position for a long time [14]. Sedated patients are not or less aware about their surroundings because in a state of unconsciousness;

Non-sedated patient have better ability to communicate about their pain and cooperate in nursing care. They are more aware about their surroundings.

Being critically ill
Try to imagine being an ICU patient.

Imagine waking up in a new and unfamiliar environment where you are forced to lay down in a bed, surrounded by many medical devices, noise, and sound.
Imagine being overwhelmed by cables, sensors and tubes that enter your body.

You cannot move, you are weak; however, your brain is working well and your last memory is about a few days ago when you were at work.
While you are trying to understand what had happened, you see people entering and leaving your room, there are people touching you, and annoying alarms that continuously go on.

Every time an alarm goes off you get scared because you cannot figure out whether that alarm means that you are in a life-threatening situation.
In addition, imagine that you are alone when an alarm goes off: no one enters the room to provide you with the expected support, and you must submit to such this event without having any control over it.

Patients in ICUs are dependent, nursed, fed and cared for by others, especially by nurses. Such conditions elicit feelings of helplessness. Care activities which do not consider the patient as a human being - but as an interesting case - can instead elicit feelings of being dehumanized. Indeed, keeping patients alive is of top priority in ICUs and, sometimes, healthcare professionals may ignore the fact that patients have psychological needs and they focus mainly on fulfilling physiological needs [5].
Healing from traumatic incidents or delicate surgeries, such as organs transplant, is painful; hence, pharmacological interventions are employed to ease such pain; however, this kind of solutions are not optimal to guarantee a healthy restoration.

“ Being critically ill in the ICU can mean that the sounds become a part of dreams and unreal experiences of various types […] Being critically ill and surrounded by unfamiliar sounds could also be seen as never knowing what to expect in the next minute ” [2]

Patients are then vulnerable. They lay in beds placed in the middle of uncontrollable sounds, such as medical alarms, and without being protected or capable to leave their room. The impact of such sounds is *brutal* and *ruthless* [2]. In these conditions, perception of reality is altered and it becomes hard to distinguish and understands the events, such as medical alarms.

Being an ICU patient means continuously shifting between fear and hope. It is like being trapped, and sometimes, even, alone and abandoned.

In general, life quality is low after ICU discharge. Many people suffer from psychological issues for long periods of time after the ICU stay. Understanding how to improve the stay is important to foster healing, to reduce hospital stay, to prevent the development of mental disorders and to increase life quality.

A better understanding of the ICU patients’ experience might help healthcare professionals to provide users with better experiences and outcomes in ICU.

This research focuses on a specific aspect of the whole ICU patients’ experience, *the patient-nurse-alarms interaction*. Such experience has been studied from the moment when a medical alarm goes off to the moment when a nurse leaves the room.

Chapter 3

Using Contextmapping as the research method to gather data about the experience of (former) ICU patients and nurses with medical alarms, the general knowledge about the ICU context and patients' psychological well being, presented in the previous chapter, is complemented with more detailed information in this chapter, where major focus is put on patient-nurse-alarm interactions and the external and personal factors that influence their experience.

The interaction between nurses and patients has been studied considering their experience from the moment when a medical alarm goes off to the moment when the nurse leaves the room. Information about users activities, reactions, emotions, thoughts and expectations have been collected.
In this chapter, a description of the process followed is given and results shown.

The research proposal has been approved by the Human Research Ethics (HREC) of the Delft University of Technology - The Netherlands, before the study began.

discovering users' needs

To gain insights about the experience of ICU patients and nurses with medical alarms, generative research techniques were used.

The *Department of Adult Intensive Care at the EMC*, as well as the *IC connect organization* were contacted, and three (former) ICU patients and two ICU nurses were recruited as the subjects of investigations during a period of observing, sensitizing and interviewing.

The focus of this research is described on the basis of research questions. Later, each methodology is explained in more detail.

Research questions
During this phase of the project, the main research question was formulated as follows:

How do ICU patients and nurses experience medical alarms when they go off?

To answer this question, it was necessary to do an investigation in the context of the ICU from the perspective of ICU patients and nurses.

What patients think about medical alarms, how nurses support patients when a medical alarm goes off were secondary questions that led me to get an overview of the experience and to understand how medical alarms contribute to the development of a state of anxiety.

Insights for possible design opportunities were then conceived.

Approach
In order to provide answers to the aforementioned questions, contextmapping, to obtain in-depth (tacit) knowledge on the experience of the users with medical alarms [66], was applied.

The research was conducted in English language.

3.1 | Methods

Contextmapping
Contextmapping techniques were used as approach to discover the needs of participants and supports in translating experiences of participants into usable insights for product development [63]. Generative tools used in context-mapping-method are helpful for participants to become aware of and explain their experiences [64].

This phase consisted of three main activities: *recruiting, sensitizing* and *interviewing*.

Recruiting
Participants were recruited with the help of the I*C Connect organization* and one of the team leaders at the *Erasmus MC*.

Involving real ICU patients was not possible due to their critical medical conditions; as a result, former patients were chosen as representative group.

The *IC connect organization* was contacted and an announcement as an invitation to participate in the study was published in their newsletter a week before meeting the members of the organization in Utrecht. In Utrecht, during an *IC Café*, a meeting organized by the organization every month to discuss about the medical problems usually people suffer by after ICU discharge, I had the opportunity to introduce my research and recruit three participants from a group of former patients, patients' family members and healthcare professionals.

The recruited former patients were later contacted via email and detailed information about the study and an Informed consent were them sent a week before starting with the research.

In addition, two ICU nurses were also recruited at the Erasmus MC and the same procedure was applied before starting with the research.

Sensitizing
A week a later, three (former) ICU patients and two ICU nurses shared their subjective experiences with medical alarms by using a sensitizing toolkit (Fig.14) which was sent to them by post a week before the one-on-one interview. The content of the toolkit was a *Booklet*, a pencil and some adhesives to use in combination with some exercises.

By using the booklet participants were triggered, encouraged and motivated to think, reflect, wonder and explore aspects of their personal context in their own time and environment [64]. This activity sensitized the participants about the problem under study and prepares them in sharing their experiences during the interviews. As a result, a deeper *level of knowledge* was reached during the one-on-one interview.

The Booklet
The Booklet (Fig.13) is a small book with exercises, containing text and graphics. A total of five exercises plus an introduction and a closing question were proposed, and to complete the Booklet about five minutes per each exercise were required. Participants had a week to complete it. Completing an exercise per day help people to slowly become aware of their experiences [64].
Each exercise covered a specific aspect of the experience with the medical alarms in the ICU. Questions were focused on two major aspects: handle medical alarms and social support (Fig. 15 and 16).

Two different booklet were designed: one for the (former) ICU patients and another for the ICU nurses. Some of the questions asked were similar for both groups, others were covering specific aspects of the experience of each user, such as nurses were asked to provide information about the main obstacles they encounter in their everyday work at the ICU when responding to an alarm.

Figure 13. *The Booklet. Cover.*

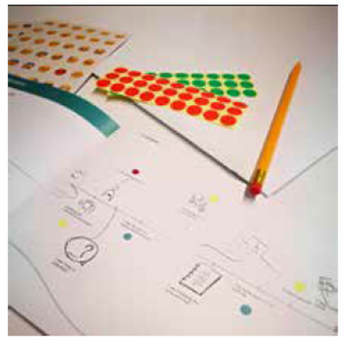


Figure 14. *The toolkit sent to the participants.*

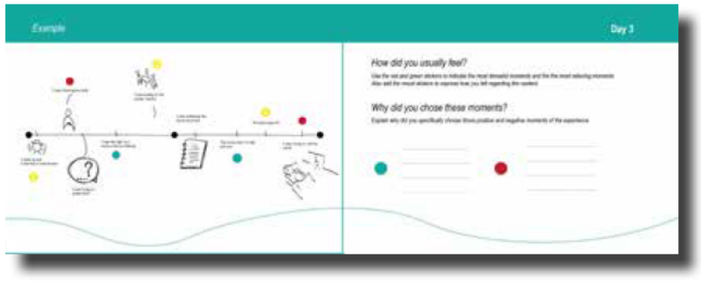


Figure 15. *The Booklet. Exercise 3. In this exercise participants were asked to map their experience at the ICU with a medical alarm. They were asked to write or draw down the mot stressful and relieving moment of the experience considering three specific steps: (a) when a medical alarm went off, (b) a nurse entered the room and (c) the nurse left the room.*

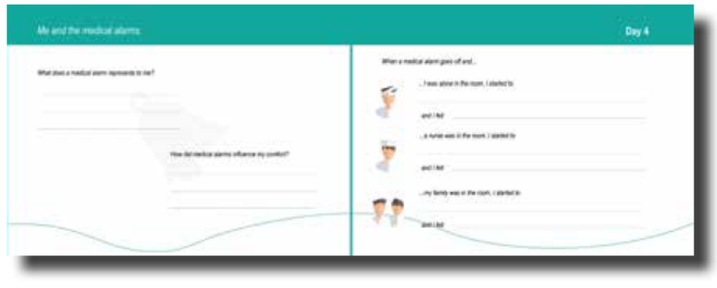


Figure 16. *The Booklet. Exercise 4. In this exercise participants were invited to reason on what an alarm represented for them and on how medical alarms influenced their comfort. In addition, it was asked to reason on their experience in relation to the support provided by nurses and family members in the case of medical alarms.*

One-on-one interviews with former ICU patients
The executed exercises in the booklet served as starting points for a one-on-one depth interview that lasted for around one hour each. After signed the *Informed consent*, participants were asked to take part in four activities.

Before starting with the one-on-one interview, we introduced each other, and I gave more detailed information regarding the project.

Activity 1 | Reflecting on the Booklet
I asked the participant to reflect on the answers given in the Booklet together.

Activity 2 | Listening to the Medical Alarms
The scope of this activity was to trigger participants memories about medical alarms to understand what medical alarms mean for them and how they make they feel. In addition, I wanted to understand how the lack of medical alarms understanding influenced their emotional reactions.

Participants had to create a *collage* using a toolkit which I designed (a paper sheet, some pictures and words) while listening to a audio-track made by me using

some medical alarms I recorded at the EMC in a previous study. Participants had about ten minutes to complete the exercise (Fig. 18) Later, they were invited to explain their collage and the associations of images and words used for each medical alarm listened.

Activity 3 | Coping with medical alarms
After a small break, I started a conversation with the participant regarding their previous experience in the ICU with medical alarms.

An *Empathy map* was used as a collaborative tool to collect data.

An empathy map is a tool used to articulate what is knows about a particular type of user in order to create an understanding of the users needs, and aid in decision making [A]. In this research, I decided to use the tool together with the users (considered as the experts) to uncover the needs that were not yet discovered.

Participants were asked to think aloud about a previous experience with medical alarms and to reflect on that experience by answering to the questions written on the map.

By using some post-its, they answered to the questions. The

Figure 17. *The toolkit. The picture shows the tools used during the one-on-one interview: a list of words and picture (top), the collage sheet, pencils, post-its and glue (centre left side), the Informed consent (centre right side), the Empathy map (bottom left side), camera, tripos, voice recorder and present (centre bottom) and the research protocol (bottom right side).*

Figure 18. *Activity 2: Listening to the Medical Alarms. In this picture, the participant is creating her own collage by using the provided toolkit nd while listening to the medical alarms audio-track.*

map was divided in six quadrants: *thoughts and feelings, what did they see, what did they say and do, what did they hear, gains and pains*.

The aim was to understand how they were reacting and whether or not they lack resources to cope with medical alarms. In addition, information about how they were supported was also collected.

Activity 4 | Future experience with medical alarms
I asked the participant to imagine the experience of ICU patients with medical alarms in the future based on their own experience. They were invited to think aloud about how in 5 years from now ICU patients might cope with medical alarms, considering that the situation regarding medical alarms will be the same as nowadays with patients still exposed to the alarms.

Insight were used for the definition of design directions.

One-on-one interviews with ICU nurses
The one-on-one interviews with nurses followed the same structure of the interviews with former patients.

The activities proposed and the questions asked were similar. By considering the perspective of nurses, I was able to better understand their uncovered needs when handle with medical alarms and in supporting a patient.

The scope was to know how nurses help patients coping with medical alarms and what are the main obstacles they encounter and they perceive as more dangerous.

Data collection
Sensitizing and interviewing ICU nurses and former patients resulted in a rich data set. Data collected consisted of photos, audio recordings, booklets (filled in by participants),collages, empathy maps and interview transcripts.

Booklets, collages and empathy maps
Participants went through the booklet before the interview by completing the exercises. During the interview, the booklet was consulted and discussed together with the researcher. Finally, the booklets were consulted during the analysis phase, as well as collages and empathy maps.

Interview transcripts
The one-on-one interviews were recorded by using a voice-recorder and transcribed word-for word. Transcriptions facilitated data analysis by making the data easy to access and interpret.

Data analysis
The qualitative data (e.g. quotes, notes), analysed by the researcher only, were interpreted, categorized, and analyzed in an *analysis-on-the-wall method* in which different levels of sense-making occurred [40]. The levels of sense-making guided the analysis on the level of data, information, knowledge, or wisdom [40].

During the analysis, the interview transcripts were used as main input in combination with the booklets filled in by the participants. Booklets were analysed by separating the pages and putting them on a wall to compare the answers of each participant with the others (Fig. 19). The same method was applied for analysing the collages created by the participants. Finally, the most relevant quotes from the interview transcripts were selected and clustered on the wall.

Data were analysed in two different sessions. Firstly, the researcher analysed the data collected from former ICU patients, and later the data collected from the ICU nurses. Finally, by using this method, it was possible to better define the experience of each user in relation to medical alarms. At the end, data were combined.

Analysis on the level of data
Participants were interviewed in two different moments of the research process. I started by interviewing the three (former) ICU patients, and after the analysis of this data was concluded, the ICU nurses were approached.

Data analysis started directly after the one-on-one interviews with each group of users. Indeed, starting the analysis as soon as the first data is gathered is considered critical to direct the next interview and observations [41]. By doing so, it was possible to generate insights and, with ICU nurses, I was able to ask more focused questions on specific aspects of the experience that led me to have a clearer understanding of the reasons why, for instance, usually patients have to wait longer than expected when a medical alarm goes off.

This approach gave me the opportunity to have a deep understanding of the context and the problem to which patients are exposed to.

Analysis on the level of Information
At this level, the interview transcripts were read through and the most relevant quotes were selected by interpreting and assigning them meanings [40]. In this process, I analysed the information and clustered them to identify two major aspects, *how ICU patients cognitively appraise the environmental stimuli* (medical alarms) and *how nurses comfort and help patients to cope with medical alarms*. In doing so, I used the *Theoretical model of Coping and Stress* [36] as a framework to understand how patients cognitively appraise an alarm, and the theory about the *types of social support* [42] as a framework to identify the types of supportive behaviours provided by nurses to patients.

For each participant, Quotes were labelled (e.g. 19_P02_ 6:22) by showing, respectively, the number of the quote, the number of the participant and the time in relation to the length of the interview. This method was helpful to facilitate their identification in the transcripts. Later, the selected quotes were cut out and clustered onto two whiteboard walls according to the groups of information they were belonging to (Fig. 20).

While selecting and categorizing quotes with respect to the two frameworks previously mentioned, several subthemes and patterns emerged.

The process of analysing on the level of information resulted in two whiteboard walls filled with categorized quotes and meaningful topics and themes.

Analysis on the level of knowledge
At the level of knowledge, all the information on the walls was brought to a higher abstraction level and the defined topics were used to discover the patients' values, needs and wishes in relation to nurses and medical alarms.

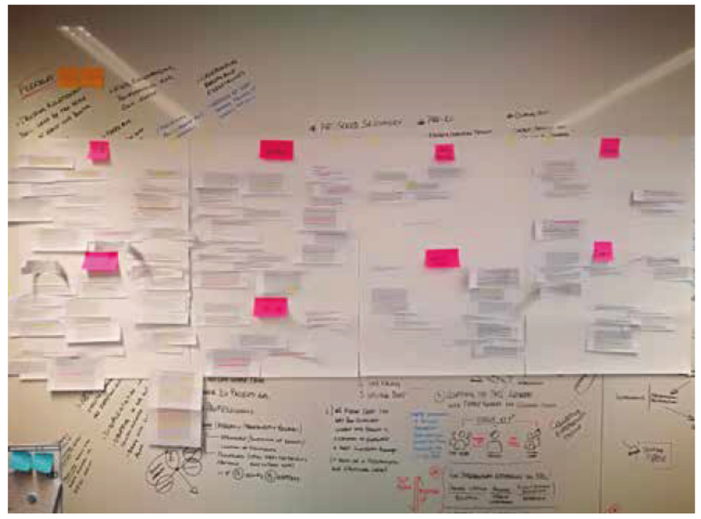


Figure 19. *Analysis-on-the-wall. Selected transcript quotes clustered on the wall .*

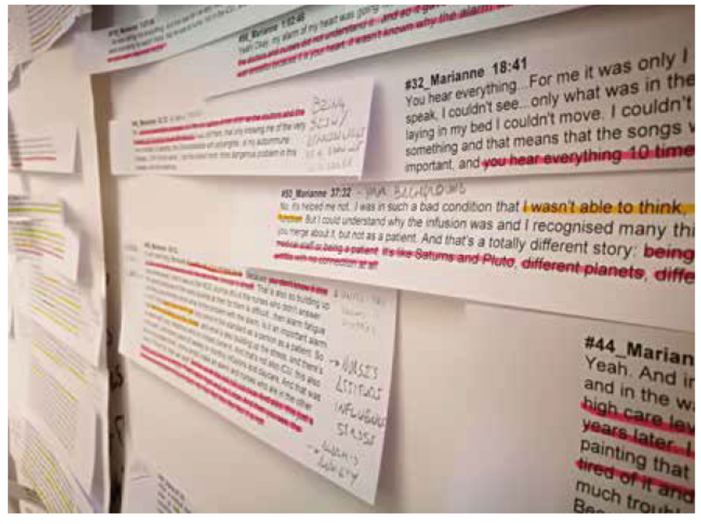


Figure 20. *Labelled quotes. The selected and cut off quotes clustered into two whiteboard walls according to the groups of information they were belonging to.*

3.2 | Results

In this study, the main target group were ICU patients. Indeed, I mainly focused on understanding patients' needs, desires and emotional reactions in relation to medical alarms and nurses' support.

Including the experience of the nurses in this study gave me the opportunity to better understand which strategies are employed to help patients coping with medical alarms and which the obstacles that negatively influence nurses' possibilities to properly support patients when a medical alarm goes off.

The qualitative data have provided insight in the ICU patients' experience with medical alarms. The study has resulted in an *User map*, and an *Issues map*.

The results led to insights in the needs of ICU patients and to design opportunities regarding strategies to reduce the risks of developing a state of anxiety when a medical alarm goes off. Based on this results, the design goal was defined and later used for the second phase (design phase) of this graduation project.

User Map
Users maps show how multiple groups of people relate to one another in a specific context over time [63].

In the user map (Fig. 26) created for this research, the interactions between patient-nurse-alarm are shown with a focus on the most common factors that adversely influence the ICU patients' experience with medical alarms.

Issues Map
The *Issues Map* (Fig 22) shows in detail the patients key issues which were extracted from the Users map.

Showing the different issues separately and in detail allows to address them individually during opportunity identification [63].

The issues map shows also the *path of emotions* of patients in relation to medical alarms and interactions with nurses.

Analysis
The data collected from the booklets and the interviews have provided insight into the *ICU's patients and nurses experience with medical alarms*, as well as into t*he meanings patients attribute to these alarms*.

In general, the knowledge acquired with this investigation provided me not only with an understanding of the phases habitually users go through when a medical alarm goes off, but also it has provided an understanding of the reasons that, in this experience, lead patients to develop a state of anxiety.

Patient-nurse-alarm interaction was investigated considering three key moments of the whole experience, starting from the moment *(1) when a medical alarm goes off, (2) a nurse enters the room, to the moment* to the moment *(3) when a nurse leaves the room.*

Data about patients' emotional reactions in relation to a medical alarm and the nurses' support, as well as information about nurses' supportive behaviours, reactions and practices to handle with medical alarms were collected.

Medical alarms for patients

Former ICU patients defined the experience with medical alarms as *too extreme* attributing to the alarms mostly negative meanings associated with negative emotions.

"[...] the noise made me crazy because it was there every moment of the day [...] when you are lying down and you can't see anything, what's happening there, and there are every moment alarms, you don't understand at all" [P03]

During their hospital stay, medical alarms discomforted the patients for two reasons: *(a) by waking them up reducing the possibility to sleep; (b) by scaring them resulting in high stress levels and anxiety.*

"[...] (medical alarms) means for me, stress, stress, stress, stress, stress, very stressful moments and not being able to sleep. Too

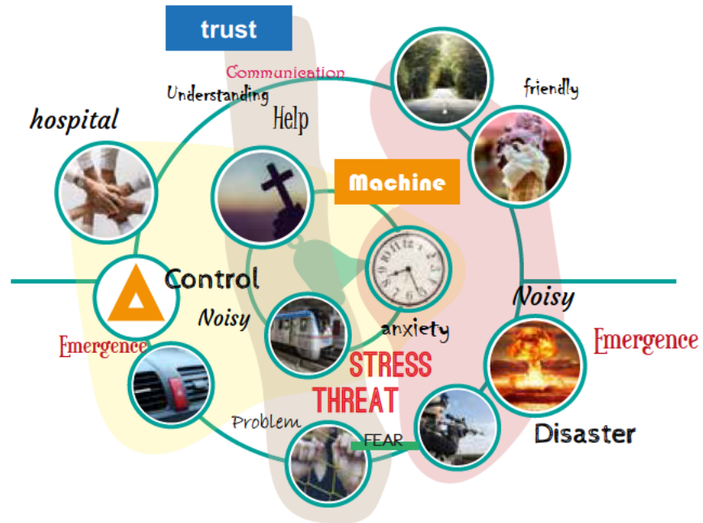


Figure 21. *The graph shows the words and pictures that participants used in their collages. The graph is divided into two sections: the positive side (top) and the negative side (bottom). Pictures and words were placed in the graph with respect to the meanings participants associated with these pictures/words in relation to the alarms. Pictures and words closer to the centre of the graph were the most selected.*

tired, too much noise […]" [P03]
Pictures like the "explosion of a bomb", an "emergency triangle", a "trapped person" holding his hands tight on a barrier, a "train in a station" and a "cross", were the most used in combination with the words "help", "understanding", "fear", "stress", "emergency", "control" and "anxiety" (Fig. 21).

" […] alarms are an emergence because that's what alarm represents for me […] an emergency triangle […]something you use when you have car trouble […]" [P01]

Due to the lack of understanding, medical alarms were experienced by patients as a threat that indicated the start of a life-threatening situation.

" […] the alarm tells me there's a problem […] you feel it like, like a threat and you're afraid […] " [P02]

" […] what if there's something wrong with me?[…]" [P01]

In addition, patients felt the alarms as a *trap* that they were not able to escape from.

" […] if there's not a nurse available, you'll feel trapped or quote in alarm saying you can't explain […]" [P02]
Without any control over the alarms, patients cannot fight them either but only surrender and submit, and waiting for the arrival of a nurse who will help them.

" […] it's out of my control because I'm in that bed being helpless […] that is something you have to surrender to submit to […]" [P01]

The patients' experience

"[…] being of medical staff or being a patient it's like Saturn and Pluto, different planets, different worlds with no connection at all " [P03]

In this study, I focused on understanding patients' needs and emotions starting from the moment when a medical alarm goes off to the moment when a nurse leaves the room after his/her intervention to stop the auditory stimulus.

Data analysis led me to identify two major needs patients have when exposed to a medical alarm, the *need for understanding* and the *need of feeling monitored*.

This section presents in detail the experience of conscious ICU patients with medical alarms.

Eight different steps that usually patients go through when a medical alarm goes off were identified. These steps were clustered into four phases: *(a) a medical alarm goes off, (b) waiting, (c) interacting,* and *(d) separating*.

The most interesting conclusion was that when a nurse enters the room, patients' stress levels reduce, as well as the state of anxiety.
Patients put lots of trust on nurses because they are the only one who can really help them with medical problems. As a consequence, patients feel safe only when a nurse is next to them; on the contrary, if patients have to face the medical alarm alone, they easily panic and get scared. With their presence and support, nurses reassure and comfort patients.

I put more attention on a specific phase of the ICU patients' medical alarm experience: *Waiting* because is the phase when patients get anxious and not only because they cannot determine whether or not an alarm is life-threatening, but especially because *the more they wait for the arrival of a nurse, the less they perceive themselves in a safe situation*.

Ambiguity of medical alarms and *long waiting* lead patients to the *uncertainty of dying*. Indeed, waiting reduces the patients' hope of being rescued because *the longer is the waiting, the less are for them the chances to reduce the risks to die*. Thus, when waiting longer than expected, patients start to doubt the fact that nurses are aware of the ongoing alarm.

In the next paragraph, the experience will be examined phase by phase.

The experience

Phase 1 | Waking up
Step 1: Waking up
When a medical alarm goes off, patients suddenly move from a state of quiet to a state of alertness and fear.
An alarm takes by surprise patients, usually waking them up, and scares them especially if they are alone inside the room while such an event occurs.

Loneliness is an additional factor

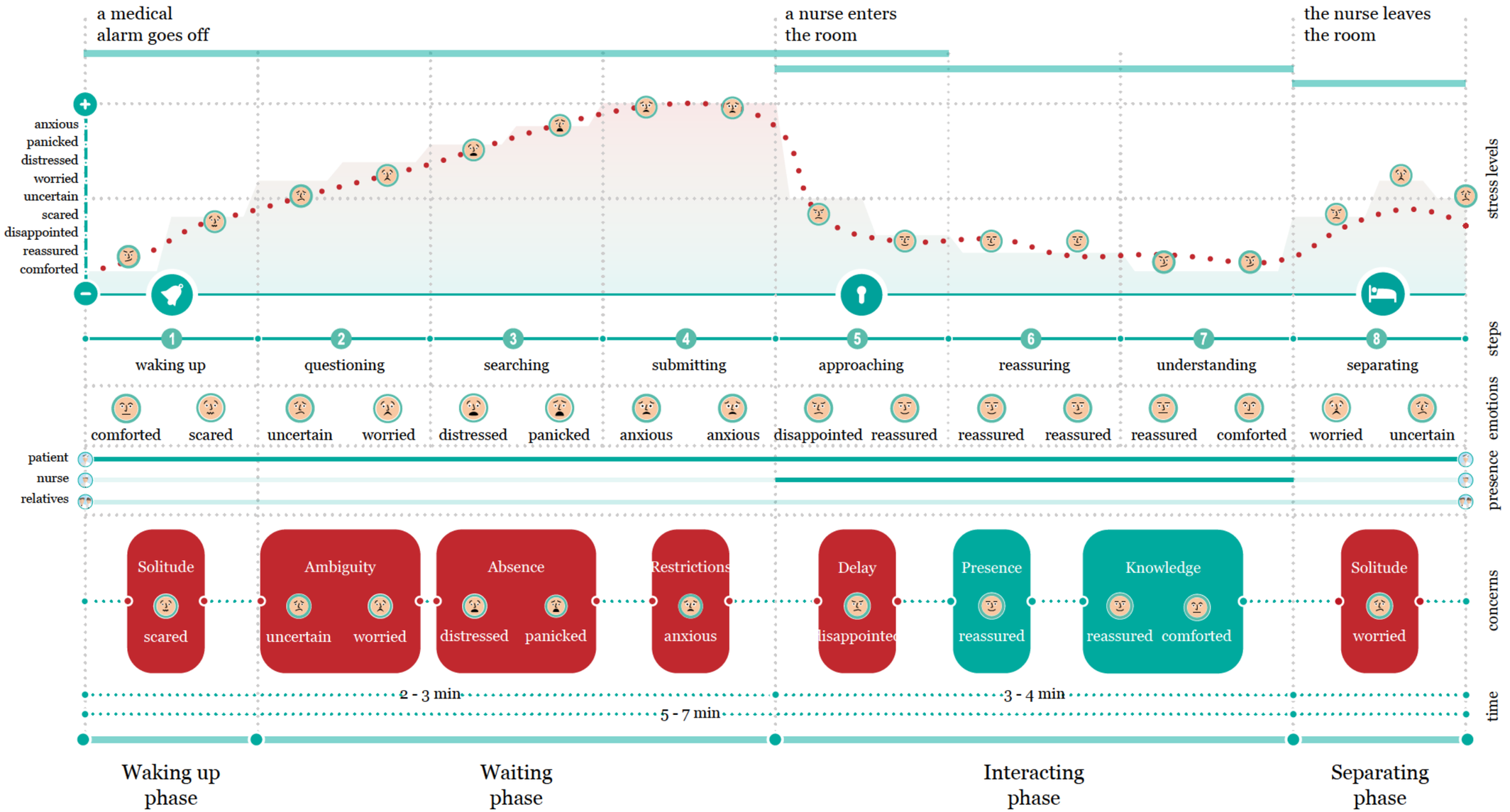


Figure 22. *The Issues Map. The map shows the experience of patients with medical alarms from the moment when a medical alarm goes off to the moment when a nurse leaves the room. On the top (in red) the hypothesised trend of patients' stress levels. The map shows also the Path of Emotions, or all the emotions patients feel when exposed to a medical alarm. On the bottom, the major issues that contribute to high-stress levels and lead patients to develop a state of anxiety.*

which triggers fear and increases stress levels, particularly if there are not nurses inside the room to take care of the situation.

Phase 2 | Waiting

Step 2: Questioning

Regardless of their real meanings, alarms are usually perceived as a threat and appraised as dangerous.

After being surprised by an alarm, patients first reaction is to seek for information that could help them in understanding whether or not the alarm is indicating a life-threatening situation.

In this phase, patients start looking around them, for instance at their vital signs (bedside monitor), in an attempt to identify the source of the alarm and try to interpret its meaning.

"[...] I couldn't find the cause of the alarm. I felt a little panic inside. What's happening? This is the start of going of dying or whatever. All kinds of things go through your head [...] I didn't understand what's happening and what were the results of what's happening." [P02]

However, due to the lack of understanding, patients can not understand what is happening to them, thus resulting in emotions like worry and uncertainty.

"[...] most of the time is a signal that medication has run out [...] but what if, what if? What if it's not? What if there's something wrong with me? [...]" [P01]

Step 3: Searching

Lack of understanding increases stress levels and generates distress. Such a condition leads patients to get panicked if a nurse has not yet intervened.

"[...] if she's not there that can give stress if there's no one there [...]" [P01]

Although patients are unable to interpret a medical alarm, they are aware that the goal of a medical alarm is to inform clinical staff about a dangerous situation that requires timely attention as the patient's survival could be under risk. Therefore, the faster the staff intervention, the lower the risks of further complications and to increase criticality.

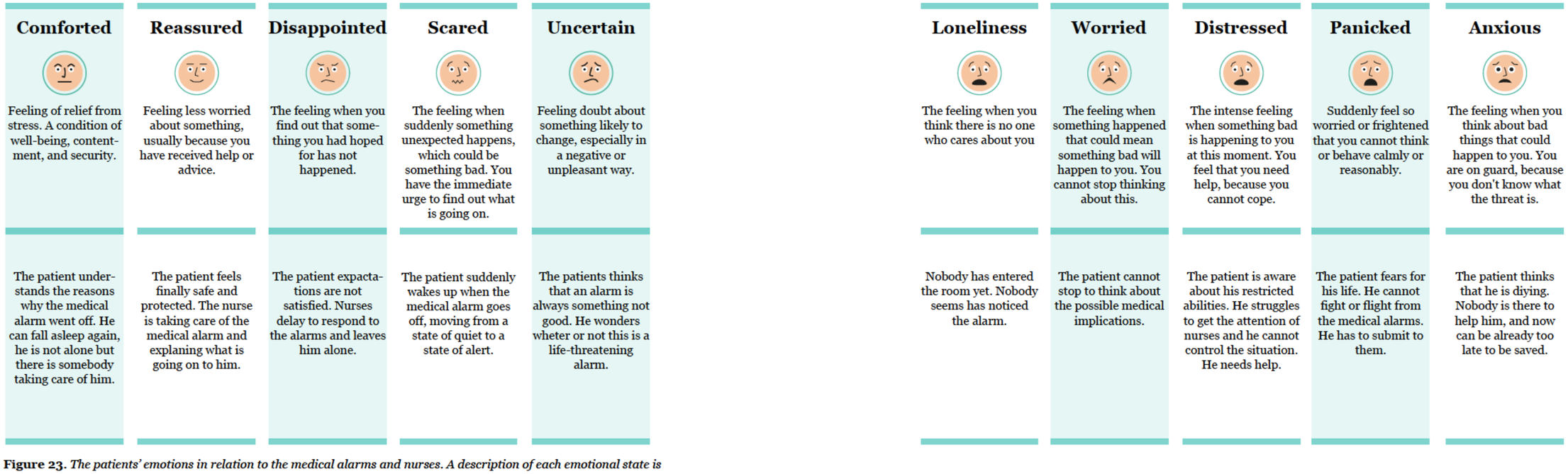


Figure 23. *The patients' emotions in relation to the medical alarms and nurses. A description of each emotional state is given, including a description of the patients behaviours when they experience these emotions.*

"[...] I want the nurse to arrive because she or he is the profes-sional, and only they can calm me down. Because if there's something really wrong with me, my family cannot help me literally, the nurse has to do that [...]" [P01]

The delayed and/or non-arrival of a nurse fail the patients' expecta-tions who rather expect a timely intervention that could remove the ongoing threat.

As a result, patients start to search for a nurse by looking at the door or the window which offer a view on the corridor outside the room. Searching and waiting for a nurse generates a further state of uncertainty, that is if the clinical staff is aware of the situation and, therefore, if they are monitoring the patient.

Step 4: Submitting
Patients in the ICU are dependent on others, especially on nurses who satisfy most of their basic needs. Nurses are also the pro-fessionals who have the responsi-bility to keep the patient alive by properly executing the treatments determined by physicians.

As a result, patients' health and safety depend on nurses' reactions to an alarm, including the time they spend before responding to it.
Due to patients' health conditions fight or flight from the threat, or the medical alarm, is not possi-ble; as a result, the only option patients have in case of an alarm is to submit until a nurse enters the room.

"[...] hearing it (alarm) and not knowing what's happening and not being able to do something about it yourself. It happens. Well, you have to accept it, but you can't do anything about it" [P02]

Under these circumstances, pa-tients feel hopeless and helpless. Indeed, their perceived sense of safety decrease as well as their stress levels increases resulting in a state of anxiety.

Phase 3 | Interacting
Step 5: Approaching
The arrival of a nurse inside the room reassures patients suddenly moving them from a state of anxi-ety to a state of calm.

Despite the late arrival of a nurse disappoints patients whose at-titude towards the nurse can be initially aggressive, quickly they calm down.

"[...] when a nurse arrives in the room, you feel safe because the nurse is there [...]" [P02]

Step 6: Reassuring
Stress and anxiety are removed after a medical alarm is off and the problem which triggered it resolved.
As already mentioned, patients have complete trust in the medical staff, thus their presence removes uncertainties and increases the perceived sense of safety resulting in lower stress levels.

"[...] I put a lot of trust in the pro-fessional [...] because the nurse or a doctor is someone who can actually help me with something medical [...]" [P01]

Phase 7: Understanding
In this phase, patients start to learn more about an alarm and familiarizing with the ICU envi-ronment.

By observing at the nurse's activ-ities and reactions, as well as by listening to their explanations, patients learn how to interpret the events. Such an interaction is crit-ical to foster familiarization with the ICU environment, including its soundscape, and re-establish calm.

"[...] as long as they are there, and they can explain to you why things happen. That is such, such relief or that can calm you down so much." [P01]

Nurses' explanations and atti-tudes influence the way how pa-tients interpret an alarm. Nurses can help patients in identifying the source and understanding the reason for the alarm, thus proper-ly reappraise the event.
The content of the message given by nurses and the way how it is conveyed emotionally influences patients. The lack of this inter-action might adversely influence patients stress levels and anxiety.

In this phase, patients reappraise the alarm. The explanations

provided help patients coping and learning what to expect if the same alarm will again go off in the future.

"[...] know a bit of the pattern, how it works, you know [...] I can go back to sleep and everything's okay [...]" [P01]

Length of stay, previous experience in the ICU, disease severity, limited physical abilities, types of treatments and medications, can reduce patients' capacity to memorize, and recognize the meaning of medical alarms. As a result, many patients need that such explanations are continuously repeated.

Phase 4 | Separating
Step 8: Solitude
Despite the medical alarm is off and there are no more reasons to be scared, being left alone by a nurse worries patients.

" [...] when the nurse leaves the room, I rather would have he would stay in the room because if then something's happened, then he would, he could act on it, and he would be there. So, that would give me more comfort [...]" [P01]

As a result, due to the high possibilities of re-experiencing another similar event, the uncertainty of dying to the next medical alarm is not excluded by patients who are left alone in a room without the supervision of a nurse who, in future, might not intervene on time.

" [...] when the nurse leaves the room [...] that can also give a little bit of panic [...] that can be stressful [...] because you're alone [...] " [P01]

Conclusions

Need for understanding
" [...] what if there's something wrong with me?[...]" [P01]

Medical alarms are ambiguous for most of the patients in the ICU. Lack of familiarity with the ICU and lack of knowledge seem to be the major causes that limit patients understanding of an alarm. Not being able to interpret an alarm generates negative thoughts and negative emotions which exponentially increase stress levels resulting in a state of anxiety.

" [...] the alarm tells me there's a problem [...] you feel it like, like a threat and you're afraid [...] " [P02]

Patients are oblivious to the meanings of medical alarms and the message they convey to nurses. Interestingly, it seems that even patients who have a medical background or previous experiences in the ICU can encounter the same difficulties.
For a patient, understanding the meaning of an alarm is fundamental for reducing stress. Regardless of its meaning, patients often tend to perceive an alarm as a threat and appraise it as dangerous.

Need of feeling monitored
For patients, knowing that a nurse takes care of them is decisive to feeling safe.

" [...] the most important part is feeling at ease and safe, and knowing that people care for you [...]" [P02]

Although patients are aware that nurses cannot stay all the time with them and that they continuously monitor them even by a distance, their absence arises negative feelings, such as the feeling of being ignored and abandoned, especially if they do not timely show up when a medical alarm goes off.

"[...] I want to have immediately access to the attention of the nurse that I'm in danger [...] I was in more than pain, in death, scary, stress [...]" [P03]

Fear and uncertainty evoked by a medical alarm are relieved when a nurse enters the room; indeed, nurses' presence increases the patients' perceived sense of safety. Feeling monitored means for patients that there is a nurse who always and timely will enter their room and save their life when an alarm goes off. Feeling monitored can be related to the need of safety, or the condition of being protected from harm or other non-desirable outcomes [43].

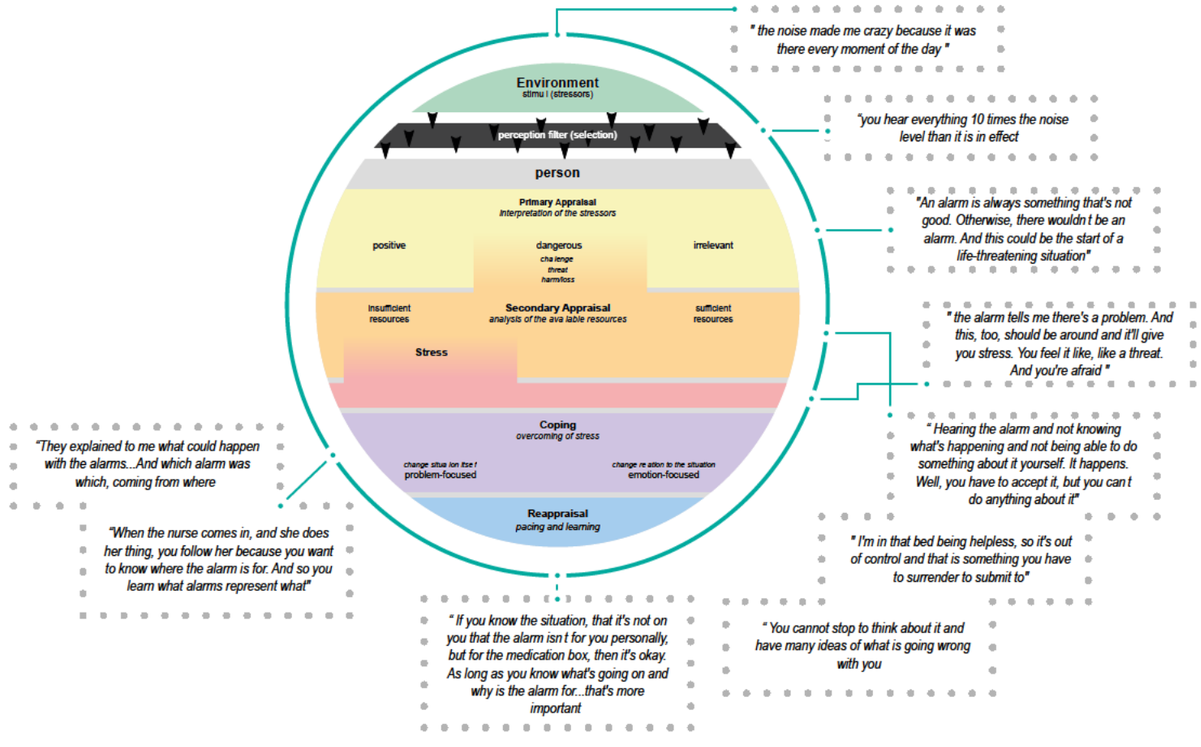


Figure 24. *The Model of Stress and Coping adopted to explain the patients' perception and appraisal of medical alarms. Quotes from interviews were used to show which are the thoughts, worries and beliefs of ICU patients and to understand how they actually perceive, appraise and cope with medical alarms.*

The nurses' experience

The nurses' experience
Nurses are a fundamental resource for the patients since "their presence contributes to reducing potential stress factors and coping constraints, maximizing coping resources and facilitating coping strategies to limit the physiological and psychological deleterious effects of the stress in critically ill patients" [1]. Nurses are resource persons who have the information patients need especially in an unfamiliar environment to reduce uncertainty and stress [3].

However, the presence of a nurse is not always guaranteed inside a room when a medical alarm goes off. They could not react over an alarm or their response could delay; as a result, the patient-nurse interaction not always occur when a medical alarm goes off.

Nurses reactions to an alarm vary with the different types of alarms, resulting in different behaviours. Nurses can decide to do not enter the room, for instance, if the ongoing medical alarm does not require an intervention (i.e., patient who cough activate an alarm on the mechanical ventilator).

The decision is taken by nurses comparing the information on their pagers with the patient's vital signs shown on the monitors and by observing the patient from outside his room. Through the window collocated strategically between the patient's bed and the monitoring desk of the nurses, the latter have a clear overview of the patient and the medical devices connected to him/her.

In general, nurses provide patients with informative, instrumental, and emotional support. They calm down a patient by using words that reassure them and explaining the reasons for an alarm.
However, different factors, related to the context, as well as to the attitudes of the nurses, negatively influence and limit such a human-human interaction.

The ICU nurses experience was analysed focusing on the practices, behaviours and decision-making process from the moment when a medical alarm goes off to the moment when they leave a room.

Information regarding the obstacles nurses encounter when handle medical alarms and the strategies employed to reduce patients' anxiety were collected.

Seven different phases were identified: *(1) Managing, (2) Receiving, (3) Interpreting; (4) Deciding, (5) Acting, (6) Comforting, and (7) Leaving.*

Phase 1: Managing
In general, at the beginning of their shift and after receiving a summary about the patients' conditions, nurses tend to adjust the threshold of the alarms accordingly to the needs of a patient and their preferences; especially during night shift, nurses tend to reduce threshold to lower the amount of alarms that could go off in order to give patients more opportunity to rest.

Effective alarm management can reduce the amount of alarms patients are usually exposed to, but it requires full attention and time by nurses who, in some case, can also anticipate over some alarms.

Phase 2 : Receiving
When a medical alarm goes off, nurses receive a message reporting the alarm on their pagers.

After checking at the pager, they need to determine to which room belongs the alarm and to do so they usually look at the lights in front of the Boxes or look at the Monitor placed on their station.

Phase 3 : Interpreting
Nurses rely on their experience to interpret an alarm. The decision about what action to take is also based on many factors. Before acting, nurses need to understand whether something is really going wrong and determine whether or not the alarm is clinically relevant.

To do so, nurses take into analysis many data provided by different devices placed inside and outside a patient's room: they look at the light in front of the door (e.g. yellow light can also mean empty pump, while a red light can also mean that the patient is calling for help), check the vitals of the patient on the monitor, think about the medical devices inside the room, check the patient through the window to understand whether he/she is comfortable or not. With this information, nurses can identify and interpret an alarm.

Phase 4 : Deciding
After data analysis, nurse decide which action is required.

If the alarm is considered true, than the patient is actually in a risk; as a result, the nurse quiclky enters the room because it is required a timely intervention to save the patient. Nurses have to make sure that the patients do not go over the edge and take them back to a safe situation. In case of a true alarm, nurses get stressed especially because they are aware that a late intervention can kill the patient.

If the alarm is considered false, there is not something worrying going on. These alarms annoy nurses, especially because are the most frequent. Unfortunately, due to their frequency, nurses in many cases could interpret even a true alarm as false. False alarms can be also caused accidentally by nurses who, for example, forget to deactivate a device while cleaning a patient.

Despite such an alarm does not indicate a dangerous situation, nurses need to intervene to stop the alarm; for instance, they might need to reattach the sensor on the patient's finger.

Some alarms cannot be heard from outside the patient's room, especially if the door is closed, because there are medical devices not connected to the pagers. As a result, unless the doors are open or the patient calls for help, nurses usually think that everythng is fine while, instead, the patient is exposed to an alarm.

Phase 5 : Acting
When entering the room, nurses need to stay calm - even if something is not going good, in order to do not further scare and stress the patient.

Inside the room, and before interacting with the patient, nurses take all the required actions to stop the alarm and solve the

problem.

Phase 6 : Comforting
After the alarm is off and the problem solved, nurses might interact with the patient. Talking, physical contact are common interactions. In addition, patients have the opportunity to ask questions.
Communication helps patients to have a clear understanding of the event, as well as their medical conditions. The ways how nurses decide to interact can vary between patients; indeed, while some patients require detailed information about an alarm, for others it is enough that a nurse just holds their hands.

Phase 7 : Leaving
Before leaving, nurses comfort again the patients usually informing them that they will be back immediately if needed whether to stop an alarm or to check on them if they make a call.

Conclusions

Nurses awareness

" [...] the alarm is the anxiousness for a patient because the patient is thinking: Is there anybody coming? I am lying here and there's a lot of noisy. So, I think that the patient is suffering because of that." [P05]

Nurses are aware of the effects of medical alarms on patients' psychological well-being, especially they believe that not knowing whether someone is coming to help, or how long a nurse will spend before entering the room, is the main source of anxiety.

" [...] they don't know if it's false, if it's true, if there is somebody coming in one minute, and the alarm sounds is very long: five minutes even longer. And then the patient is just there and nobody's reacting...for their feelings is very, very bad also for their psychological thinking." [P04]

Nurses think that a patient who is exposed for a long period of time to an alarm can feel alone, isolated and abandoned if nobody is reacting on it.

" [...] I can understand that if an alarm goes off [...] and there is no reaction, you feel alone, you feel isolated, you feel abandoned. I should feel like that, like: " What's going on? Nobody is reacting: Help! Help![...] " [P04]

Also, patients - especially if conscious - can contribute to increasing the quantity of the alarms, because they tend to repeatedly play the ring-bell if nobody is showing up.
Nurses are also aware that patients are always watching at them and they are influenced by the way how they react over a medical alarm and by the activities they perform.

" [...] they're always watching us and I don't think we consider how important that is...how we react on the room...in the room with our activities." [P05]

Supportive behaviours
When entering the room, nurses provide patients with three different types of supportive behaviours (Fig.25): *(a) instrumental support, by resolving the problem reported by an alarm; (b) emotional support, by comforting the patients, and (c) informational support, by informing patient about the reason for an alarm.*

Patients' profile and communication
Nurses must know their patients on a personal level to be able to properly approach them when comforting and removing anxiety. There is a very large difference between patients and what they want to know and how much information they need to feel comforted. As a result, the information provided by nurses to patients vary between patients.

Physical patient
A physical patient is a person who doesn't have interests in receiving detailed information about an alarm but, instead, prefers physical contact and reassuring words to feel comforted. In addition, physical patients are individuals who usually do not ask any question, especially because they totally trust the nurses and their decisions.

Intellectual patient
An intellectual patient is a person who is curious and wants to know always more than the basic information provided usually by nurses. Such type of patients are very interested in the alarms and they usually ask a lot of questions, not only about the reason or the meanings of alarms, but also about the nurses' activities and behaviours.

Language barriers
Sometimes nurses can encounter language barriers, because some patients do not speak their language. As a result, comforting them can be difficult, thus nurses have to find other ways to do it. They need to be creative in the way they can make the patient comforted; for instance, sometimes, they use Google translate or their hands to communicate with a patient.

Obstacles
From data collected, several factors that act as obstacles for nurses and reduce their possibilities to timely intervene over an alarm were identified.

Nurse - patient ratio
Sometimes everyone is already busy with a patient and nobody is available if a new alarm goes off. Especially if nurses have more than one patient to take care of, it

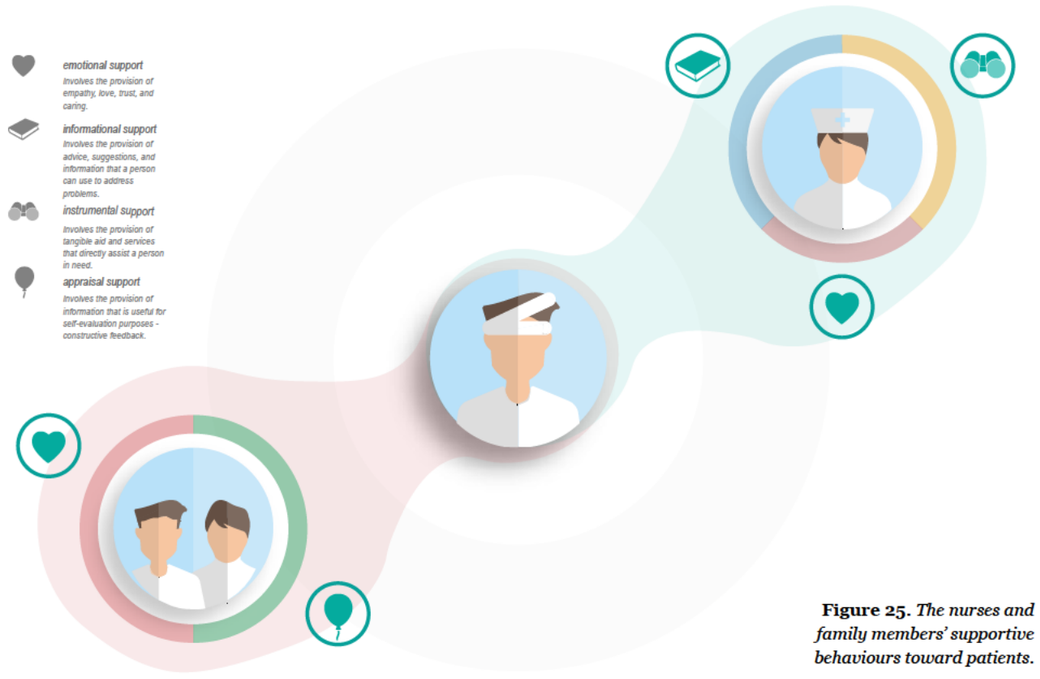


Figure 25. *The nurses and family members' supportive behaviours toward patients.*

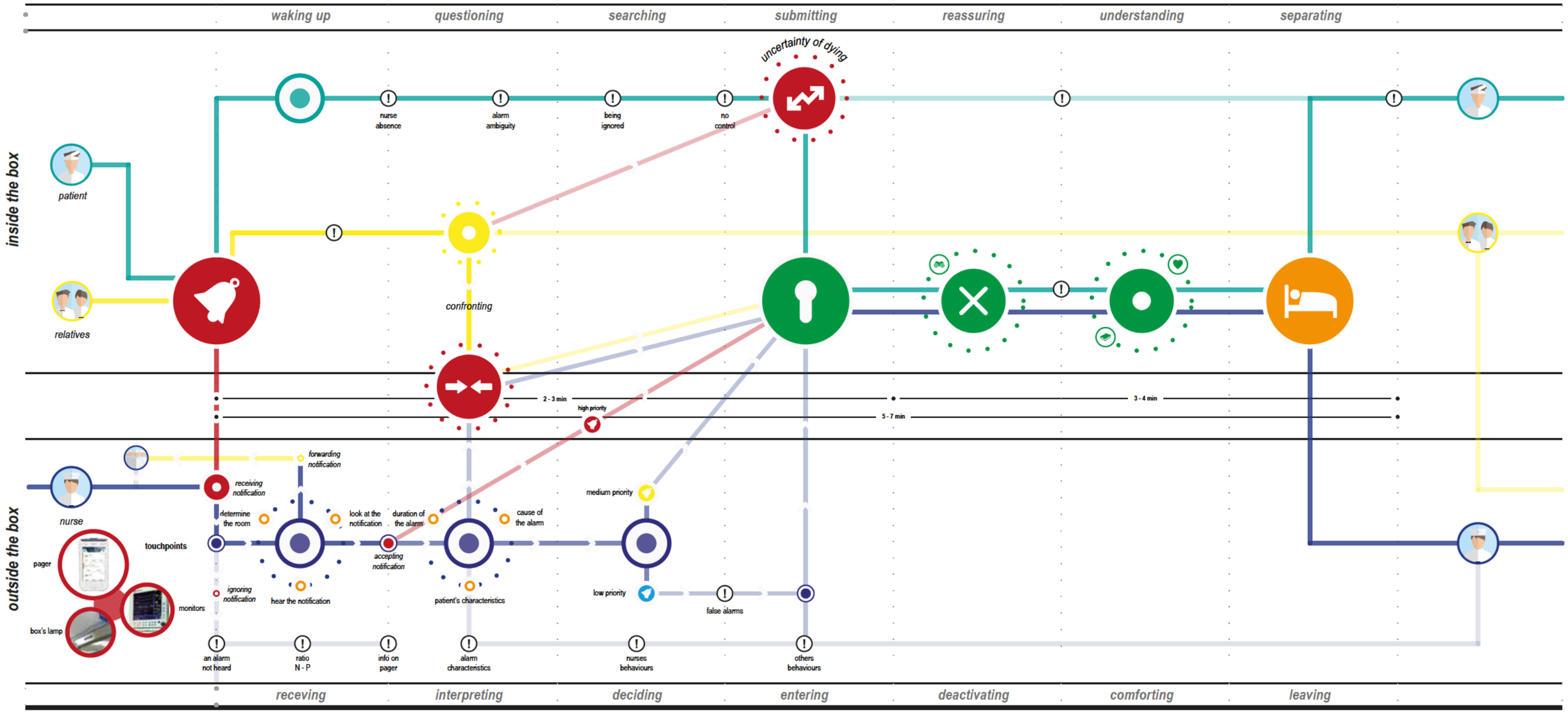


Figure 26. *Users map. Users map. The map shows the experience of patients and nurses in relation to medical alarms. From interviews, it was possible to collect data related to the family members which are here shown. The map summarizes the interactions between these users when a medical alarm goes off and with respect to the phases discussed previously. It also shows the major issues that contribute to the development of a state of anxiety on patients (big red circles). While the light-blue and yellow line represent the experience-flow of patients and family member, the dark-blue line shows the experience-flow of the nurses including the obstacles that influence their response time over medical alarms. In addition, it is possible to see that the reactions of nurses towards an alarm vary with the types of alarms.*

is common to respond with delay and leave patients waiting longer than expected.

In addition, being responsible for more than one patient reduces the time and the quality of care nurses can provide to each patient.

Acute patients
When nurses are busy with a patient, especially if in an acute condition, forgetting or not noticing the message on their pager reporting an alarm from the room of a second patient is common. In addition, even if the notification is noticed, suddenly leaving the room of a patient who needs still more care is dangerous for his health and safety; as a result, or another nurse will take care of the alarm or the patient has to wait for his nurse until she finishes with her task.

Information on Pager
Nurses think that the information about alarms on their pagers is not satisfactory and such lack of information lengthens their response times. Indeed, before making a decision, nurses have to interact with other devices to properly interpret an alarm. Especially when busy and distant from their workstations, nurses suffer by such a problem.

Alarms: false, repetitive and not heard
Types and repetition of alarms influence nurses' reactions. The high frequency of false alarms, as well as repetitive alarms, make nurses less responsive and upset, thus adversely influencing their time responses.

The response to an alarm may also depend on its duration. In fact, alarms that do not last long are usually not checked. Also, the medical alarms which are not connected to the pagers (e.g. from dialysis machine) limit the possibilities for a nurse to timely support a patient.

Wrong behaviours
Nurses
Some nurses usually respond with delay to an alarm because less responsible than other colleagues.

Give the pager to a colleague
Leaving the pager to a colleague may increase the risks to respond with delay over an alarm, especially if all the pagers hold by a nurse notify an alarm at the same moment.

Patients' attitudes
The quantity of alarms can also depend on patients' attitudes. Patients who ring regularly on the alarm bell to get the attention of a nurse (especially for not urgent reasons) annoy and make nurses less responsive. Thus, nurses who take care of patients with such an attitude might leave them waiting for long time before acting.
Family members
Loved ones can act as an obstacle for nurses and can also contribute to the development of a state of anxiety on patients.
Patients' relatives can annoy and obstacle the work of nurses interrupting their flow. As patients, they do not understand alarms and tend to overreact when one goes off.

For family members and friends can be shocking assisting to an alarm and, especially they can get stressed and overreact because of misinterpretation and if nobody timely provide their loved ones support.
Sometimes, they can be even more nervous and scared than a patient, thus they tend to quickly leave a room and to call nurses for help from the corridor. Such a behaviour, negatively influence patients stress levels and state of anxiety.
In these cases, and regardless of the tasks they are doing, a nurse has to promptly react and to calm the family and the patients down by entering the room.

Figure 27. *Experience flow. The illustrations on the next page show two possible scenarios that can occur in the ICU when a medical alarm goes off. In yellow, the experience of a patient when a family member is with him during the alarm. In this case, the family member overreacts to the alarm (he leaves the room for looking for a nurse) thus contributing to the development of a state of anxiety and increasing of stress levels in patients. In light-blue, the experience of the patient who is alone when an alarm goes off. In both cases, the uncertainty of dying arises for two reasons: lack of alarm understanding and lack of medical support.*

3.3 | Conclusions

It appears that medical alarms might contribute to the development of psychological disorders as their occurrence elicit a state of anxiety.

Regardless of their real meanings, patients perceive medical alarms as a threat and appraise them as dangerous which cannot be overcome. Patients only option is to submit to alarms and to wait for the help of a nurse.

Patients major resource to cope with a medical alarm is the social support provided by nurses. Family members and friends support is relevant but not enough because they usually lack of the information needed by a patient to properly cope with an alarm. Nurses, instead, are trained to handle medical alarms and provide medical help. Especially, nurses are aware of the effects of alarms and behaviours on patients psychological wellbeing; as a result, they know how to interact with their patients to calm them down and remove anxiety. Effective verbal and non-verbal communication restore comfort and the sense of safety in patients. Without such *human-human interaction* patients remain in a continuous state of anxiety raised by the *uncertainty of dying*.

When a medical alarm goes off patients move from a state of quiet to a state of alertness resulting in discomfort and, usually in sleep disruption. Alarms are sudden and they scare patients who cannot control nor interpret them, especially due to their lack of understanding. Without any available resource, patients experience negative emotions which result in increased stress levels. Waiting for the arrival of a nurse is the only option they have, but t*he longer is the waiting time, the higher are the risks for patients to develop a state of anxiety*. In addition, the absence of the medical staff adversely affects the perceived sense of safety making patients feeling ignored and abandoned.

Although patients are unable to cope with a medical alarm, they are aware that the goal of a medical alarm is to inform clinical staff about a dangerous situation that requires timely attention as the patient's life could be under risk.

Lack of resources and lack of control make patients feel trapped and hopeless. In addition, the delayed and/or non-arrival of the nurses fail the patients' expectations who rather expect a timely intervention that could remove the ongoing threat.

Furthermore, in critically ill conditions patients tend to have an altered perception of time, therefore a short waiting time can be perceived as really long.

On the other hand, nurses face many obstacles in the ICU which affect their response time to an ongoing alarm. Intense workload, busy work-shift, alarm fatigue, false and repetitive alarms are some examples.

Most significant is the impact of *false alarms* on nurses' reaction to an alarm. False alarms represent more than 80% of the total number of alarms in ICUs. Their extreme frequency negatively influence nurses' actions leading, also, to *alarm fatigue*. When an alarm is considered false, nurses tend to postpone an intervention, especially if already busy with something or some other patients.

Hence, while nurses are aware of the reason for the alarm and whether or not a patient is in a danger, patients are oblivious and, often, alone with the ongoing alarm.

Removing the mystery generated by ambiguous medical alarms and by long waiting time might reduce the risks of developing a state of anxiety. Patients might benefit from a system that acknowledge and provide them with information that increases their perceived sense of safety.

As a result, by considering the whole experience of ICU patients with medical alarms, I wanted to focus on the *Waiting time* (Waiting phase) considered as the phase during which patients develop a state of anxiety. I believe that the interaction between nurses and patients should be extended to provide continuous support.
Finally, I believe that there is a strong relation between the development of anxiety and the perceived sense of safety: *the higher is the perceived sense of safety, the lower will be the risk to develop a state of anxiety*. Consequently, it is necessary to investigate on *how to keep the feeling of safety high in case of an ongoing alarm and lack of support*. I assume that *if a patient feels safe when a medical alarm goes off and in absence of a nurse, the risks to develop a state of anxiety can be lower compared to the current situation.*

Therefore, it is necessary to understand:

How to restore the patients' perceived sense of safety when a medical alarm goes off and the nurse is unable to communicate with them?

Design directions

The idea of developing an interactive tool that put in communication nurses with patients by a distance was already discussed with the parties involved in this graduation project at the beginning of this journey and still considered as a solid direction to follow at this stage of the design process.

The knowledge acquired from the fieldwork research guided to the definition of the concept and helped with the designation of strategies that could be employed to reduce the risks of developing a state of anxiety on ICU patients through the use of such a tool.

The goal of the interactive tool was described as follow:

an interactive tool that by a distance put nurses in communication with patients to comfort them thus increasing their perceived sense of safety when a medical alarm goes off.

Four different strategies were identified.
The tool could be used by nurses to *(a) reassure and (b) acknowledge patients by making them aware about nurses decisions over the alarms, (c) promote alarms understanding to remove ambiguity, and (d) distract the patient to move their attention from the medical alarms.*

From these strategies three design directions were conceptualised: *(1) Educating patients, (2) Acknowledging patients, and (3) Entertaining patients.*

Educating:
Promoting understanding
Patients, after being introduced to medical alarms at the beginning of their ICU stay, might interact, while a medical alarm goes off, with a tool that promotes the understanding of the type and the reasons of the alarm, as well as of its source.

Promoting the understanding of medical alarms could remove ambiguity and reduce uncertainty, thus helping patients to properly appraise them when they occur.

Acquired knowledge in combination with information provided by nurses to patients through the interactive tool during hospitalization, might enable the latter to easily identify and properly interpret the stressor.

Acknowledging:
Reassuring and acknowledging
Patients could be passively involved in the nurses' decision-making process.
For instance, informing patients that a nurse is aware of the alarm might increase their perceived sense of safety and reduce the uncertainty of being ignored and abandoned.

Making patients aware of the fact that a nurse is already taking care of them might reduce the risks of developing a state of anxiety and reassure them too.

For instance, nurses could share such information through the interactive tool by communicating their location, the time needed to enter the room or that they have received the notification.

Engaging:
Distracting
Patients' attention to medical alarms might be moved to something that distracts and entertain them while waiting for the arrival of a nurse.

Distracting a patient might help them forget about the possible emergency and also influence the perception of time, making the waiting time more pleasant and less stressful.

For instance, alarms might be shown as animated visuals that change in shape and size accordingly to the types of alarm, their frequency, decibel or duration.

Chapter 4

Insights from the fieldwork research led the second phase of this graduation project. In the previous chapter, the psychological effect of a medical alarm on patients was presented and a hypothesis generated: the higher is the perceived sense of safety when a medical alarm goes off, the lower will be the risk for a patient to develop a state of anxiety while waiting for the arrival of a nurse.

The knowledge achieved regarding the needs of ICU patients in relation to medical alarms and regarding the obstacles encountered by nurses that negatively influence their temporal responses to medical alarms have contributed to having a clear understanding of the context.

In this chapter, two activities performed with ICU nurses at the EMC are presented: a generative session with 24 participants and an observational study.

The scope of these activities was (1) to understand how to design an effective communication tool and to (2) define together with experts the concept.

defining the concept

4.1 | Patient- nurse- alarm nteractions

The information gathered in the interactions with nurses help patients to familiarize with the ICU environment, including its soundscape, and to promote understanding; instead, the lack of support reduces the possibilities to adapt to this environment adversely influencing the psychological well-being.

Nurses interact with patients for different reasons among a day, especially because patients are totally dependent to them and not capable to satisfy even their basic needs due to their medical conditions.

One of the most common interaction is in the case of a medical alarm. When a medical alarm goes off, nurses are required to check their patients and make sure that everything is fine.

Medical alarms are encoded *messages* meant for nurses who have the knowledge to decode them (Fig. 28). Firstly, nurses are the (intended) *receiver* of this message; but, after decoding it, they cover the role of *senders* of a message which they will provide to patients to help them interpreting and properly appraise a medical alarm. Therefore, when no interaction with nurses occurs, patients, who are themselves (even if not intended) receivers of the encoded messages - because directly exposed to the alarms - cannot decode them.

Basically, medical alarms guide nurses towards the problem by helping them monitor a patient more effectively, thus increasing their control over the situation. Nurses use such auditory stimuli as a means to identify the source of an alarm, to understand the level of urgency and to decide which action to take. Therefore, alarms require nurses a significant cognitive effort and which must be performed in a very short period of time.

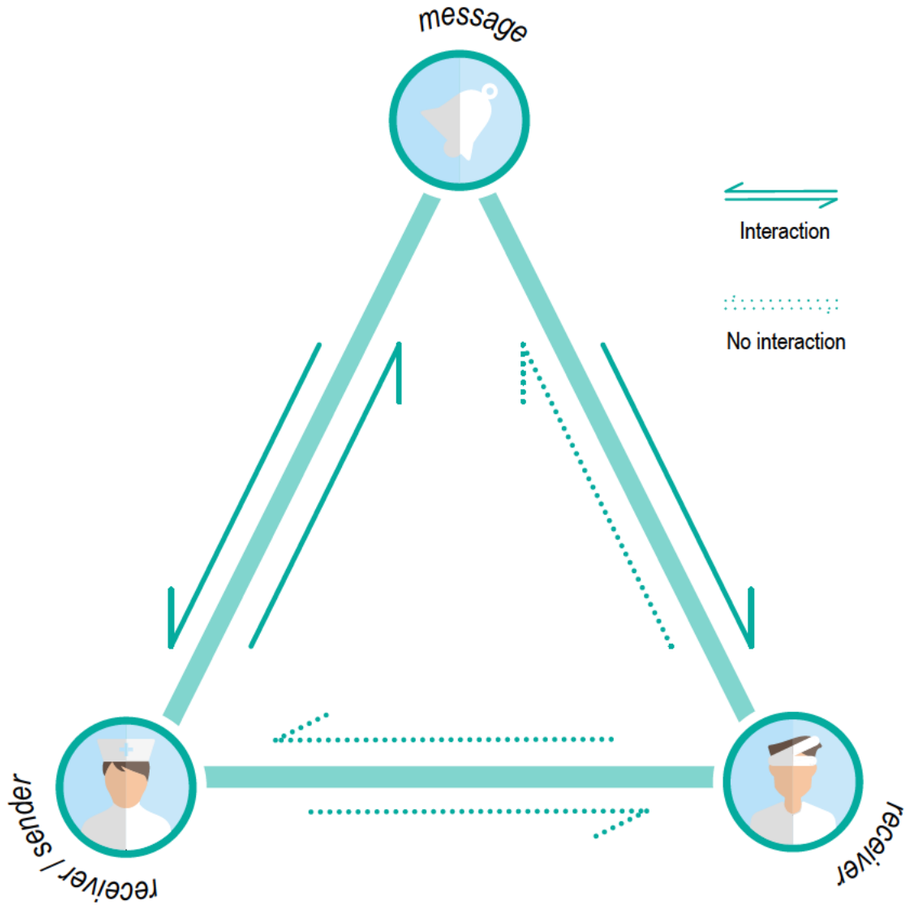


Figure 28. *The nurse-patient-alarm interaction. In this illustration, it is possible to understand how the interaction between nurses, patients and a medical alarm happens. The message (alarm) is received by both users but only nurses are able to decode it. When the nurse interacts with the patient the content of the message is explained and the patient can properly appraise the alarm. However, when this interaction does not occur, patients are not able to understand the alarm, thus resulting in high-stress levels and anxiety.*

On the other hand, patients by continuously observing to nurses' actions and reactions towards an alarm and listening to their explanations, reappraise the alarm and learn how to interpret them. Nurses' verbal and no-verbal communication influence patients' emotional reactions, and represent the content of the message which nurses deliver to a patient.

Many factors, such as ratio nurse-patient, many alarms, busy schedules, beliefs and stress levels, influence the way how nurses react and interact with patients when a medical alarm goes off, usually making them less sensitive and supportive.

Lack of support lead patients to the development of a state of anxiety.
To remove such a risk, the interaction between nurses and patients must always and timely occur because nurses are the only resource patients have to cope with such a threat.

4.2 | Concept definition

Generative session

With the intent to understand how to design an effect ive communication tool, further research on the nurses and patients interactions in relation to medical alarms was performed to define how the communication occurs with respect to the content and the way how messages are conveyed. By doing so, I was aiming at defining the communication goals and qualities of the interactive tool. As a result, a workshop was organized during a *Clinical Class* at the EMC.

Activities

27 nurses (13 male, 14 female) participated to the session. Participants were asked to reason on *how they comfort a patient when a medical alarm goes off*.

The session was divided in three steps: (1) sensibilization through the presentation of the fieldwork research and outcomes, (2) a group activity and (3) discussion.

After a brief introduction, nurses were divided in four groups and provided with a paper sheet (tool), pens and post-its (Fig. 29 to 33). They were invited to reason on the strategies they employ to comfort patients when a medical alarm goes off. At the end of this activity, each group was invited to present their work to everyone. During presentations, questions were asked.

During the session, *Dr E.O.Vieira* was present. She introduced me to the nurses and helped with facilitating the session. The presence of an expert was critical to discussing the topic in detail and gathering rich insights.

Approach

The *Peplau's Theory of Interpersonal communication* [3] was used as framework to design a tool and formulate research questions. According to [3], there are four different steps nurses and patients need to go through to build up a profitable relationship: *(a) orientation, (b) identification, (c) exploitation, and (d) resolution*. These steps were used as a guide to help participants reasoning on the verbal and non-verbal communication employed in the interaction with patients for the provision of information that helps the latter to cope with a medical alarm.

Research questions

Verbal communication
What nurses say?

1. Orientation
How do you prepare patients about medical alarms?
2. Identification
How do you help patients to identify medical alarms?
3. Exploitation
How do you help patients to cope with medical alarms?
4. Resolution
How do you assure that patients are comforted?

Non-verbal communication
How do nurses convey the message?

1. Orientation
How do you prepare patients about medical alarms?
2. Identification
How do you help patients to identify medical alarms?
3. Exploitation
How do you help patients to cope with medical alarms?
4. Resolution
How do you assure that patients are comforted?

Analysis

The session was audio-recorded to analyse it afterwards. Transcriptions were made to facilitate the phase. Quotes and insights from the sheets of the assignments and from discussions were compared, clustered and interpreted by using Peplau's model and, later, summarized to determine the characteristics of such interpersonal relation.
Content of messages and the way

how they are conveyed by nurses to patients were identified. Findings were used to formulate the Interactive tool personality traits, as well as to define the levels of information.

Results

From data analysis appeared that nurses, to remove anxiety evoked by medical alarms, usually follow a set of rules that describe the type of verbal and non-verbal communication that should be employed in interacting with the patients. In addition, I learned that the provision of information (the content and way of conveying a message) varies according to the characteristics of a patient as age, social class, personality, health status can impact upon stress and anxiety.

A clear understanding of the content of the messages, as well as the way how these must be conveyed, was reached.
Starting from the analysis of how a message is conveyed (non-verbal communication), I was able to define some personality traits a nurse should show in such interaction.

Hence, when a medical alarm goes off, nurses should have a reassuring and friendly attitude (regardless of the type of alarm). A relaxed posture, slow-talking, a low and soft tone of voice, eyes contact and - with some patients - even physical contact (e.g. touching the shoulder, hold the hand) are fundamental ingredients to employ in the attempt of calming a patient down and remove anxiety.

In the analysis of the content of the conversation (verbal communication), it has emerged that there are topics commonly treated and presented, usually in a specific order, to patients.

In general, nurses need to be *explanatory* and use a *simple language*. Firstly, and since their ICU admission, patients should be introduced to medical alarms providing explanations regarding the types of medical alarms, how nurses handle medical alarms and which reactions patients should expect from nurses in relation to the different alarms.

During the hospital stay, when a medical alarm goes off nurses should provide more detailed information, such as the causes of an alarm and its source, including instructions that could help patients to prevent the occurrence of some alarms. At the end of this interaction, and before leaving the room, nurses should always give patients space and time to ask questions. Nurses should make sure that patients have understood what has happened and whether they are at ease; finally, they should always reassure patients that they are continuously monitored, even if from a distance.


Figure 29


Figure 31


Figure 32


Figure 30


Figure 33

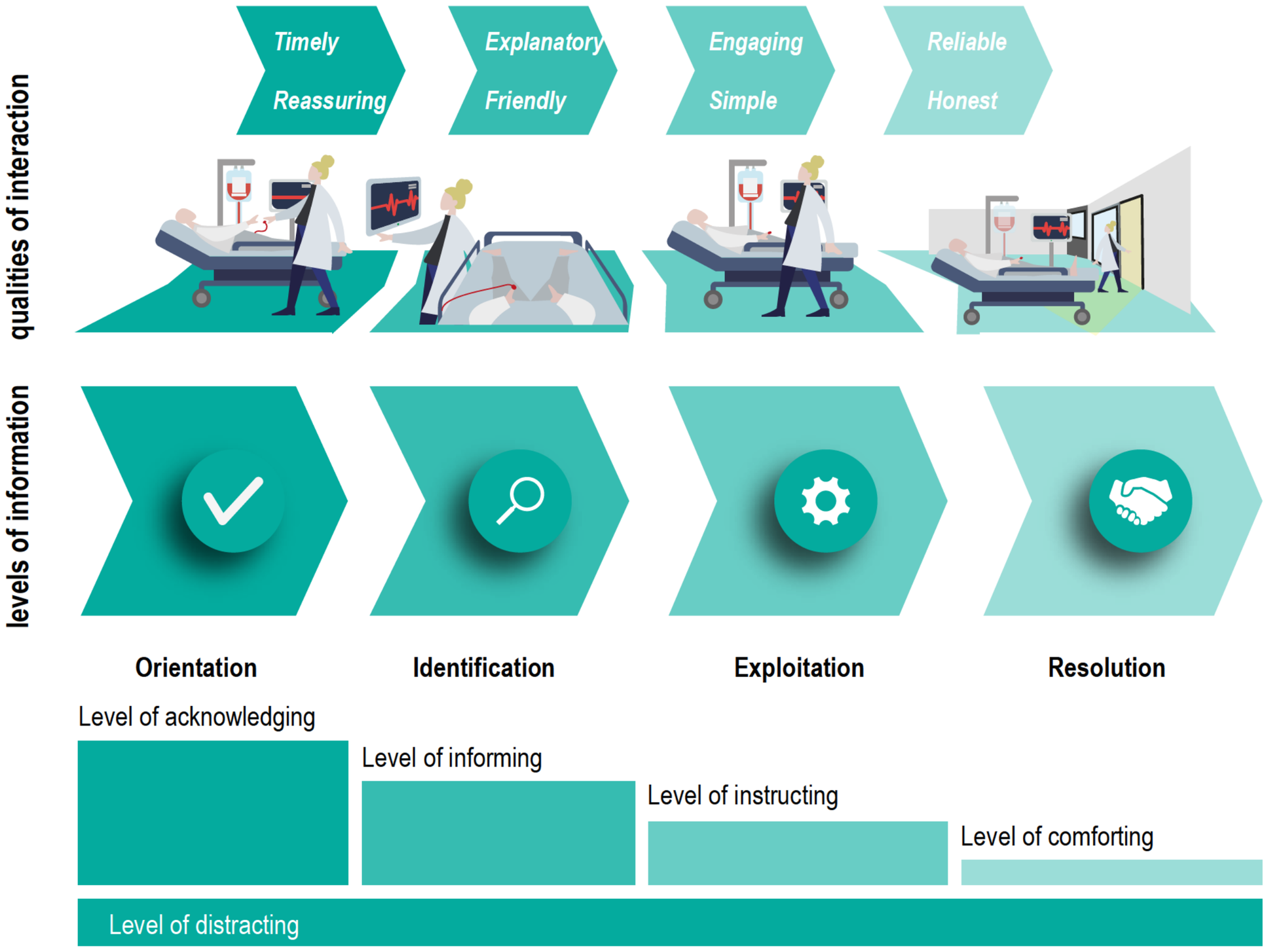


Figure 34. *Levels of information and interaction qualities. The communication between a nurse and a patient is characterized by the types of info provided (levels of information), as well as the way how the nurse convey the message (interaction qualities).*

1. Orientation
Explaining the alarms

" [...] explain that there are two kinds of alarms: a no emergency and an emergency alarm. In case of a no-emergency alarm it will take some minutes before there will be a nurse in the room."

" [...] explain that most kind of alarms are non-emergency alarms and tell that not every alarm is serious [...]"

2. Identification
Explaining the cause of an alarm

" [...] if an alarm often goes off, explaining that it is because of a certain thing, such as moving of the patient's hand [...]"

"[...] tell which machine gives the alarm"

3. Exploitation
Explaining how to prevent some medical alarms

" [...] explain how to take care for his/her SPO2 sensor "

" [...] explain how to move his wrist in case of an arterial catheter [...]"

4. Resolution
Explaining that they are continuously monitored

" [...] telling the patient that even they cannot see us, nurses always see them or at least their vitals [...] "

Conclusions

Focusing on the interpersonal relationship between patients and nurses and on the way how they interact when a medical alarm goes off, it is possible to observe that the information provided to patients have multiple roles: to acknowledge, to promote understanding, to comfort, to instruct and to distract (Fig. 34).

Levels of information

In the interaction with nurses, verbal and no-verbal communication aims to acknowledge a patient, as well as inform, instruct, comfort and distract him/her from an alarm. These actions can be described as communication goals or levels of information.

To reduce the risks of developing a state of anxiety while waiting for the arrival of a nurse when a medical alarm goes off, it was necessary to consider the achievement of the same goals through the use of an interactive tool that put these users in communication by a distance. Most important was to think about the provision of messages that satisfy the patients' need of feeling safe.

Five levels of information were defined: *(1) level of acknowledging, (2) level of informing, (3) level of instructing, (4) level of comforting and (5) level of distracting*. These levels were used as guidance for the definition of the content of the messages that are provided through the interactive tool.

1. Level of acknowledging. It is the level in which nurses enter a room to intervene thus showing patients that they have noticed the alarm.

2. Level of informing. It is the level in which nurses give information to the patients about the medical alarms thus promoting their understanding.

3. Level of instructing. It is the level in which nurses teach patients how to prevent the occurrence of some alarms.

4. Level of comforting. It is the level in which nurses make patients feel better by being kind and sympathetic towards them.

5. Level of distracting. It is the level in which nurses take the patients' attention away from the alarms and what they were doing and thinking.

Design qualities

The definition of the personality traits of the Ideal nurse was necessary to determine the interaction style of the interactive tool. A research conducted by [44] about *Sound Cultures of Critical Care* was consulted. In this study, the researcher identified three different types of ICU nurses who are distinguished by two general "driving forces": orientation of wellbeing and perceived control. According to [44], nurse's orientation of wellbeing explains whether a nurse acts more from the perspective of her personal wellbeing or more from the perspective of other's wellbeing; while, with nurse's perceived control, the researcher referred to the extent to which a nurse experiences having control over her environment.

A. The Docile - Novice nurse who is the nurse with less experience and who always looks to the other nurses with more experience for confirmation. This type of nurse always behaves for the other's well-being, and she can be defined as a Follower nurse;

B. The Opinionated – Professional nurse who is the nurse who hates the sounds and usually behaves less kind and focusing only on his/her own needs and well-being. This type of nurse can be described as an Individualistic nurse;

C. The Assertive – Ally nurse who is the nurse who thinks that sounds are bad for everyone, and especially for patients, but if nurses work as a team they can improve/reduce the sounds. This type of nurse can be described as Collective nurse.

Each personas has specific characteristics which reflect the way how they behave, also, towards medical alarms, as well as the way how they support patients.

As a result, I was able to select a list of qualities that should belong to the personality traits of the *Ideal nurse*. Focusing my attention on the *Assertive - Ally nurse* and the findings from the generative session, I had an overview of the ideal behaviour a nurse should have towards medical alarms and in supporting patients. The selected qualities were, then, translated into an interaction style that provided guidance for making interaction design choices for the development of the Interactive tool.

Personality and interaction style

The Ideal nurse is empathetic. Her aim is to promote patients well-being by reducing the possibilities of experiencing stress and anxiety. She is an attentive and friendly nurse who timely takes action when a medical alarm goes off.

Regardless of the types of alarm, she always wants to interact with her patients to reassure them; as a result, patients trust her because she is always present and honest. Patients cannot feel alone when she is around, because she always checks them even from outside their room communicating through gestures. She always wants to let patients know that they do not have to worry because she takes care of them.

The Ideal nurse wants patients to understand what is happening and that patients collaborate with her. Hence, by using a simple language, she provides clear explanations that patients can easily understand and use to cope with alarms.

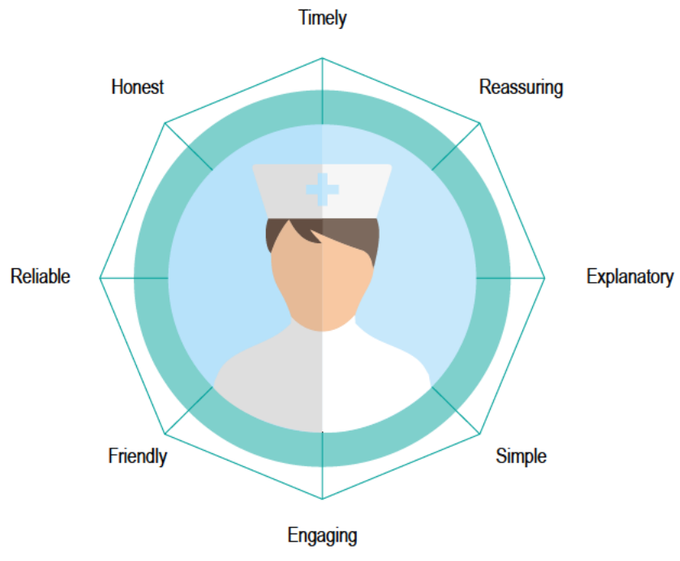


Figure 35. *The Ideal nurse. The adjectives describing the Ideal nurse refer to the way how a nurse should interact with a patient when a medical alarm goes off in order to reduce the risks of increasing stress levels and to remove anxiety.*

Observational study

The department of Adult ICU of the EMC was visited an additional time and more detailed information about the way how patients and nurses interact and use the space were collected [45].

The investigation conducted at this phase of the design process was necessary to define and test together with experts the concept.

Activities
During the investigation, two different activities were performed, *(1) observations and a (2) role-playing activity*.

Observations
In this activity, I covered the role of *a participant as an observer* by shadowing a nurse [45] during the evening shift, from 3pm to 11pm. This role gave me the possibility to better empathise with the nurses and to understand how they make decisions and react towards alarms. By wearing a nurse's uniform, patients and their family members were not aware of my presence that day, but they perceived me as a part of the clinical staff. This approach helped me to become a participant of the nurses' workflow and without influencing other users behaviours.

Approach
During the investigation, there was a nurse who guided me through the ICU; the nurses' workstation, the patients' boxes, the medical devices and medical alarms were shown and explanations about how nurses handle medical alarms given.

Different alarms went off and the physical reactions of patients were observed from inside their rooms. A pager was given to me and explanations about how to interpret the notification reporting an alarm given by the nurse.
In general, each time a medical alarm was going off, I was guided by a nurse throughout his decision-making process: from the moment a notification was received on the pager, until the moment of entering the patient's room and comforting the latter.

The nurse showed me how medical alarms are handled and how the various types of medical alarms influence the behaviours (e.g. in case of a false alarm, nurses usually tended to delay their intervention). In addition, I observed how, by a distance, nurses are able to distinguish medical alarms and which strategies they usually employ to calm patients down.
Finally, I was collecting notes through a book-notes and taking pictures reporting some relevant information (e.g. vital signs in the monitors outside the room).

Results
The observational study gave me an overview about nurses' workflow and a deeper understanding of the difference between true (clinically relevant) and false (not clinically relevant) alarms.

The observations helped me to identify the *nurses' need for communication* with their patients when an alarm goes off. Nurses acknowledge the importance of communication to restore calm and remove anxiety, thus, when they cannot timely react over an alarm, they get stressed.

In addition, the current system (pager) does not contribute to addressing such a need, and nurses would like to have more control on their pagers, for instance, they would like to have access to their patients' vitals without the need of checking on other devices and, as a result, being able to communicate directly with them without the urgency of reaching their rooms, especially when a false alarm is going off.

Conclusions
Experiencing the ICU from the eyes of nurses helped me to appreciate what's being a nurse in the ICU means.

Nurses try their best to properly support their patients, sometimes running within the unit to reach a room. The lack of a system that gives them the opportunity to communicate by a distance with a patient reduces the time they could spend interacting with their patients. The pressure that nurses experience is often really high. Nurses need to make fast decisions and to be focused while caring for a patient; indeed, a wrong decision or a fast attempt to resolve a problem could cost the life of a person.

During the interaction with a patient, nurses should be able to do their job properly while offering the expected support to each patient they care for.

Choosing to become an ICU nurse is a vocation. These people save lives and give patients and their relatives hope. I saw that sometimes is really hard even for a well trained and long experienced nurse to stay strong, especially when they are dealing with a patient who might not survive.

For this reason, it is important providing nurses with a solution, an interactive tool, that also satisfy their need for communication with a patient in order to reduce the stress they usually experience when not able to properly support their patients.

Role-playing

A discussion about the concept was opened. In this second activity, I was introduced to several nurses who were working in my unit.

Most of the patients were already asleep; as a result, I had the opportunity to recruit four nurses for a role-playing activity. The scope of this activity was to test the concept and to define together with experts the content and the structure of the design.

Role-play is a "representation technique that allows explaining a service or product idea by acting out an exemplification scenario of use" [46]. By using this technique, I was able to capture different insight and learn more about the concept, especially how it could be implemented within the current system and how users could interact with such a system.

Approach

Participants were firstly invited to sit in a room adjacent to the unit where I introduced the concept and we had an initial discussion about its functionalities.

Later, while we were walking around the unit, they were invited to think aloud and imagining to use such a tool. Nurses were using their pager and showing how they usually interact with other devices when they make decisions and how they would like to control the flow of information from this device. In addition, we entered inside a patient's room where we discussed types of information and methods for the provision of such information to patients.

Finally, data were collected through a book-notes and pictures captured.

Results

Nurses believed that the possibility to communicate by a distance with patients who are waiting for their arrival can increase the perceived sense of safety.

Although the levels of acknowledging, informing and instructing have aroused more interest among participants, promoting the understanding of alarms was considered as relevant only in case of false alarms. The provision of information can contribute to build-up the relations with patients and *open new collaborations*.

Patients - who are conscious and not paralysed - could autonomously deactivate an alarm (e.g. reattach the Pulse oximetry sensor) if nurses can send them a message that shows them how to reattach, for instance, a sensor. In addition, such collaboration might also contribute to the reduction of the duration of some medical alarms.

Regarding the level of acknowledging, the idea defined with nurses was to *passively involve patients in the nurses' decision-making process* showing, also, the time required by a nurse to reach the room; about the levels of informing and instructing, more attention on the content of the message needed to be put because such solution should not contribute to increasing patients' stress levels and anxiety.

By reasoning on the types of alarms and how nurses usually react to each type of alarm, two scenarios were identified: *in the case of clinically relevant alarms* nurses always and timely enter the patient's room, thus the provision of information should be limited to the level of acknowledging; *in the case of a no-clinically relevant alarms* (e.g. false alarms), the provision of information can be extended to all the levels, especially because nurses tend to delay with their response.

The levels of comforting and distracting were also discussed and it was concluded that it must be the content of the messages and the way how these are communicated to reassure and move patient attention away from the auditory stimuli.

Conclusions

Role-play was a powerful method which gave me the opportunity to understand the strengths and the weakness of my concept, as well as to generate new ideas.

Enabling nurses to communicate with a patient by a distance might benefit many users, including family members who usually overreact when a medical alarm goes off.

By using the interactive tool, nurses might experience less stress when unable to communicate with their patients and, also, spend more time with their patients.

The interactive tool might contribute to the improvement of the quality of care by giving nurses a means through which always can support their patients, and to patients the possibility to receive the expected and needed support.

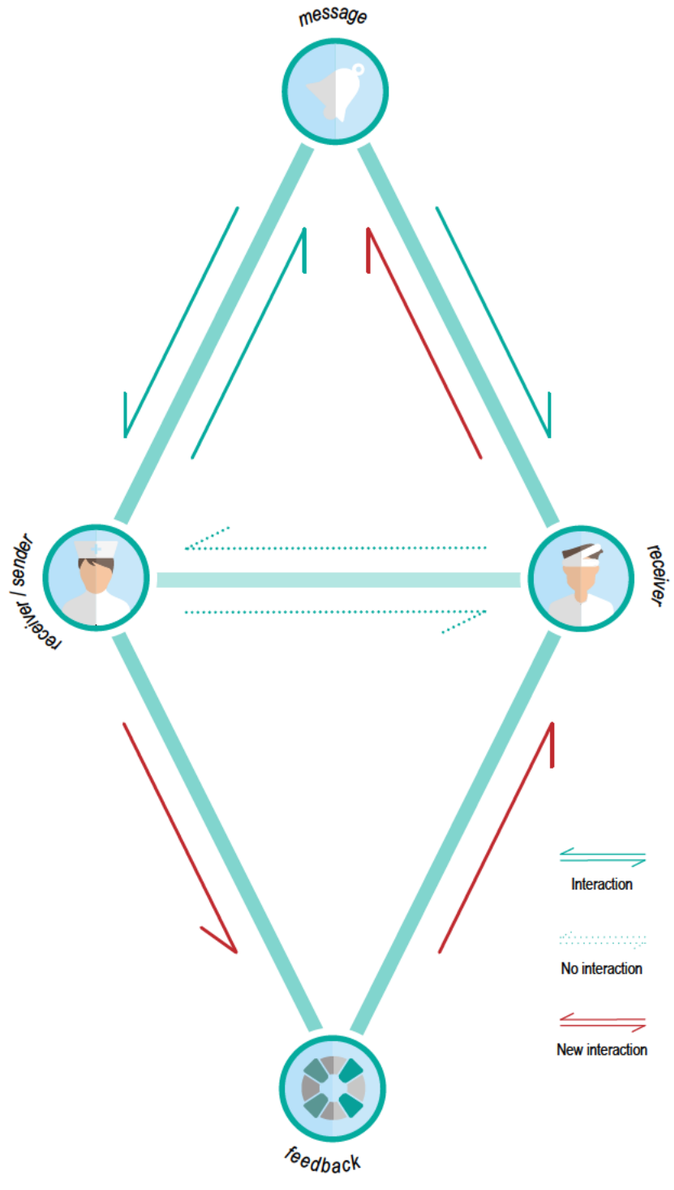


Figure 36. *Concept. The figure shows the role of the Interactive tool in the nurse-patient-alarm interaction. The provision of feedback/information by a distance make nurses able to interact with their patients especially when they cannot timely intervene in the case of a medical alarm.*

4.3 | Design requirements

In this section, the characteristics of the Interactive tool are described and a list of requirements is provided. Meeting these requirements will increase the possibilities to satisfy the nurses' need for communication and the patients' need for feeling safe.

The qualities of the Ideal nurse and the levels of communication were used to define the content, appearance and interaction of the interactive tool. The aim of the interactive tool is to put nurses and patients in communication by a distance to timely acknowledge and inform the latter about an ongoing alarm.

Control

- The Interactive tool should not be controlled by patients but being always active; only nurses should be able to deactivate it if needed or requested;

- Through their pagers, nurses should control the interactive tool and have direct access to the patients' vitals data to timely and adequately make a decision on the types of information to share;

- Patients should be given a reasonable amount of time to consult and interpret each information; Interaction

- No physical interactions should be required to patients to access the information which, instead, should be automatically provided in the form of visual feedback through a communication channel easy to access from their bed, such as a screen;

- The interaction with the interactive tool should reassure and engage patients by capturing their attention and distract them from the auditory stimuli;

- The interactive tool should not produce any sound so as not to increase noise pollution inside the room;

- The interaction style of the interactive tool should be designed according to the Ideal nurse's personality traits qualities: timely, friendly, engaging, honest and reliable;

Content

- The message provided must be explanatory and easy to interpret without requiring patients any cognitive effort to comprehend it;

- When there are no active alarms, the interactive tool should always show patients information about the nurse who is taking care of them to make them feeling monitored;

- When a medical alarm goes off, the interactive tool should passively involve a patient in the nurses' decision-making process by showing whether a nurse has been informed and has accepted the notification reporting the alarm, if she is taking care of the alarm and how long to wait before her arrival;

- The information provided should always be honest and reflecting the reality to do not fail the patients' expectations;

- When is possible, the interactive tool should also show to patients the reason for an alarm and instructing them on how to deactivate some of them;

Appearance

- The appearance of the interactive tool should reassure and comfort patients;

- The information shown on the interactive tool should be easy to recognize and discriminate, concise and consistent;

- The information provided in the interactive tool should be readable at a distance of three meters, especially if considered the use of the TV screen placed in each room and positioned at a distance of about three meters from the patients.

Chapter 5

In this chapter, the functionalities of the Interactive tool are described.

Based on the design goal "Designing an interface that reduces the risks for (conscious) patients to develop a state of anxiety through the timely provision of feedback on medical alarms during waiting for the arrival of a nurse" and the literature research, the requirements presented in the previous chapter were reviewed and adopted for the development of Overcome.

The design of the user interface is explained in relation to some selected principles for the presentation of the information reported in the ISO 9241-112:2017. Finally, the content and animation of each visual element of the interface, as well as a concept about the functionalities that should be implemented in the current system (pager) to give nurses control of Overcome are described.

designing Overcome

5.1 | Functionalities of Overcome

In this project, we focused on patients who are conscious during ICU stay and who do not suffer from any psychological disorder, such as Delirium. Some of the most common factors patients in the ICUs are exposed to were considered for the development of the design, such as attachment to wires, tubes or sensors, high noise levels, unfamiliar setting (environmental constraints), inability to move the body, being forced to stay always in a supine position on the bed (external demands), pain, lack of control of the situation, altered perception of the time, memory loss (coping constraints).

Patients' use of *Overcome* is limited to providing a message, or feedback, that informs about the nurses' decisions about an ongoing alarm, thus removing the uncertainty of being monitored and set their expectations in relation to the clinical staff reactions; instead, explanations and instructions about medical alarms can reduce the uncertainty elicited by their ambiguity. Therefore, the patient is required to read the information shown and adjust his/her emotional reactions to the medical alarm.

Considering the patients' constraints, it was necessary to think about providing a message that not requires any cognitive effort for their interpretation; as a result, the use of visual elements was adopted.

Overcome is a digital interface which informs visually patients through medical alarms feedback provision. The tool wants to satisfy the *nurses' need for communication* and the *patients' need for feeling safe*.

Nurses might control *Overcome* by a distance through their Pagers deciding whether to activates or deactivates it and on the types of feedback to provide.

Finally, in the current situation, the support patients receive by nurses to cope with a medical alarm is provided only when a nurse enters the room; in addition, to reduce the risks of developing a state of anxiety is necessary that such support is timely provided.
Overcome might then fill the gap related to the lack of support experienced by patients when a nurse delays to intervene. However, for the effective removal of a state of anxiety, the presence of a nurse should always be guaranteed after feedback provision. Indeed, a digital interface cannot replace a nurse whose role is also to answer patients' questions and provide emotional support.

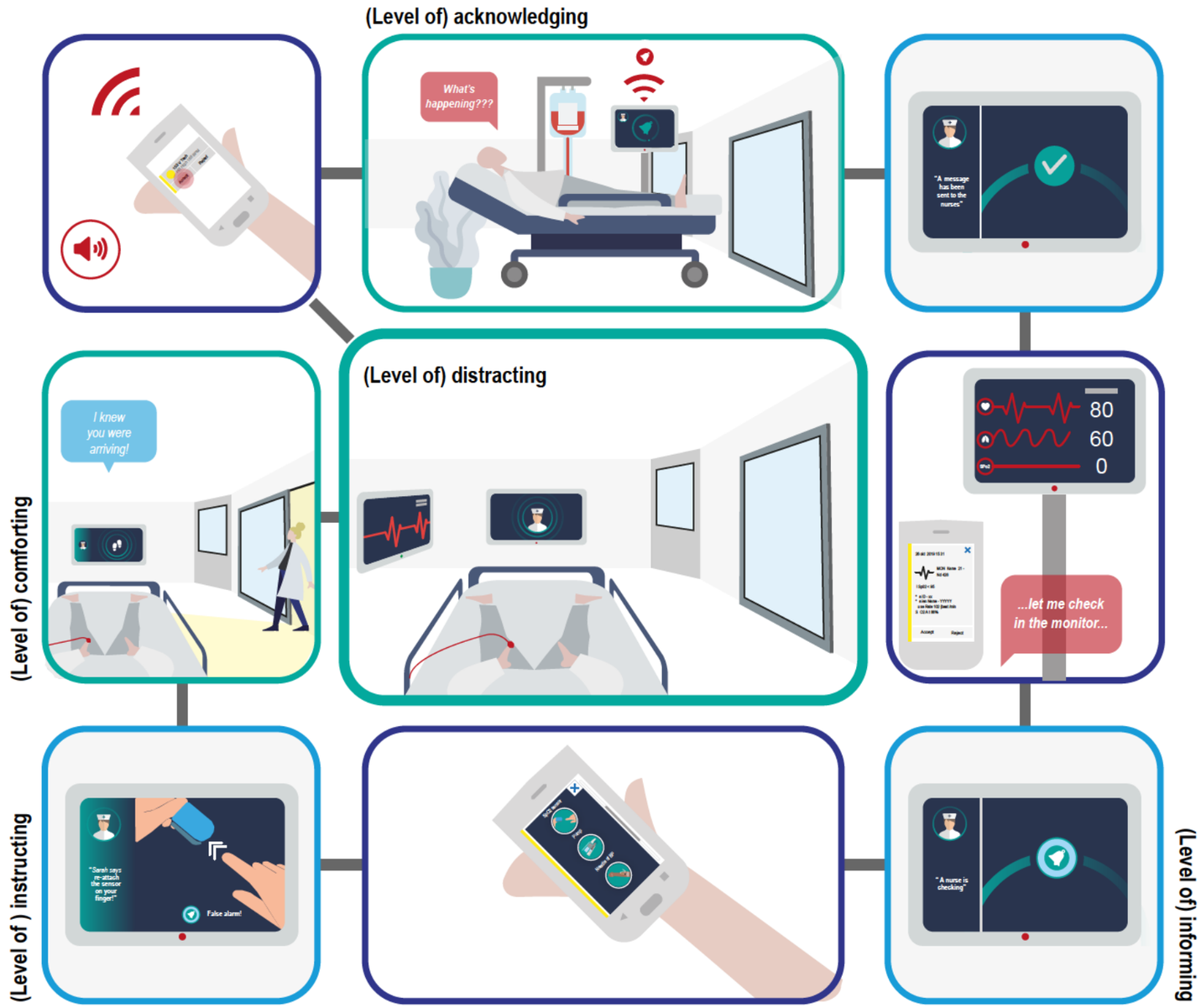


Figure 37. *Concept. The illustrations shows how Overcome interacts with the patient and how nurses can control it.*

5.2 | What is a feedback?

For patients, the message must be comprehensible and easy to access without requiring them any physical or cognitive effort.

Research on the field of *Visual design*, which investigates "methods to communicate and inform visually users" [47], led me to focus on the development of a feedback interface, where the use of *icons, labels* and *progress bars* support users' memory and reduce cognitive load when interacting with the system [47].

Feedback is defined as "actions taken by (an) external agent(s) to provide information regarding some aspect(s) of one's task performance" [48]. When designing feedback and to improve its effectiveness, is necessary to pay attention to the *timing, delivery,* and *content of the feedback,* as well as on the *technology, modality* and *presentation and user experience* [49].

Technology
Feedback can be delivered through many different technological channels, such as websites, Smartphone apps, wearable, home displays, etc.

Content
Content, which must fit the receiver characteristics, affects feedback effectiveness. As a result, it is necessary to understand and take into consideration the recipient *motivation, traits, abilities* and *preferences* when determine the content of the feedback to determine, for instance,
the level of detail [49].

Timing
To improve effectiveness, feedback should be provided with no or a short delay to give the recipient the opportunity of changing his/her behaviour while the action is occurring (reflection-in-action). Instead, long delay feedback can be expected to be less effective because leads users to r*eflection-on-action* or reflections on activities already occurred which reduces the possibility for a change on behaviour [49].

Modality
To increase feedback effectiveness, it is also necessary to select the *optimal delivery channel* or a combination of channels, such as visual, auditive, or tactile channels. The optimal modality choice depends on the possibility of disruption and the need for detail [49].
For instance, visual modes are more disruptive than the auditory, which is in turn more disruptive than tactile feedback. Similarly, visual feedback can contain more detailed information than auditory, which in turn has more capacity for detail than tactile feedback [49].

Frequency and duration
Feedback frequency and duration also influence its effectiveness.
In general, the more frequent the feedback is delivered, over a longer period of time, the more the intervention will contribute to behaviour change [49].
It is important to consider that the frequency and duration of a feedback depends on users' cognitive capacity. As a result, as long as the frequency of the feedback does not overwhelm an individual's cognitive resources, more feedback is better [49].

Presentation and user experience
Visual design aspects, as well as aesthetics determine the attitude of users towards design as well as the perceived ease of use (but not actual use) [49]. For instance, an intervention whit a pleasant and friendly interface more likely will make users more inclined to use it. A clear design can improve the fluency of feedback, as well as help and lead users to focus on the most important information.

Conclusions
Feedback must be adapted to the recipients' needs and abilities (e.g. cognitive abilities). To increase feedback effectiveness, it is necessary to understand who are the final recipients and why they need feedback. This information helps to determine what is the message to convey (*content*), where and when it needs to be delivered (*technology and modality*), as well as how feedback should be presented (*presentation and user experience*). Ultimately, feedback should be timely provided with no delay (*timing*) and in a continuous and frequent manner (*frequency and duration*) to be effective.

5.3 | Layout and content

According to the design requirements, Overcome is a feedback interface who nurses control by a distance through their pagers (Fig.37).

Although the use of two different devices, a pager and a TV screen, is required for the system to run, the aim of this graduation project was to understand *how the provision of feedback through a TV screen* (placed inside the patients' room) *can contribute to the reduction of the risks of developing a state of anxiety in patients who are exposed to a medical alarm*; therefore, it was not my goal to develop the pagers' interface nor to test the extent to which the system satisfies the nurses' need for communication.

In the interaction with Overcome, patients are not asked to physically interact with the interface: they do not have to manipulate the interface nor to move between tasks, applications, files, sections or views, but they are asked to read the information shown and comprehend them.

Finally, three different ISO standards were adopted for the development of the Overcome's feedback interface and for testing comprehensibility of the graphical symbols designed.

Control and interaction
Overcome consists of a TV screen - already placed on the patient's room - and the nurses' pager. Through the *pager* (controller) nurses will provide feedback that will be shown in the form of *animated icons* in the *TV screens* (information screen). The information screen will keep patients informed about the events and without requiring them any interaction.

When a medical alarm goes off, nurses receive a notification reporting the alarm on their pager. From their pagers, nurses can visualize, accept or decline a notification. Through Overcome, nurse-pager interactions and their decisions will be shown synchronously on the information screen.

On the one hand, information describing the steps a nurse takes in the decision-making process will be shown to patients in the corresponding order and as looped animation, and their duration will depend on the time the nurse spends before proceeding to the next step. On the other hand, a progress indicator with bullet points will visually guide the patient through the approaching process showing the completed and missing steps including the time needed by the nurse before entering the room.

Content and appearance
Level of acknowledging
The level of acknowledging is the first level of information. By reflecting on the "seen-function" utilized by *WhatsApp* (which informs the sender that his/her message has been sent, received and visualized by the receiver of the message), the concept of feedback in the form of an *animated check-mark* (Fig. 40) growing on an animated bell (representing the ongoing alarm) has been formulated.

In general, the value of the "seen-function" is to provide more transparency over the course of a conversation to the users involved. This function can be described as an "awareness cue that helps to compensate for the lack of social information and which support conversation" [50].

In Overcome, this concept has been adopted and applied to acknowledge a patient. As a result, patients (unintended receiver of the alarm) will be informed that the notification reporting the alarm has been sent through the pager, and received and visualized by the nurse (intended receiver of the alarm). Hence, the *animated check-mark* will remove the mystery related to the uncertainty of being monitored thus increasing the perceived sense of safety.

Finally, at this level of information, other types of feedback will be provided to patients in an attempt to increase their perceived sense of safety: *(a) a nurse is (continuously) monitoring the patient* (Fig. 38), *(b) there is an alarm going off* (Fig. 39) *and (c) a nurse has received and (d) accepted the message* (Fig. 40).

Level of informing
The level of informing implies the promotion of medical alarms understanding. Patients' interpretation of a medical alarm is based on the explanation and the reactions of nurses towards the alarm.

In Overcome, I applied this knowledge to provide patients with feedback that inform them about the activity undertakes by a nurse to solve the alarm and feedback to understand the source for the alarm. As a result, feedback in the form of *an animated hand lens* (Fig. 41) moving around an animated bell and feedback of an animated object (representing the source of the alarm) have been designed.

The aim of the animated hand lens is to inform patients that a nurse is checking on the reason for the alarm and to reassure the latter that the nurse is already taking care of the problem even if not yet inside the room. Subsequently, the *animated icon of the reason for the alarm* (Fig. 42), such as the SpO2 sensor, is shown to promote the patients' understanding over the alarm. A label explaining the source and reason for the alarm will help the patient to better interpret the message.

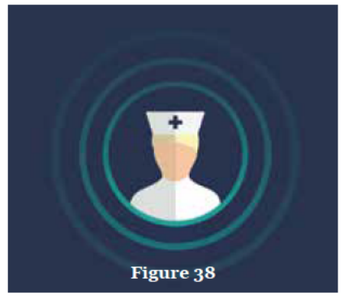


Figure 38

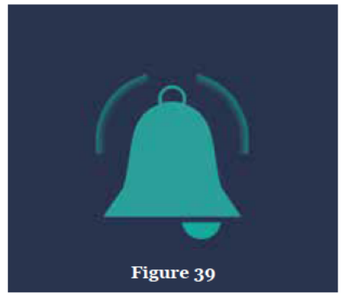


Figure 39


Figure 40


Figure 41

Level of instructing
The level of instructing implies that nurses provide patients with indications to solve the alarm. In the current situation, nurses show patients how to prevent the occurrence of some medical alarms by giving them suggestions about which behaviours they should avoid, such as the brisk movement of a limb that could cause the detachment of a sensor or the needle for measuring blood pressure.

However, instructions can be given at the discretion of the nurse only in the case of false alarms and to patients who are able to perform such a task.

In Overcome, animated icons showing patients *how to solve the alarm* (Fig. 43), *such as how to reattach a sensor or how to place a limb were designed*. These icons are a guide for patients to solve autonomously an alarm and to reduce their duration.

Level of comforting
Comforting a patient entails the presence of a nurse inside the room who through the provision of empathy and caring support the individual with reassuring words and/or physical contact. As a result, such a level of comfort can be achieved only through human-human interaction.

In Overcome, the level of comforting was accomplished by designing an *animated icon of a nurse walking* (Fig. 44). It was assumed that informing a patient that a nurse is on the way to entering his/her room can reduce uncertainty and comfort the patient.

In addition, feedback in the form of a *progress indicator bar* (Fig. 45) was also designed to provide patients with information about how long is the waiting time.
On the one hand, showing the waiting time might have a negative effect if the nurse enters the room in delay compared to the time shown. Indeed, showing the time might increase patients' expectations and, a delay, result in more stress. On the other hand, to do not fail the expectations of a patient, the waiting time shown must reflect the reality.

Therefore, more research on sensors and into the development of a network that could enable the accomplishment of such a goal is needed. Perhaps, the use of *GPS* embedded in the pagers, or *Bluetooth Beacons* installed in different locations in the unit could help to calculate the time a patient needs to wait based on the velocity and exact location of a nurse.


Figure 42

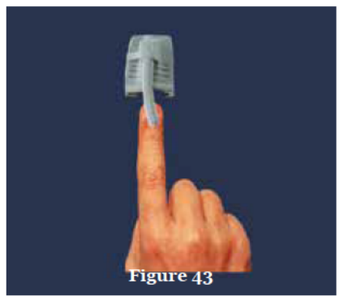


Figure 43

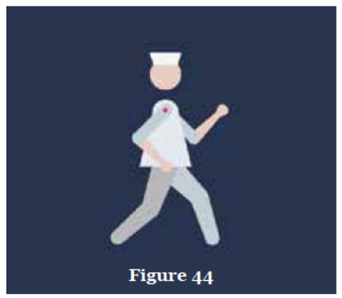


Figure 44

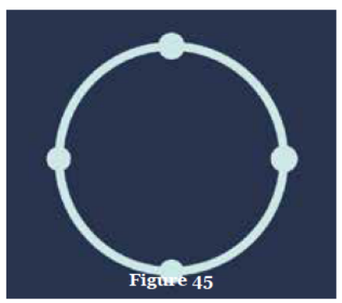


Figure 45

Level of distracting
On the level of distracting, the aim of Overcome feedback interface is to move the attention of the patient from the auditory stimuli, as well as help to properly appraise them. Animated icons, labels and progress indicator bar not only provide patients with information to promote their understanding and increase their perceived sense of safety, but also to distract them from the medical alarms.

Presentation of information and user experience
To guide focus on and prioritise certain information, a visual hierarchy was needed to establish and modulate the influence of the various elements implemented.

Three user-interface elements were chosen for the provision of information: *(a) text, (b) Animated Icons, and (c) progress indicators*.

Progress indicator was used to show the time required by a nurse to enter the patient's room; *animated icons*, considered as the most important piece of information, were used to visually show the content of the message; *text*, in the form of *label* was used to provide users with additional information and to improve the understanding of the meaning of animated icons.

ISO 9241-125:2017
Guidance on visual presentation of information

The ISO 9241-125:2017, which provides recommendations relating to the design and evaluation of visual user interfaces, was adopted for developing a user interface that could enable ICU patients to perform the required task effectively, efficiently and with satisfaction [52]. The ISO includes specific rules and gives provisions for the organization of information taking account of human perception and memory capabilities [52].
The ISO provides explanations of the different *areas, or section or region* of a display or window (Fig. 46), that characterize a user interface and which must be considered for the distribution of information when designing the layout since each region must display specific information:

1. Identification area, where the title of the displayed information is provided, is often located above the input/output area;
2. Input/output area, where information is received form users and/or presented to users;
3. Control area, where control information and/or controls - user-interface elements - for interaction, command entry and command selection is provided, may be positioned in different parts of the display - such as the input/output area;
4. Message area, where information such as status updates and/or other information - e.g. progress indication - is provided, may be positioned in different parts of the display - such as the input/output area.

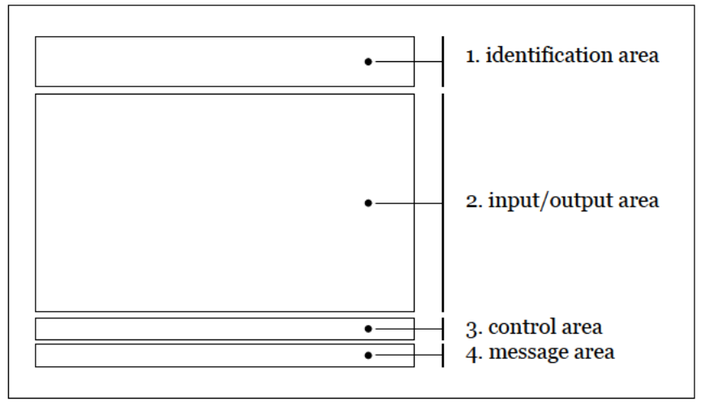


Figure 46. *ISO 9241-125:2017. Possible layout of different areas.*

Rules given in this document were not applied in its entirety rather selected according to the requirements established from design research.

In conclusion, for the application of the ISO 9241-125, there are requirements that must be accomplished by referring to other ISO

standards which provide general information about the visual presentation of information. As a result, for this project, I took into consideration the general principles for the presentation of visual information provided by *ISO 9241-112:2017*.

In the next paragraph, the *ISO 9241-125* is discussed in more detail and a list of rules adopted in this project is presented. These rules regard three sections of the ISO, *(a) Section 4 - Application of ISO 9241-125, (b) Section 5 - Visual structuring of information and (c) Section 7 - Graphical objects*.

Section 4
Application of ISO 9241-125
This section consists of four subsets, *(1) Subset 4.1 - Accessibility, (2) Subset 4.2 General guidance for presentation of information, (3) Subset 4.3 - Guidance on the presentation of visual information and (4) Subset 4.4 - General issues for the display of visual information*.
In this project, the *Subset 4.2* was accounted and more details are presented in the paragraph *ISO 9241-112:2017*.

Section 5
Visual structuring of information
This section consists of two subsets, *(1) Subset 5.1 - Arranging and labelling information and (2) Subset 5.2 - Using windows to present information*, and only *Subset 5.1* was accounted for the development of the interface (Table 1).

Section 7
Graphical objects
This section consist of two subsets, *(1) Subset 7.1 - Cursors and pointers and (2) Subset 7.2 - Icons*, and only Subset 7.2 was accounted because no cursors and pointers are used for this interface (Table 2).

ISO 9241 - 112:2017
Principles for the presentation of information

The principles presented in the *ISO 9241-112:2017* were used to design an interface that prevents users from experiencing usability problems with presented information, such misinterpret information since the meaning of the information is ambiguous, etc.
In general, the principles are not necessarily independent from one another and the applicability and the priority given to each principle vary with the specific field of application, user groups, and the dialogue technique chosen [53].
In Table 3 more details about the principles.

Table 1

ISO 9241-125 | Section 5 - *Visual structuring of information*
The information presented in the Overcome' feedback interface follows the these rules:

Information location

Information should be located to meet user expectations and task requirements;

Required information

All the information required to perform a given task should be displayed in the input/output area;

Consistent location of areas

Areas used in the dialogue within an application should be consistently located;

Density of displayed information

The density of displayed information should be such that the information is not perceived as being "cluttered" by the user and does not lead to a degradation of tasks performance;

Distinction of groups

- Ensuring visual distinction of group, groups should be perceptually distinguished by spacing and location;
- Application of Gestalt principles (a) law of proximity, elements in close spatial proximity are perceived as belonging to each other; (b) law of similarity, elements are perceived as belonging to each other if they are similar; (c) law of closure, non-existent parts of a figure are added or incomplete figures are completed automatically.

Sequencing

If the task requires a specific sequence for the presentation of data, visual information should be placed in an order which support that sequence;

Arrangement of groups for rapid detection and discrimination

If the task requires rapid visual search for a user interface element, group of user interface elements or a piece of information, each user interface element, group and piece of information should, if possible, occupy a portion of the display area that is covered by the visual focus of the eyes (i.e. central field of the view);

Labelling user interface elements

User interface elements (e.g. fields, items, icons and graphs) or groups of user interface elements (e.g. groups of checkboxes) should be labelled unless their meaning is obvious and can be understood clearly by the intended users;

Label designation

Labels should name the purpose and content of the designated information item;

Grammatical construction of labels

Labels should be grammatically consistent, e.g. consistent use of noun-verb combinations;

Label position

Labels should be consistently located adjacent to the designated user-interface element;

Separation of labels and associated information

Labels should be distinguishable from the information which they are designating (e.g. icons, and graphs).

Table 2

ISO 9241-125 | Section 7 - *Graphical objects*
The icons presented in the Overcome' feedback interface follows these rules:

Neutral icons

In choosing graphical representations for objects and actions, gender, racial, or other stereotyping should be avoided;

Easy learning

To facilitate learning, concrete objects, familiar symbols, or metaphors commonly associated with what is being represented should be used

Table 3

ISO 9241-112 | Section 6 - *Principles and recommendations*
The layout of Overcome' feedback interface follows the these principles:

Detectability

The presented information is detectable if the information is presented so that it will be recognized as a present [53]. Detectability concern four different aspects: prominence, timely presentation of information, design the controls to be detectable, and continuity. The guidance related in making controls detectable by the users were not considered as Overcome's feedback Interface does not requires patients any physical interaction.

Prominence
- The user's attention should be directed towards information as required;
- The focus of attention should be set on important information;
- The most important information (including critical elements) should be presented to stand out from other presented items of information and secure the user's attention.

Timely presentation of information
- The sequence of presentation of information should take into account the logical flow and priority/importance of the information that is being presented;
- Information that is less important should not interfere with the presentation of important information;
- The system should indicate when it is busy.

Continuity
- The system should make the user aware of the end of a set of information.

Freedom from distraction

Presented information is free from distractions if "the information is presented so that require information will be perceived without other presented information interfering with its perception" [53]. Distractions can result from both distracting events and information overload.

- Presented task-relevant information should be clearly distinct from any background or changing information that is added to the presentation for non-task-relevant purposes.

Discriminability

The presented information is discriminable if "the information is presented such that discrete items or groups of items can be accurately differentiated, and if the items of information are presented in a manner that supports their association with or differentiation from other items or groups of items" [53].

Structuring
The information should be structured in a consistent manner according to the semantic approach that best suits its use [53].
In this sub-section, four different types of approaches to structure information are given.

For my project, I decided to use approach B - **usage-based structuring** */ option 1 -* **importance-based structuring**, *where the content is structured based on the estimated order of relative importance of different chunks of content to the user.*

Presentation attributes
- Items of information that are logically dissimilar should be presented differently to make their differences obvious.

Proximity
- Information should be presented in groups which can be recognized as distinct from one another;
- Items of information that belong together should be presented in physical/temporal proximity to one another;
- Objects in spatial, temporal, or acoustic proximity to one another should be sufficiently separated to avoid accidental activation of the wrong object;
- Physical and/or temporal spaces should be used to separate groups of information.

Similarity
- Items of information that are logically dissimilar should be presented using one or more different attributes to draw attention to their dissimilarities.

Interpretability

The presented information is interpretable if "it will be comprehended as intended" [53].

Comprehensibility
- Information should be complete (e.g. containing all information items relevant for completing a task);
- Information on the current states that affect interactions and processing should be available;
- Choices representing states should be titled using adjectives (e.g. active/inactive) that unambiguously represent the state.

Unambiguous meaning
- Information should be presented with vocabulary that the user is familiar with;
- Information should be expressed in a way which will facilitate the user's understanding;
- Simple linguistic constructions and word forms should be used whenever possible;
- Presented information should be unambiguous.
- The meaning of abbreviations, acronyms, symbols, and symbolism (including metaphors) should be clear to the user.

Closure
- Where the presented information is intentionally incomplete, this incompleteness should be clearly indicated.

Textual coherence
- Short sentences should be used, where possible;
- Sentence structure should follow the preferred ordering of the language being use (In English, the ordering of subject-predicate-object improves readability).

Selection and use of media/modality
- Where it is necessary to present dynamic media concurrently in a single modality (e.g. two audio tracks, two video presentations), they should be managed or configurable so that the user can obtain the primary information by focusing on only one of the media at a time.

User capabilities
- Information presentation should be within the cognitive abilities of users;
- Cognitive workload may be reduced by: (a) focusing on the goal(s) and task(s) in a manner unambiguous for the users; (b) providing the users with strategies for accomplishing goals and tasks; (c) providing support for the users' task(s), (d) providing all necessary information in a manner unambiguous for the users, (e) reducing memory demands on the users, and (f) providing information in a manner that best suits the users' individual needs.

Conciseness

The information presentation is concise if "only the necessary information is presented" [53].

Conciseness of content
- The presentation should avoid excess information (e.g. excessive wordiness, unnecessary visual attributes, unnecessary background music, unnecessary tactile stimulations);
- Redundant information should be minimized unless it supports understanding;
- The user should be presented with information that supports the recognition of which possible tasks can be accomplished at this point in the interaction;
- The system should enable users to access different amounts of information in order to meet their individual needs.

Consistency

The presented information is consistent if "items of information with similar intent are presented similarly and items of information with different intent are presented in different style and form within and across the interactive systems and the user's environment" [53].

-Terminology should be consistent throughout the interactive system, including terminology for object names, classes of objects, actions and events, command/control names, control options and attributes, abbreviations, instructions and prompts, feedback and error messages, and status reports.
- The grammatical format (e.g. verb tense) of similar items of information should be consistent;
- The behaviour of components should be consistent throughout the interactive system;
- The relative positioning and layout of different groups of user interface elements should be consistent throughout the interactive system.

Identification area

*The **title** of the displayed information is provided*

Message area

*Information about the status update is provided in the form of two looped-animation: a **bar** (both side) and the **nurse's icon** showing that the system is properly working and the nurse is connected.*

Output area

The (main) information is presented to users.

Message area

*The information about the status update is provided in the form of a **progress indicator** showing, also, the steps required to conclude the interaction.*

Message area

*Information about the status update is provided in the form of a **looped-animation**: a bar showing that the system is properly working.*

Looped animation

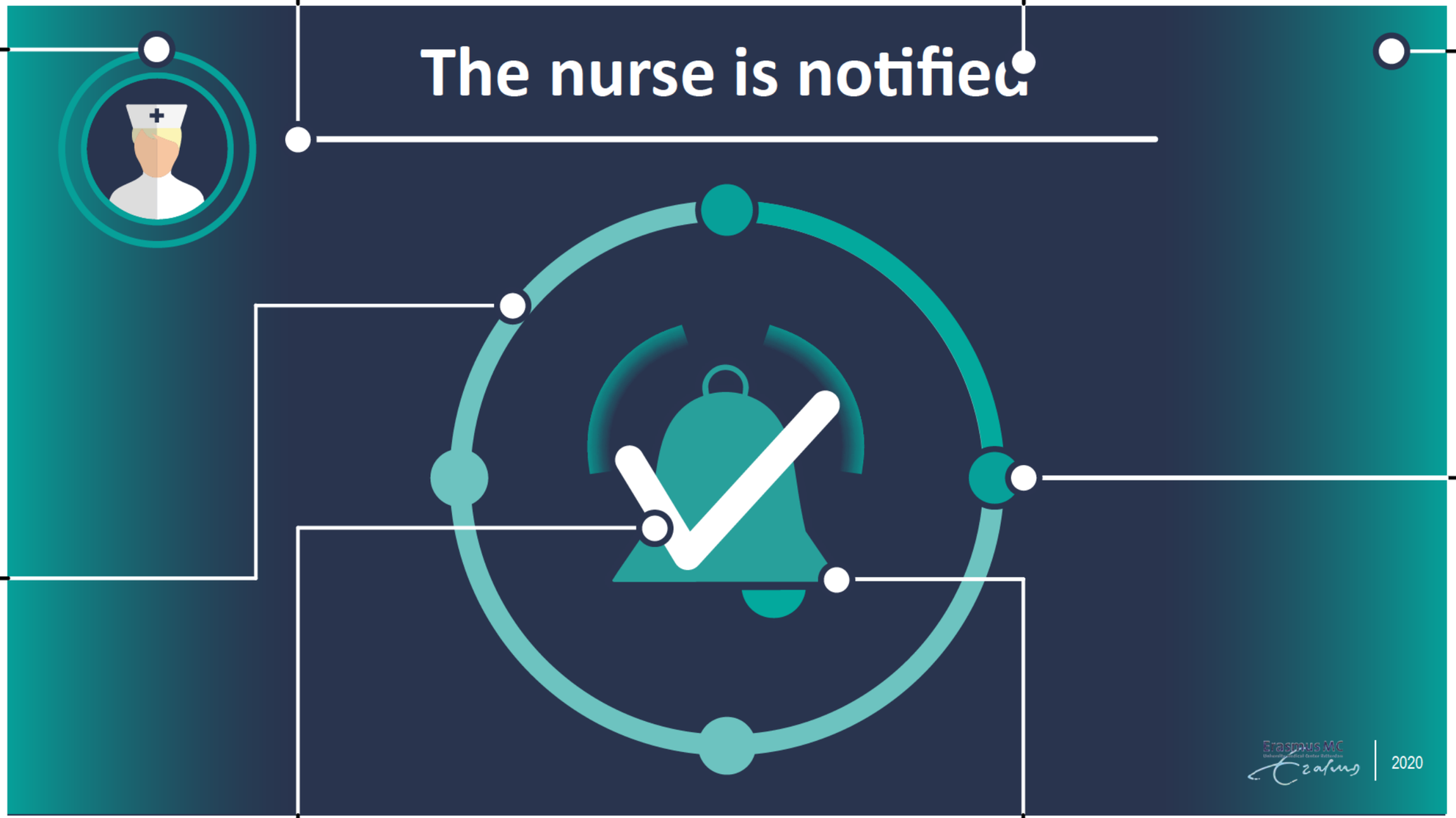
The line situated between the label and the progress indicator is a looped animation which continuously changes in length, thus highlighting the content of the label and separating text from other visual elements.

Label

The label is positioned on the top part of the interface to facilitate users readability.
The use of a label is needed to guide users during the process and increase the understandability of the animated icons.

Animated Icon

The animated icon on the top left of the interface is a representation of a nurse who is taking care of the patient. This is a looped animation. The position in which the icon is positioned is the final one, or the position reached after a medical alarm is detected. The icon grows in size and changes its position (middle of the interface) after the alarm is stopped and the nurse left the room.



Looped animation

The two bars placed on both side of the interface offer feedback that the system is working, but it does not give any further information about how long the user will have to wait.

Progress indicator

The progress indicator is positioned in the middle of the interface surrounding the animated icon.
It communicates to users approximately how much time remains them to wait.

Bullet points

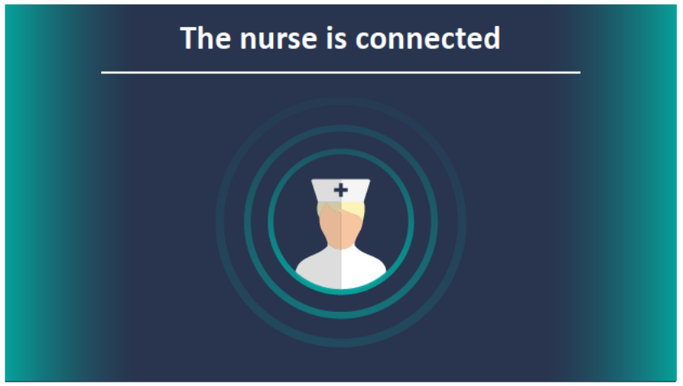
Four bullet points are integrated in the progress indicator. Each one is changing in color after the progress line reach them. Their aim is to show that an activity has been concluded.

Animated Icon

A second animated icon is positioned on top of the main icon. This icon is also animated and visually explains to users the meaning of the step in which they are.

Animated Icon

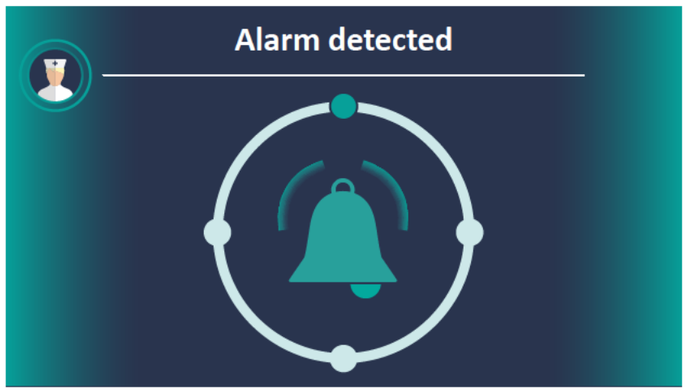
The Animated icons are looped animation positioned in the middle of the interface to stress their importance. They are the most significant information shown to patient containig the main message to convey. There are three different animated icons: a ringing bell, a walking nurse, and a moving hand. Only at the third and fourth step, the ringing bell will be replaced by the other animated icons.



Level of acknowledging

Step 01.
Animated icon of the pulsing nurse.

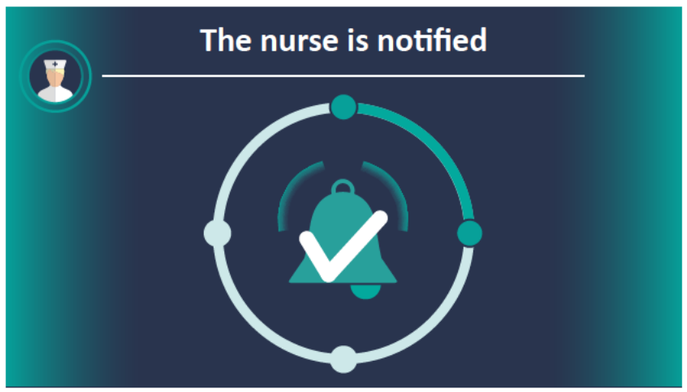
This animation (and the label) are continuously shown. Only in the case of an alarm, it reduces in size moving to the top-left corner of the interface.



Level of acknowledging

Step 02.
Animated icon of the bell.

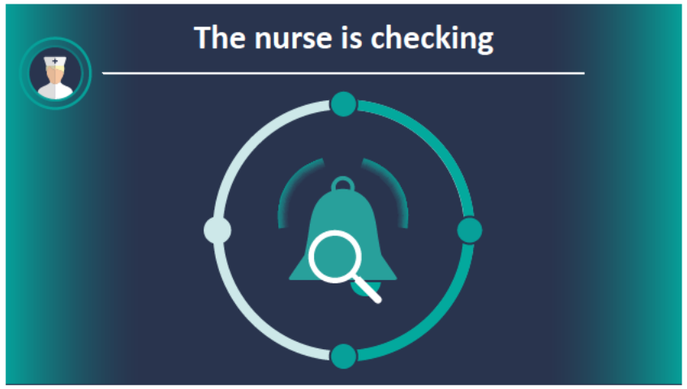
This animated icon (and the label) is shown when a medical alarm goes off and disappears only after the alarm is deactivated.



Level of acknowledging

Step 03.
Animated icon of the Check mark.

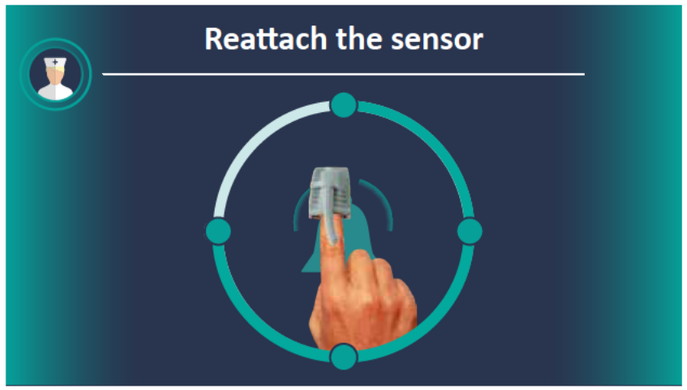
This animated icon (and the label) is shown only after a nurse has received, read and accepted the notification reporting the medical alarm.



Level of informing

Step 04.
Animated icon of the hand lens.

This animation (and the label) are shown while the nurse is checking over the alarm.



Level of instructing

Step 05.
Animated icon of the reason for the alarm / how to solve the alarm.

This animated icon (and the label) is shown after the nurse has interpreted the alarm.

The icon of a "hand and a sensor" is just an example; indeed, the icons can vary according to the types of and the sources of alarms.

Level of comforting

Step 06.
Animated icon of the walking nurse.

This animated icon (and the label) is shown in correspondence of the nurses' approaching phase in which the latter is walks towards the patient room.

5.4 | Prototype

To validate whether the design qualities were well translated and the information effectively provided, a prototype was created in the form of a video which served as a reproduction of the Overcome's feedback interface.

Firstly, by using *Adobe Illustrator*, the layout of Overcome and the user-interface elements were designed. Labels, icons and the progress indicator were later animated and properly arranged on the interface by using *Adobe After Effects*.

For the video, created in Adobe After Effects, it was necessary to reason upon the steps patients go through when a medical alarm goes off (Paragraph 3.3), to determine the duration and how the user-interface elements must interact between them.

Based on literature research, on average patients can wait from a minimum of 20 seconds to a maximum of 5 minutes before a nurse enters the room [22]. By comparing this data with those collected during the observational study conducted at the EMC as student-intern where I also measured the reaction time of ICU nurses on medical alarms, I concluded that on average, at the EMC, the waiting time is about 2 minutes.

Such a conclusion was used to establish how long the provision of feedback must last during the waiting phase (questioning, searching and submitting). In addition, about two minutes were added to the total length of the video considering the phases of waking up, interacting and separating.

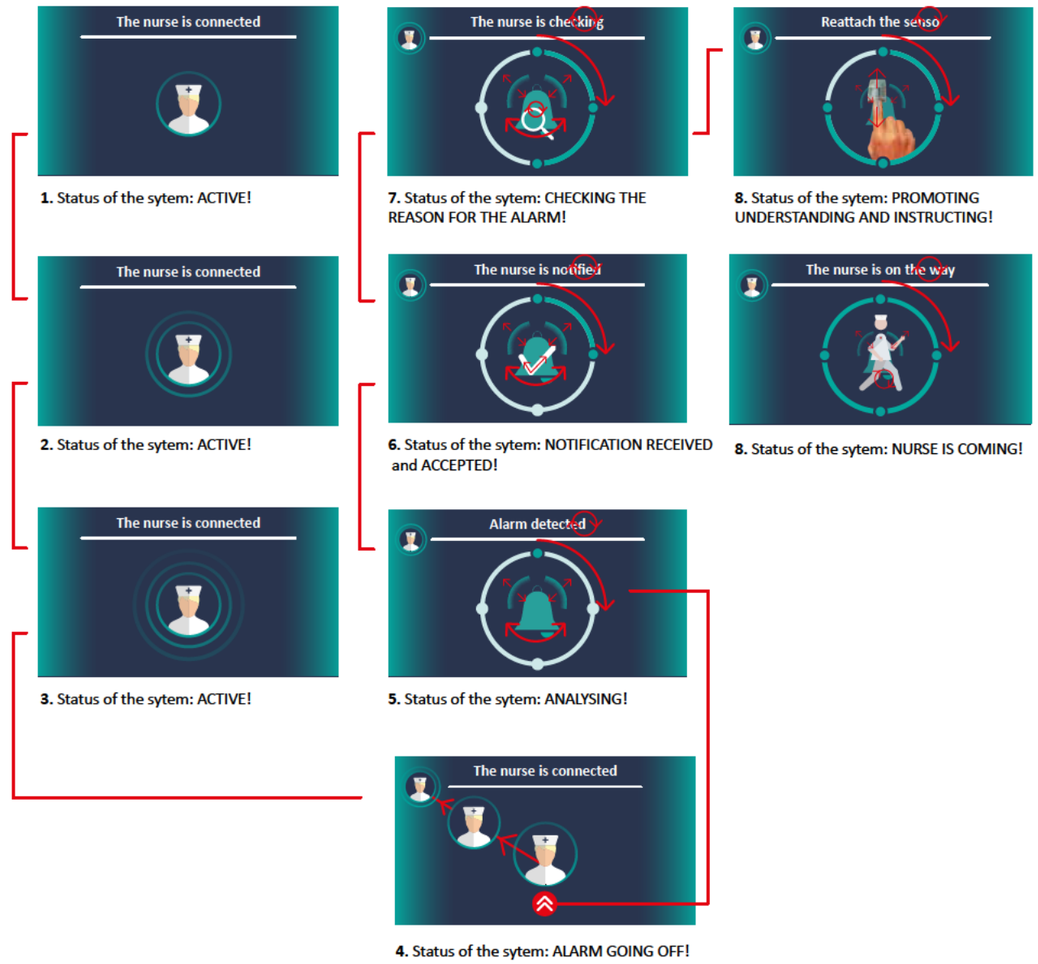
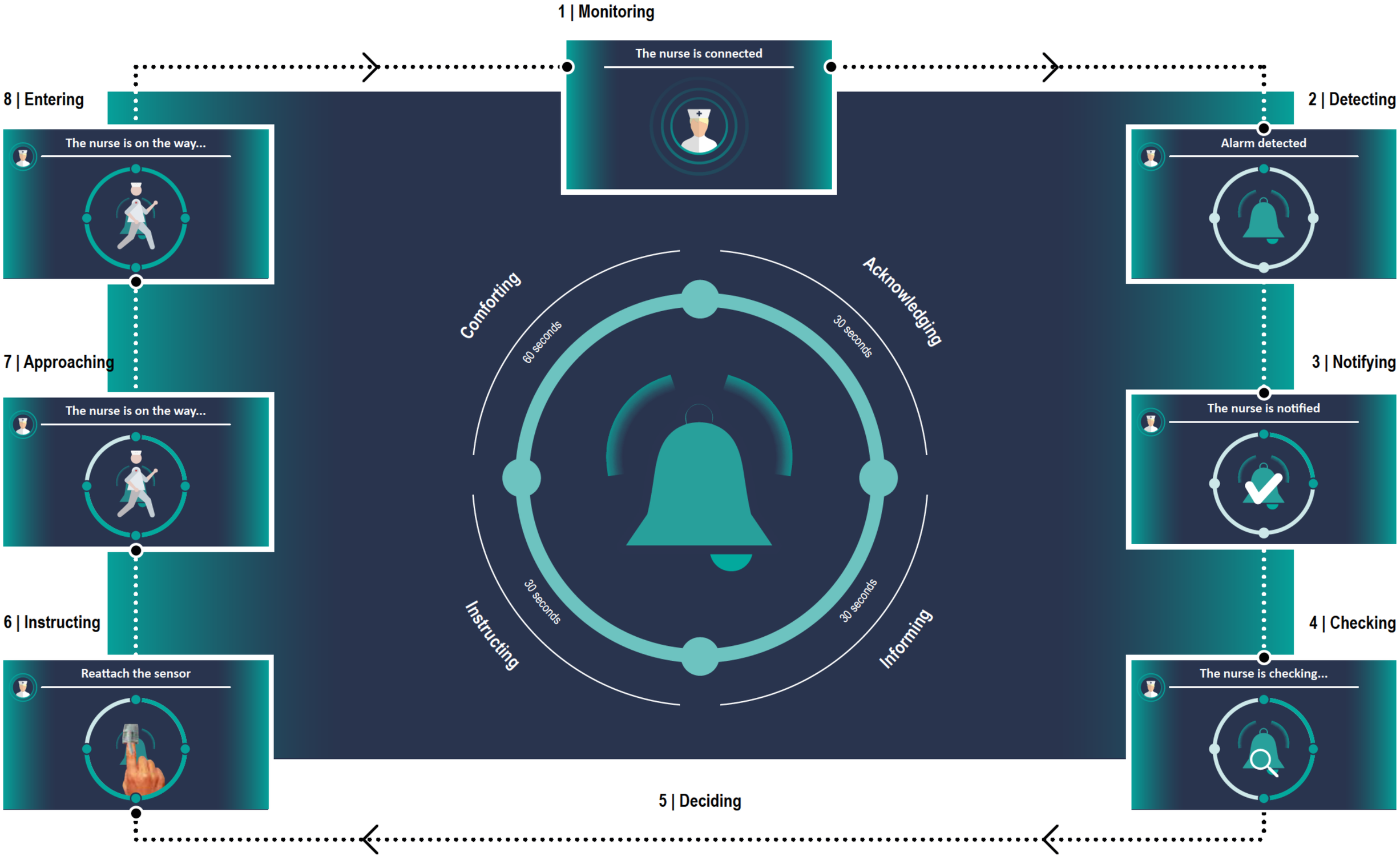


Figure 47. *Motion graphics. The figure shows how the animated icons interact with each other.*


1 | Monitoring
The nurse is connected
2 | Detecting
Alarm detected
3 | Notifying
The nurse is notified
4 | Checking
The nurse is checking...
5 | Deciding
6 | Instructing
Reattach the sensor
7 | Approaching
The nurse is on the way...
8 | Entering
The nurse is on the way...
Acknowledging
30 seconds
Informing
30 seconds
Instructing
30 seconds
Comforting
60 seconds

5.5 | Testing comprehensibility

In the development of the interface, particular attention was put on the principle of Interpretability presented in the *ISO 9241-112:2017*, which is discussed on the next section of this chapter. Due to ICU patients restricted cognitive abilities, the risks of misinterpret information presented are high.

Providing patients with ambiguous information could add stress and anxiety, thus failing the design goal. As a result, it was important to test the extent to which these animated icons (which represent the main information) were easy to comprehend.

The animated icons were designed to visually inform a patient promoting the understanding of medical alarms and nurses reactions to increase their perceived sense of safety.

To test their comprehensibility, the ISO standard 9186-1:2014 was adopted as a guide to design the test.

ISO 9186-1:2014
Method for testing comprehensibility

The ISO standard 9186-1:2014 specifies methods for assessing the comprehensibility of graphical symbols.

The standard provides a measure of the extent to which a variant of a graphical symbol communicate its intended message. Its purpose is to ensure that graphical symbols and signs using graphical symbols are readily understood. The intention is to encourage the development of graphical symbols which are correctly understood by users when no supplementary (i.e. explanatory) text is presented [51].

The study
The aim of this study was to understand how well the animated icons - shown out of the context - were understood by people from different age-groups, gender and educational levels. As a result, a comprehension test has been conducted over the Internet and a total number of 30 persons participated. In addition, because of the main users of these animated icons are conscious ICU patients, we decided to invite former ICU patients and to compare their answers with those given by people that represent the general population.

Most of the participants were recruited through Facebook, in particular from Facabook's groups of former Intensive Care patients. Participants were invited to answer to questions in a Google form and to share their personal data.

Participants
80% of the participants (24) were female (age 45.08), while the remaining 20% (6) were male (age 38). In addition, 50% of the participants were former ICU patients (13 female / age 52.85 and 2 male / age 54), 47% general population (10 female / age 25.14 and 4 male / age 30) and the remaining 3% was an ICU nurse (1 female / age 43) who was included in the group of former patients. Finally, former ICU patients were older (48.2 years old) than the other respondents (34.4 years old).

Participants were divided into two groups: general population (N=14) and former ICU patients (N=16).

12 of the 15 former patients were in coma or induced coma for most of the time spent in the ICU and they were not conscious during the period of hospitalization.

The test
Seven animated icons were proposed to the participants and for each animated icon, two questions were asked (*Q1. What do you think this animated icon means? and Q2. What do you think will happen when you see this animated icon?*).
Firstly, participants were briefly introduced to the context where the animated icons were shown. In addition, information about the concept and the design goal were also given. In conclusion, participants were invited to evaluate the animated icons by writing down what they thought each icon meant and what could they expect that would happen when such icons were shown.

Data analysis
The five standard categories proposed by the ISO 9186-1:2014 were applied to analyse the data collected. The five standard categories are: *1=correct; 2a=wrong; 2b=wrong and the response given is the opposite of the intended meaning; 3=the response given is "don't know"; 4=no response is given* [51].

Responses in category 2a and 2b are both to be categorized as "wrong", but those which indicate an interpretation opposite to that intended are to be listed separately and their frequency recorded separately [51].

For each group, responses were analysed separately and later compared. The intended responses for each animated icon were prepared by the researcher and used to categorize the responses given by the participants. Each given response was assigned to one of the five standard categories and the results were tabulated in a matrix.

The matrix has three columns and one row for each category of response: 1 Correct, 2 Wrong, 3 Don't know, and 4 No response. For each animated icon, the number of responses given in each category was counted and entered in the column headed "f" (frequency). The frequencies were later converted to obtain percentage values by dividing them by the total number of responses given for each animated icon in category 1 to 3, and later multiplied by 100.

The percentages were entered in the column headed "%". Finally, the cumulative percentage values were entered in the column headed "cum%".

Question A : *What do you think this animated icon means?*

Animated Icons	1. correct		2a. wrong		2b. wrong/opposite		3. don t know	
	f	%	f	%	f	%	f	%
1	10	33%	19	64%	-	-	1	3%
2	20	67%	9	30%	-	-	1	3%
3	17	57%	11	37%	-	-	2	7%
4	24	80%	3	10%	-	-	3	10%
5	17	57%	12	40%	-	-	1	3%
6	21	70%	8	27%	-	-	1	3%
7	17	57%	12	40%	-	-	1	3%
Tot.	**126**	**60%**	**74**	**35%**	**-**	**-**	**10**	**5%**

Table 1. *General results from all the participants (N=30) - Question A. f (frequencies) - % (percentages).*

Results
According to the given responses, the animated icons were comprehensible for the 58% of the participants (correct answers = Question A : 60% - Question B : 55%). In general, participants provided clear evaluations for most of the icons shown, only one of the seven animated icons was difficult to interpret by all the respondents (Animated Icon 1).

In Table 1, it is possible to see that the animated icons 2, 3, 4, 5, 6 and 7 were well understood by all the participants, while only the animated icon 1 was not really clear. In addition, the table shows that a low percentage of respondents (5%) was not able to provide an explanation about some proposed icons; thus, it can be concluded that the message the animated icons intend to convey is comprehensible even without the provision of additional information. This result can be classified as satisfactory, considering the 58% as our index of comprehensibility.

In Table 2, it is possible to see that for most of the participants providing an explanation about what they could expect when they see the animated icon 1 was difficult; however, in general, respondents found easy to explain their expectations when an icon was shown. Interestingly, despite the 63% of respondents clearly provided an explanation about what to expect with the animated icon 4, 30%, instead, found difficult to give an explanation. In conclusion, we can say that the results from this question are satisfactory, with an index of comprehension equal to 55%. Thus, it seems that people can have a clear understanding of what they could expect after seeing such icons.

Question B : *What do you think will happen when you see this animated icon?*

Animated Icons	1. correct		2a. wrong		2b. wrong/opposite		3. don t know	
	f	%	f	%	f	%	f	%
1	9	30%	19	63%	-	-	2	7%
2	17	57%	12	40%	-	-	1	3%
3	18	60%	10	33%	-	-	2	7%
4	19	63%	2	7%	-	-	9	30%
5	22	73%	7	23%	-	-	1	3%
6	16	53%	13	43%	-	-	1	3%
7	15	50%	13	43%	-	-	2	7%
Tot.	116	55%	76	36%	-	-	18	9%

Table 2. *General results from all the participants (N=30) - Question B. f (frequencies) - % (percentages).*

Animated Icons

Animated icon 1

The intended meaning of the animated icon 1 (Fig.48) is: "The nurse is connected" (Question A), while the explanation expected about what could happen when people see this icon is: "A nurse is monitoring me" (Question B).

In Table 3 and Table 4, it is possible to see that for all the three groups of participants the animated icon was not comprehensible. The concept behind this icon is to communicate people/patients that a nurse is monitoring a patient continuously; instead, most of the respondents linked this icon to the concept of calling a nurse. Participants were thinking that such an icon is shown after a patient uses the alarm-bell to call a nurse; thus, they were expecting that, after calling, a nurse will approach the patient's room. As a result, the icon seems to symbolise the accepted help-request from a nurse. However, despite of this unexpected result, the concept of calling a nurse might be categorized on the section of correct answers because the idea of calling gives the feeling of being connected with a professional who, after receiving a request, will reach the patient.

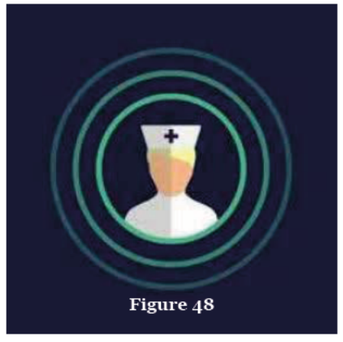


Figure 48

Animated icon 2

The intended meaning of the animated icon 2 (Fig.49) is: "Alarm detected" (Question A), while the explanation expected about what could happen when people see this icon is: "A nurse will come to handle the alarm" (Question B).

Table 3. *Question A: What do you think this animated icon means?*

Participants	N	Correct	Wrong	Don't know
Former pat.	16	38%	55%	7%
General pop.	14	29%	71%	-
Total	30			

Table 4. *Question B: What do you think will happen when you see this animated icon?*

Participants	N	Correct	Wrong	Don't know
Former pat.	16	19%	67%	14%
General pop.	14	50%	50%	-
Total	30			

In Table 5 and Table 6, it is possible to see that the animated icon was comprehensible for most of the participants; however, former ICU patients were those that encountered more problems in providing the correct answer.
The concept behind this icon is to communicate people/patients that a medical alarm has been detected by the system. Respondents provided, in most of the cases, a good interpretation of the meaning and expectancy. Especially within former patients, the icon was more related to the call bell; thus, they were expecting that such an icon is shown when a patient press the button for the call bell. However, what participants were expecting could happen after seeing this icon was the arrival of a nurse who will handle the alarm and/or check what the patient needs.

Figure 49

Table 5.

Participants	N	Correct	Wrong	Don't know
Former pat.	16	44%	49%	7%
General pop.	14	93%	7%	-
Total	30			

Table 6.

Participants	N	Correct	Wrong	Don't know
Former pat.	16	50%	44%	6%
General pop.	14	64%	36%	-
Total	30			

Animated icon 3

The intended meaning of the animated icon 3 (Fig.50) is: "The nurse is notified" (Question A), while the explanation expected about what could happen when people see this icon is: "A nurse will soon come to handle the alarm" (Question B).

In Table 7 and Table 8, it is possible to see that for most of the respondents in the three groups the animated icon was comprehensible.

Figure 50

Table 7.

Participants	N	Correct	Wrong	Don't know
Former pat.	16	63%	24%	13%
General pop.	14	50%	50%	-
Total	30			

Table 8.

Participants	N	Correct	Wrong	Don't know
Former pat.	16	50%	37%	13%
General pop.	14	71%	29%	-
Total	30			

Th e concept behind this icon is to communicate people/patients that a nurse has been notified and has accepted to handle the medical alarm. As a result, patients should expect that there is a nurse who already is taking care of them (by a distance).
Despite the general positive results, some of the participants interpreted wrongly the check-mark on the animated bell. The check mark was described as a sign that indicates that everything is ok (despite an alarm is going off) and the alarm has been already handled/switched off. However, in the real situation, this animated icon will be shown while an alarm will go off and before a nurse will handle it.
In conclusion, it seems that the check mark is an ambiguous sign that could lead some people/patients to a wrong interpretation and conclusion.

Animated icon 4

The intended meaning of the animated icon 4 (Fig.51) is: "The nurse is checking" (Question A), while the explanation expected about what could happen when people see this icon is: "A nurse is looking for the cause of the alarm" (Question B).

In Table 9 and Table 10, it is possible to see that for all the three groups of participants the ani-

mated icon was comprehensible. The concept behind this icon is to communicate people/patients that a nurse is checking for the cause of the alarm. In general, the interpretation of this animated icon was good and participants were able to understand what to expect by seeing such an animation. However, a considerable percentage of respondents were not able to provide an answer, especially when question B was asked.
In conclusion, it seems that the lens moving on the bell can be difficult to interpret for some people, and it might lead to confusion and uncertainty rather than clarify the situation and provide comfort.

Animated icon 5
The intended meaning of the animated icon 5 (Fig.52) is: "The nurse is on the way" (Question A), while the explanation expected about what could happen when people see this icon is: "A nurse is arriving " (Question B).

In Table 11 and Table 12, it is possible to see that while the general population and the ICU nurse correctly interpreted the animated icon, the former patients had a wrong interpretation of it.
The animation with a nurse who runs has been described, especially by former ICU patients, as an emergency situation. The concept behind this icon was to communicate patients that someone is coming to help them, but it was not our intention communicate a state of emergency. The hurry nurse was preferred over a walking nurse because we hypothesised that seeing someone running could have made patients feel safer. Indeed, the idea of a running person might give the impression that a nurse will reach a patient very soon.


Figure 51

Table 9.

Participants	N	Correct	Wrong	Don't know
Former pat.	*16*	*81%*	*12%*	*7%*
General pop.	*14*	*71%*	*15%*	*14%*
Total	**30**			

Table 10.

Participants	N	Correct	Wrong	Don't know
Former pat.	*16*	*63%*	*4%*	*33%*
General pop.	*14*	*64%*	*7%*	*29%*
Total	**30**			


Figure 52

Table 11.

Participants	N	Correct	Wrong	Don't know
Former pat.	*16*	*31%*	*62%*	*7%*
General pop.	*14*	*86%*	*14%*	-
Total	**30**			

Table 12.

Participants	N	Correct	Wrong	Don't know
Former pat.	*16*	*50%*	*43%*	*7%*
General pop.	*14*	*100%*	-	-
Total	**30**			

In conclusion, it seems that the icon requires some adjustments to facilitate people comprehension and to lead them to a correct interpretation. It is important to consider the fact that seeing a person who runs can make others feel in danger. As a result, patients should became more stressed, instead of calm down.
Finally, the way how this animated nurse is moving need to be adjusted from running to walking.

Animated icon 6
The intended meaning of the animated icon 6 (Fig.53) is: "The sensor is detached/Reattach the sensor" (Question A), while the explanation expected about what could happen when people see this icon is: "The patient needs to reattach the sensor " (Question B).

In Table 13 and Table 14, it is possible to see that for all the three groups of participants the animated icon was comprehensible, except for the former ICU patients who in the question B provided a not correct answer.
The concept behind this icon is to communicate people/patients that the SPO2 sensor is detached from the patient's finger, and it, also, invites the patient to reattach it.
Some former patients interpreted this animated icon as a message that inform and invite people to measure their oxygen level or vital signs, or as an emergency. However, for most of the others participants the message conveyed and the invite of reattach the sensor was clear; only in some cases, some respondents were not sure whether the invitation of reattaching the sensor was intended for the patient or the nurse.
In conclusion, it seems that the animated icon must be presented with additional information that clarify what is happening and who have to perform the action suggested.

Animated icon 7
The intended meaning of the animated icon 7 (Fig.54) is: "Alarm off" (Question A), while the explanation expected about what could happen when people see this icon is: "Everything will be quiet" (Question B).

In Table 15 and Table 16, it is possible to see that for all the three groups of participants the animated icon was comprehensible, except for the general population who interpreted the cross (X) over the bell in different ways, such as the alarm do not need to be checked, a non urgent situation or malfunctioning.
The concept behind this icon is to communicate people that an alarm has been switched off. However, as in the case of the check mark (animated icon 2), the cross can be misinterpreted.
In conclusion, it seems that the Cross (X) is ambiguous and it can lead patients to misinterpret the message that wants to be conveyed. It is important to notice that, in this case, was more difficult for the general population to correctly interpret such a message, while it was easier for the former patients.


Figure 53

Table 13.

Participants	N	Correct	Wrong	Don't know
Former pat.	*16*	*56%*	*37%*	*7%*
General pop.	*14*	*86%*	*14%*	-
Total	**30**			

Table 14.

Participants	N	Correct	Wrong	Don't know
Former pat.	*16*	*50%*	*43%*	*7%*
General pop.	*14*	*64%*	*36%*	-
Total	**30**			


Figure 54

Table 15.

Participants	N	Correct	Wrong	Don't know
Former pat.	*16*	*56%*	*37%*	*7%*
General pop.	*14*	*57%*	*43%*	-
Total	**30**			

Table 16.

Participants	N	Correct	Wrong	Don't know
Former pat.	*16*	*56%*	*33%*	*7%*
General pop.	*14*	*36%*	*57%*	*7%*
Total	**30**			

Conclusions

In general, the results from the comprehension test were satisfactory; in fact, 58% of all the participants were able to provide a correct interpretation of the animated icons. In addition, former ICU patients are those that had lower performance (correct answers: A: 52% / B: 48%) compared to the other respondents (correct answers: A: 67% / B: 64%). As a result, we can conclude that for former ICU patients the index of comprehension is equal

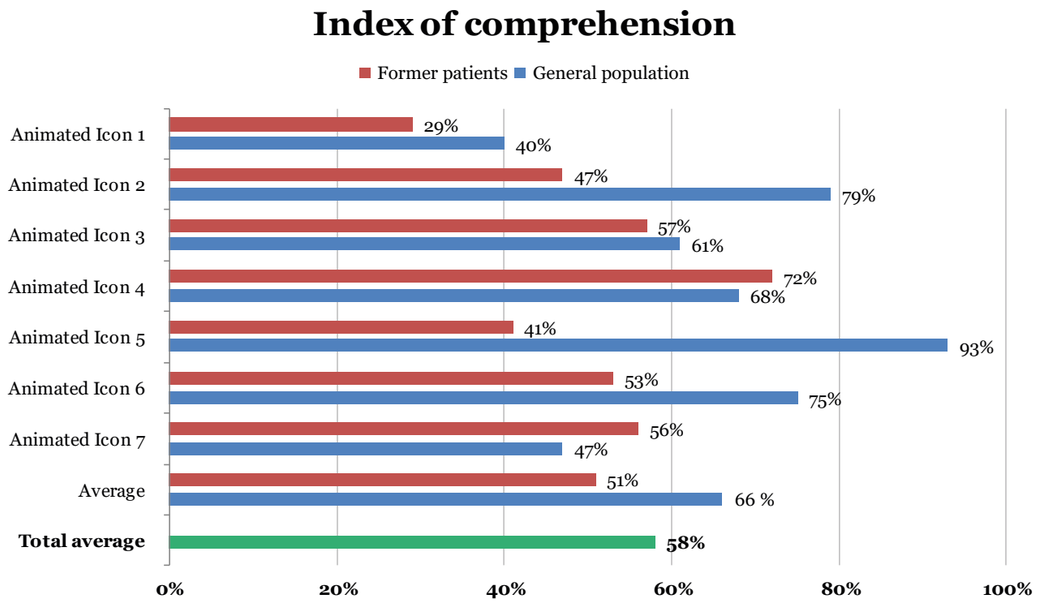


Figure 55. *Index of comprehensibility for each animated icon with respect to the two groups, and total average.*

to 50%, while for the general population the index is equal to 66%.

According to this result, we can conclude that the animated icon 1 (Fig.48) was the less understandable for both the groups; while the animated icons 3, 4, 6 and 7 (Fig. 50, 51, 53 and 54) were equally understood by both the respondents of each group; however, the animated icons 2 and 5 (Fig. 49 and 52) were more easy to comprehend for the group of the general population, than for the group of former ICU patients.

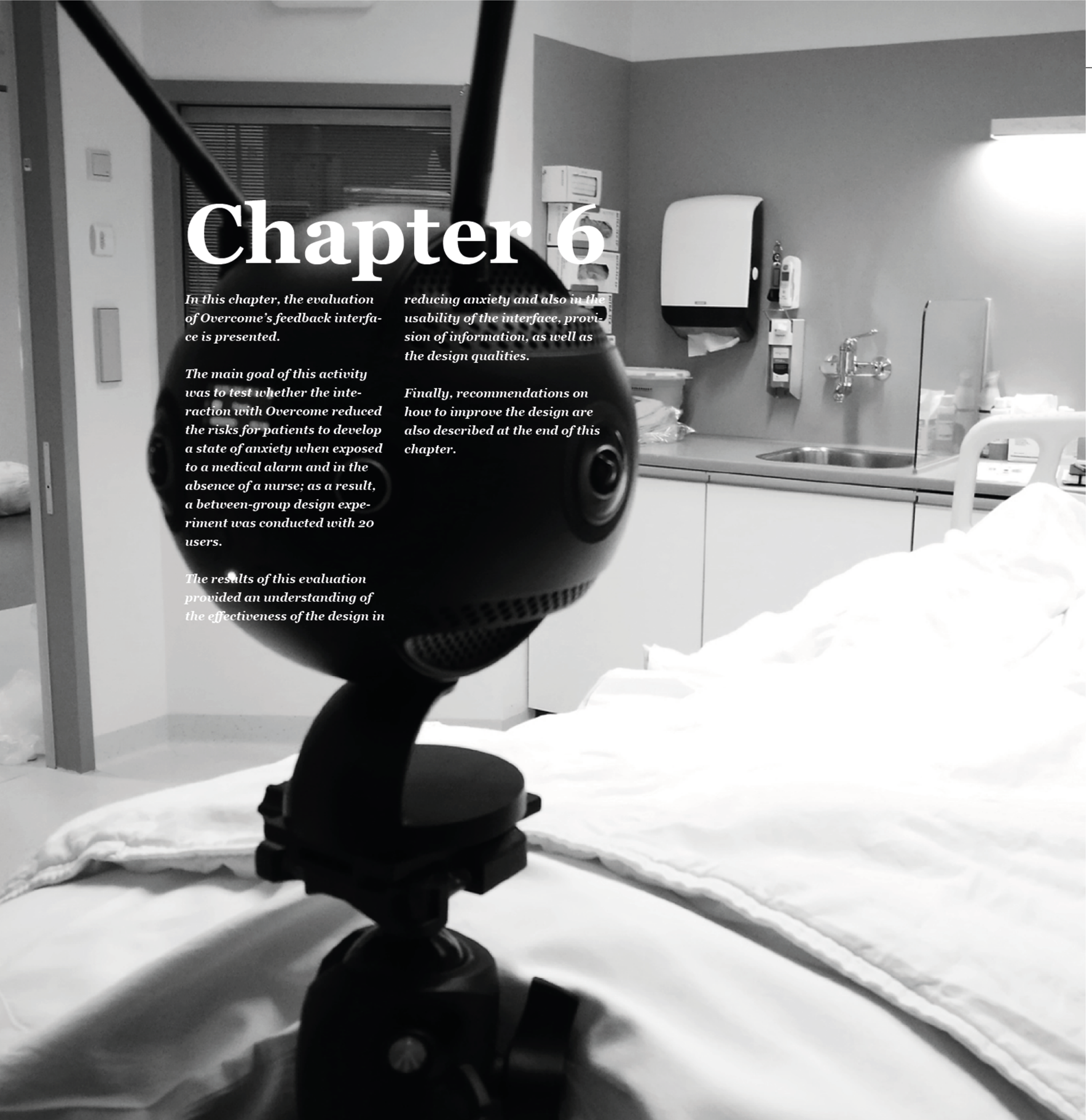
In light of this conclusions, it seems necessary to improve the design of the animated icons making them more clear and less confusing.

Firstly, it is important to reduce the ambiguity that some element could create during interpretation. To help overcome the ambiguity of some icons, a text label must be present alongside an icon to clarify its meaning in that particular context. Implementing labels that provide users with an explanation of the message that the animated icons want to convey, is considered a good solution that might reduce misinterpretation and ambiguity. By showing a label, the percentage of people that can understand the meaning of each animated icon might dramatically increase.

In addition, some animated icons, such as the Animated Icon 5, need to be modified to change in people the perception of being in a state of emergency. Indeed, it is important that these animated icons help patients to reduce not only uncertainty, but also to reduce the risks of developing a state of anxiety; thus, the way how the message must be conveyed need to be as more reassuring as possible inviting patients to calm down and relax while waiting for the arrival of a nurse.
Finally, I believe that such animated icons need to be introduced by the medical staff to patients, as well as to family members and friends of the patients, before interacting with them. Previous explanations about the meanings of the animated icons and how and when they will be shown to the patients are necessary to increase comprehensibility within users.

Limitations

The animated icons were shown out of their context and without providing all the information that has been, instead, included in the final prototype. De-contextualization and lack of information might have influenced the ability of these participants to clearly understand such animated icons. Therefore, presenting this information in the real context to real patients who are in a state of consciousness, might give different and more satisfactory results and if presented with the remaining information.



Chapter 6

In this chapter, the evaluation of Overcome's feedback interface is presented.

The main goal of this activity was to test whether the interaction with Overcome reduced the risks for patients to develop a state of anxiety when exposed to a medical alarm and in the absence of a nurse; as a result, a between-group design experiment was conducted with 20 users.

The results of this evaluation provided an understanding of the effectiveness of the design in reducing anxiety and also in the usability of the interface, provision of information, as well as the design qualities.

Finally, recommendations on how to improve the design are also described at the end of this chapter.

evaluating the design

6.1 | Virtual reality

Testing a design with real patients in the hospital is not possible without the permissions of the Medical Ethical Committee. As a result, it was necessary to found an alternative that could have given me the possibility to evaluate my design in a similar environment as the ICUs.

I decided to opt for Virtual reality (VR) to create a digital environment where all the factors, to which patients in an ICU room are usually exposed to, can be simulated.

At the *Delft University of Technology* there is the *VR Zone Lab* where students, as well as employees of the University, can access and develop their own VR or AR (augmented reality) project with the technical support of experts. After introducing my project to the members of the VR Zone Lab, a decision about the method to use to create a digital version of an ICU room was taken. A week later the meeting, I went with two experts from the VR Zone Lab at the department of Adult Intensive Care of the EMC to film a video using a 360-Degree Spherical Virtual Reality Camera.

The video was shoot inside an empty room with just a bed and some medical devices inside; in addition, a nurse was recruited to take part in the video as an actress. With the use of a storyboard, I explained the outline of the video and what needed to happen in the video (from start to finish) in order to provide participants, who later tested my design, with the experience of the ICU from the eyes of a real patient.

Two weeks were needed to edit the VR video. By using Adobe Premiere, the prototype (a video reproducing the Overcome's feedback Interface) was digitally implemented on the VR video and placed where it would be in reality, or on the TV screen of the patient's room.

6.2 | VR videos

For the test a total of four videos were created, an *Introductory video* (Fig. 57), a video showing the *current situation* (Fig. 59), and two videos showing the *envisioned situation* (Fig. 58).
The main difference between the last two videos is on the types of information Overcome's feedback interface shows.
The division into two videos in which the information provided by the interface are different, it was made by taking into consideration that the levels of information need to be studied separately to better understand which of these levels mostly contribute to reducing anxiety.

It was decided to have participants test the interface that provided information on the levels of *acknowledging* and *informing*, including the levels of *comforting* and *distracting*.

Introductory video
The goal of showing this video was duplex (1) to help participants to familiarize with the ICU environment and its soundscape, and (2) to create empathy with ICU patients.
For about two minutes, participants had the opportunity to look around while listening to a *background voice* which was explaining them the reasons "why they were admitted in the ICU" and "their medical conditions". This video served as a means of emotionally preparing participants for the experience. Through this video, I tried to evoke emotions such as worry, fear and anxiety, which are generally experienced by patients admitted to ICU.

Video 1: Current situation
The goal of this video was to make the participants from the control group experience the ICU as currently is. In this video, there was no prototype implemented, but participants were just exposed to a medical alarm while waiting for a nurse.

Video 2: Envisioned situation
The goal of this video was to make participants experience the ICU as envisioned. During this experience, participants from the experimental group were also exposed to a medical alarm while waiting for a nurse. The only difference with the previous video was that, through Overcome, they were provided with feedback while the alarm was going off.

Videos 1 and Video 2 have the same structure and content: a continuous *background sound* produced by different medical devices, the *patient alone and paralyzed on the bed*, a *medical alarm* that goes off after 30 seconds and which ends after 2 minutes, and after the arrival of a nurse who opens the door and enters the room, the *interaction with the nurse* who reassures the patient and deactivates the alarm, and finally, the nurse who leaves the room leaving the patient alone.
The only difference between these videos is in the implementation of *Overcome* (test variable). Only articipants belonging to Group B (experimental group) were therefore provided with medical alarms feedback while waiting for the arrival of a nurse.

Each video (1 and 2) last about 3 minutes and 30 seconds (Fig. 56) and they are structured as follow:

Phase 1 | Waking up | 30 sec.
In this phase, the patient/participant is alone inside the room and sourranded by background sounds.

Phase 2 | Waiting time | 2 min.
Step 1. Questioning | 40 sec.
In this step, the patient is surprised by a sudden and loud medical alarm thus moving from a state of quiet to a state of stress. Also, the background sounds are still active and the patient is alone.

Step 2. Searching | 40 sec.
In this step, the patient is still alaon and he isexpected to look around the room and searching for information that could help him to understand the reason for the alarm and to interpret it. A Bedside monitor showing the vitals signs, is placed next to the bed.

Step 3. Submitting phase | 40 sec.
In this step, the patient is alone and he is expected to submit to the alarm. It is possible to see what is happening outside the room through the door; indeed, the patient is expected to look at the door waiting for the arrival of a nurse.

Phase 3 | Interacting | 30 sec.
Step 1. Approaching | 10 sec.
In this step, a nurse enters the room. The alarm is still active.

Step 2. Comforting phase | 10 sec
In this step, the nurse talks and comforts the patient while deactivating the medical alarm.

Step 3. Understanding phase | 10 sec
In this step, the nurse helps the patient to understand the reason for the alarm while putting the detached sensor back.

Phase 4 | Separating | 30 sec.
The alarm is off and the nurse leaves the room leaving the patient again alone. Once alone, the patient is surrounded still by the background sounds.

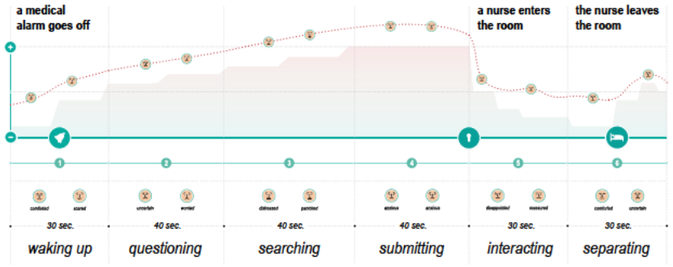


Figure 56. *Structure of Video 1 and 2.*

Figure 57. *Introductory video.*

Figure 58. *Video 2: Envisioned situation.*

Figure 59. *Video 1: Current situation.*

6.3 | Methods

A *Between-group design experiment* was performed in a three-day study period to compare the physiological reactions and subjective evaluations of anxiety in relation to the proposed experience between the experimental group (Group B) - who interacted with Overcome (variable tested), and the control group (Group A). Therefore, only participants from the experimental group were asked to evaluate Overcome's feedback interface on usability, provision of information and design qualities.

Research questions

Research questions were mainly focused on the *Waiting phase*. Three main questions were formulated and asked to both groups:

Stress and anxiety

To what extent participants feel anxious with/without the feedback provision?

To what extent the perceived sense of safety in participants changes with/without the feedback provision?

To measure stress levels and the perceived state of anxiety data from a Hear rate valiability (HRv) device, Slider device and State Anxiety Scale questionnaire [50] were collected.

Experience

How do the participants experience the waiting time in relation to the medical alarm in terms of:

- *being Acknowledged during the medical alarm;*
- *being Informed about the medical alarm;*
- *being Distracted from the medical alarm;*
- *being Comforted during the medical alarm.*

Furthermore, additional questions were formulated and asked only to participants of Group B:

What do participants think about the use of Overcome's feedback interface in terms of usability, design qualities and presentation of information?

Usability

The *System Usability Scale* (SUS) was used as a tool for measuring usability, and participants were asked to grade from 1 (Strongly disagree) to 5 (Strongly agree) 10 items.

Design qualities

To what extent Overcome is:

- Unreliable/Reliable;
- Unfriendly/Friendly;
- Deceitful/Honest;
- Uninvolving/Engaging;
- Worrying/Reassuring;

Table 17. *Participants.*

Participants	Group A	Group B
Age	26.1	28.2
Male	7	6
Female	3	4
Total	**10**	**10**

- Overwhelming/Simple;
- Uninformative/Explanatory;
- Late/Timely.

Presentation of Information

To what extent the presented information are:

- Easy to detect;
- Free from distractions;
- Easy to discriminate;
- Easy to interpret;
- Concise;
- Consistent.

Participants

Three weeks before starting with the test, a recruitment flyer was physically and digitally posted, respectively, at TU Delft and on Facebook.
In total, 20 people (19 students and 1 nurse | average age 27.2 years) were recruited, and 65% of them were male and 35% female (Table 17).
Finally, for the test participants were divided into two groups:
- *Group A | Control group* (7 male and 3 female | average age 26.1);
- *Group B | Experimental group* (6 male and 4 female | average age 28.2).

Procedure

After being recruited, participants were informed about the study goal, while more detailed information was provided the day of the test.

The study was conducted at the *Faculty of Industrial Design Engineering - Tu Delft*, in a silent room to make sure the participants were concentrated and not disturbed during the test. The duration of the test was about 50 minutes for each participant.

The room was divided into two areas:
- *Area A | Welcome and interview area;*
- *Area B | Testing area.*

In *area A*, participants were introduced to the problem and invited to sign the *Informed consent*. Before moving to area B, they were asked to answer to the *State Anxiety Scale questionnaire* (STAI).
In *area B*, participants were asked to participate in the test as they were ICU patients. To help them further immerse in the experience, a bedside monitor, pictures of the ICU, a hospital cabinet and a hospital bed were placed around to recreate a hospital room.

Before starting with the test, participants worn the *HRv chest strap* (Fig. 63/b) and sat on the

Figure 60. *Area A. Welcome and interview area.*

Figure 61. *Area B. Testing area.*

Figure 61. *Area B. Testing area.*

hospital bed. In addition, after the *Slider device* (Fig. 63/a) was placed on the bed next to them, the *VR glasses were worn* (Fig. 62). While calibrating and connecting the HRv chest strap and the Slider device with their respective softwares, the Introductory video was them shown. At the end of this video, participants from Group A were shown the video 1, while participants from group B were shown the video 2.

At the end of the video, and after removing the VR glasses and before leaving the bed, participants were asked to answer to the *State Anxiety Scale questionnaire* (STAI) for a second time.

Lastly, after the HRv chest strap was removed, a *semi-structured interview* was performed in Area A.

Figure 62. *VR set.*

Figure 63. *(a) Slider device, (b) HRv chest strap.*

Measurements

To test the impact of Overcome in the reduction of anxiety, physiological and subjective evaluations were performed to assess levels of stress and anxiety. In general, the test was recorded by means of audio and video.

To measure stress levels, *Heart rate variability (HRv)* was measured by using a chest strap that participants wore during the test and which was connected via Bluetooth to an application (Elite HRV) that recorded the HRv values. The chest strap was placed in contact with the skin and in the centre of the chest after the sensors had been moistened with water.

To measure anxiety, a *Slider Device* with values from 1 (Not anxious at all) to 10 (Really anxious) was given to participants to interact with during the experience in order to grade the perceived level of anxiety; to help participants with scoring, three elements in relief with respect to the surface of the slider were added at the beginning, middle and end of the slider to help participants orientate through the sense of touch.

Furthermore, participants were asked to answer to the *State Anxiety Scale questionnaire* (STAI) questionnaire in order to assess their state of anxiety before and after the experience in VR. In both cases, they were asked to answer the questionnaire considering *how they felt in the specific moment the questionnaire was given* [50]. As a result, I was able to compare their state of anxiety before and after the experience thus having an understanding about whether it has increased or not after being exposed to the experience in VR.

Data on experience, usability, design qualities and provision of information were collected by using a *Google form* that participants filled out while thinking aloud during the semi-structured interviews. Before answering to these questionnaires, participants from Group B were shown the Overcome's feedback interface through a TV screen placed on Area A. As a result, participants were able to give more detailed information about how the use was experienced.

Analysis

In general, data from each participant were individually analysed and later, according to the type of data, collected in *Excel documents* to compare the responses of Group A with those from participants of Group B.

To determine if there was a *significant statistical difference* between the two groups, a *t-test* was performed, especially for data related to HRv, Slider device , STAI questionnaire, and experience.

Heart Rate variability (HRv)

HRV provides a measure to express the activity of the Autonomic Nervous System (ANS), which is part of the Central Nervous System (CNS). ANS consists of the sympathetic division, which is responsible for the *fight or flight responses* of our body during an activity, and the parasympathetic division, which is responsible for saving energy and promoting rest [43].

In general, the sympathetic division leads to an increase in heart rate (HR), while the parasympathetic division induces a lower HR. These two divisions are constantly interacting, and this interaction is reflected in HRV which, then, can be used to measure stress [58]. In general (Fig. 64), HRV looks at the correct differences in time between consecutive heartbeats (also called inter-beat intervals, RR intervals, NN intervals, etc).

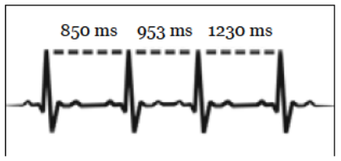


Figure 64. *HRv. RR Intervals.*

Analysis of RR intervals

Data collected from the HRv chest strap were transferred via Bluetooth into the *Elite HRV application*. From the app, data were downloaded as a *text document* in which a list of *RR-intervals* (e.g. 674 - 701 - 701 - 678 - 642 - etc.) was provided. The data were transferred and analysed by using the free version of the software *Kubios HRV Standard 3.3.1*. For each participant, information about the date of birth, gender, height (cm) and weight (kg) were entered into the software and the MAX HR (bpm) automatically calculated. These data were used by the software in HR zones and energy expenditure computation [54].

On average, for each participant, the HRV recordings lasted about 7 minutes, but only the range of time from minute 02:26 to 05:56 (which is the time range corresponding to the measurements taken when Video 1 or 2 were shown) was considered for analysis.The first 02:26 minutes were related to the Introductory video.

The *03:30 minutes* (Fig. 65) considered were divided into four parts corresponding to the *Waking up, Waiting, Interacting and Separating phases*. In addition, the Waiting phase was subdivided into 3 subparts: *Questioning, Searching and Submitting*. This division gave me the opportunity to study how participants' stress varied from the beginning to the end in each part of the experience, especially in relation to the feedback provision in Group B, thus evaluating which information affected the most on stress levels. For each part, the *Stress Index (SI)* was calculated by the software. Kubios calculates SI by doing the square root of the *Baevsky's stress index* [54] values resulting in a value that can range from < 7.1 (low-stress level) to >= 30 (very high-stress level).

The SI values calculated were later entered in one Excel docu-

ment with respect to the number of the participant and the group to which he/she belonged. Finally, a *T-test* was performed to determine whether or not there was a significant statistical difference between Group A and Group B with stress levels.

(Anxiety) Slider device
The Slider device and the dedicated software were borrowed at the Delft University of Technology. The device and the software were initially developed to study how people perceive sounds on a scale from 1 (pleasant) to 10 (unpleasant). The software collects the data generated by the slider in a timestamp sequence (e.g. 00:01:18.03,1 - 00:01:18.13,2 - 00:01:18.23,8 - etc.), in which the last number after comma represents the value given by the participant.

After data collection, timestamp sequences were downloaded from the Slider device's software in the form of a text document, and the given values transferred to Excel. In Excel, and for each participant, only values from minute 02:26 to 05:56 were considered for analysis. In addition, I divided this data into four parts corresponding to the *Waking up, Waiting, Interacting and Separating phases*. In addition, the Waiting phase was subdivided into 3 subparts:

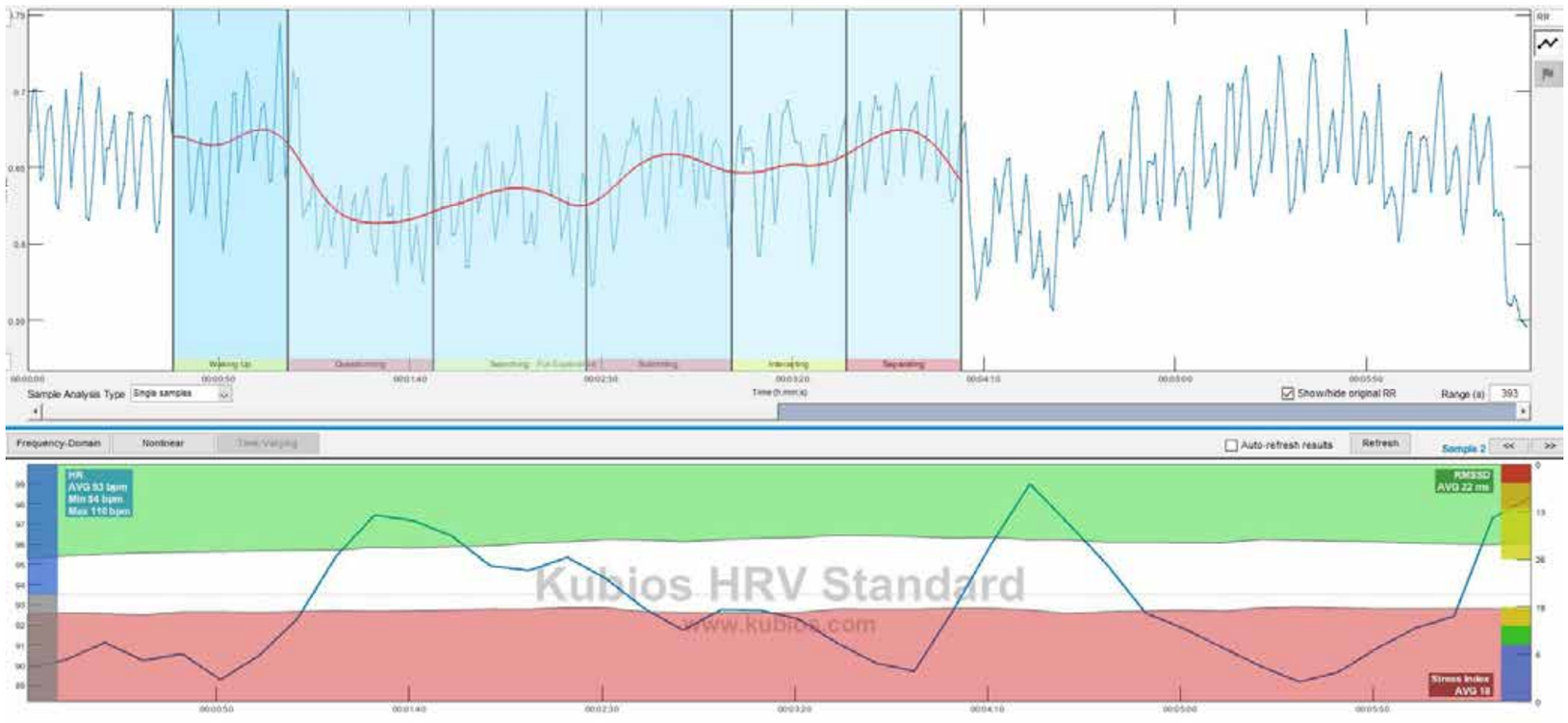


Figure 65. *Kubios HRV Standard 3.3.1. The figure shows how the RR intervals are visualized on Kubios. In light-blue, the intervals analysed (03:30 min.) which are related to the six phases of the experience.*

Questioning, Searching and Submitting.

For each step, the average of values within ranges of 5 seconds was calculated. These values were later entered in one Excel document with respect to the number of the participant and the group to which he/she belonged. Finally, a *T-test* was performed to determine whether or not there was a significant statistical difference between Group A and Group B with perceived anxiety.

State Anxiety Scale questionnaire
The State-Trait Anxiety Inventory (STAI) is a questionnaire used to measure via self-report the presence and severity of current symptoms of anxiety and a generalized propensity to be anxious [50]. It consists of two subscales: the *Trait Anxiety Scale* (T-Anxiety - 20 items) and the *State Anxiety Scale* (S-Anxiety - 20 items).

For this study, only the *State Anxiety Scale* was taken into consideration, which evaluates the current state of anxiety, asking how a person feels "right now," using items that measure subjective feelings of apprehension, tension, nervousness, worry, and activation/arousal of the autonomic nervous system [55].

In the 20 S-Anxiety items scores can be given from 1 (not at all) to 4 (very much so). However, 4 indicates the presence of a high level of anxiety only for ten items (e.g. "I feel frightened" or "I feel upset), while a high rating indicates the absence of anxiety for the remaining ten items (e.g. "I feel calm" or "I feel relaxed") [55].

The obtained scores were later entered in one Excel document with respect to the number of the participant, the group to which he/she belonged and the order of completion. Finally, a *T-test* was performed to determine whether or not there was a significant statistical difference between Group A and Group B before and after the experience regarding the state of anxiety.

Experience
To calculate the experience of participants, they were asked to give a score from 1 (no at all) to 7 (very much so) to 6 different items. 4 of these items were related just to the *Waiting phase*, when the participant was exposed to the medical alarm and waiting for the arrival of a nurse. As a result, it was asked:

- to what extent did you feel acknowledged when the alarm was going off?
- to what extent did you feel informed about the alarm?
- to what extent did you feel distracted from the medical alarm?
- to what extent did you feel comforted while the alarm was going off?

The remaining 2 items were related to the perceived sense of safety

and to the overall experience. To calculate the perceived sense of safety, participants were asked to score from 1 (not at all) to 7 (very much so) the extent to which they perceived themselves safe while the alarm was going off. To calculate the overall experience a question was asked in which participants had to score from 1 (bad) to 7 (good) the overall experience.

The scores were later entered in one Excel document with respect to the number of the participant and the group to which he/she belonged, and a *T-test* was performed to determine whether or not there was a significant statistical difference between Group A and Group B in relation to how they experience the waiting time.

System Usability Scale (SUS)
The SUS is a tool for measuring usability. It consists of a 10 item questionnaire with five response options for respondents, from 1 (Strongly disagree) to 5 (Strongly agree).

A SUS produces a single number representing a composite measure of the overall usability of Overcome. Scores for individual items on the scale are not meaningful on their own.

The SUS questionnaire was proposed only to participants from Group B. Data collected were later entered in an Excel document with respect to the number of the participants, and a standard deviation calculated. Finally, results were used to draw conclusions on the usability of Overcome and to define possible improvements.

Design qualities
Evaluations from Group B on the design qualities were used to determine the quality of the experience in terms of quality of interaction with Overcome.

Qualities were presented in couples (negative/positive adjective) and participants were asked to score the most representative value that could have described the experience of use by placing their answer next to the most representative adjective.

Data collected were later entered in an Excel document with respect to the number of the participants, and a standard deviation calculated. Finally, results were used to draw conclusions on the quality of the interaction between the interface and the user and to define possible improvements.

Provision of information
Evaluations from Group B on the presentation of information were used to evaluate the layout of Overcome.

Participants were asked to score from 1 (strongly agree) to 7 (strongly disagree) the extent to which:

- *All the Information on the Overcome's feedback interface was easy to detect;*
- *All the Information on the Overcome's feedback interface was free from distractions;*
- *All the Information on the Overcome's feedback interface was easy to discriminate/distinguish;*
- *All the Information on the Overcome's feedback interface was easy to interpret;*
- *All the Information on the Overcome's feedback interface was concise;*
- *All the Information on the Overcome's feedback interface was consistent.*

Data collected were later entered in an Excel document with respect to the number of the participants, and a standard deviation calculated. Finally, the results were used to draw conclusions on the layout of the interface and its content and to define possible improvements.

6.4 | Results

From fieldwork research, resulted that high-stress levels and a low perceived sense of safety elicit anxiety. Therefore, stress and perceived sense of safety are closely related, as the stress levels increase as the perceived sense of safety decreases. As a result, a hypothesis was generated: t*he higher is the perceived sense of safety, the lower will be the risk to develop a state of anxiety.*

For the evaluation of the design, two hypotheses were formulated: (1) *levels of stress and anxiety are lower in participants from Group B who are provided with feedback than participants from Group A;* (2) *the perceived sense of safety is higher in participants from Group B who are provided with feedback than participants from Group A.*

Proving these hypotheses could have given me the possibility to show that the provision of feedback that acknowledges, informs, comforts and distracts patients who are alone when exposed to a medical alarm, have a beneficial effect on their psychological well-being.

As a result, values concerning stress levels and the perceived sense of safety, as well as the subjective evaluation of anxiety, from participants of Group B, were compared with those from participants of Group A to determine whether there was a statistical difference between these groups.

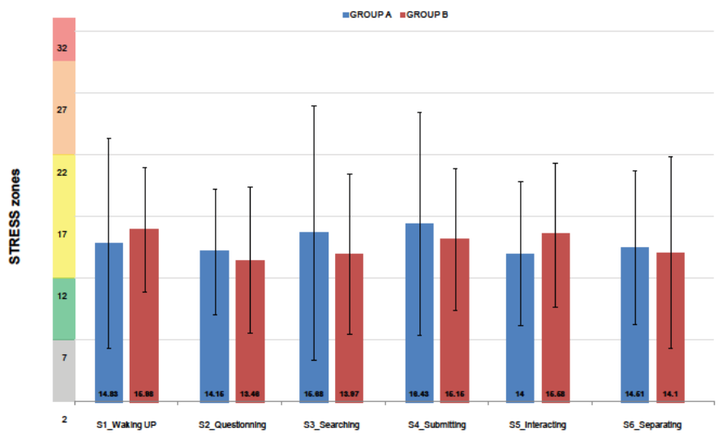


Figure 66. *HRv: Stress index. The values are related to the full experience.*

	Full Experience			Waiting		
	Avg	StDv	p - value	Avg	StDv	p - value
Group A	11 84	5.519	0.748	13.01	6 371	0.842
Group B	11.1	4.563		12.47	5 510	

HRv and SI - (N = 20)
A *t-test* was conducted to determine the effect of medical alarms feedback provision on stress levels.

In general (Fig. 66), between Group B that was provided with feedback (M = 11.10; SD = +/- 4.56) and Group A with no feedback (M = 11.84; SD = +/- 5.51) there was not a significant difference (p= 0.75).
However, main attention was put on the *Waiting phase* (Questioning, Searching and Submitting) and, for each step, a t-test was conducted.

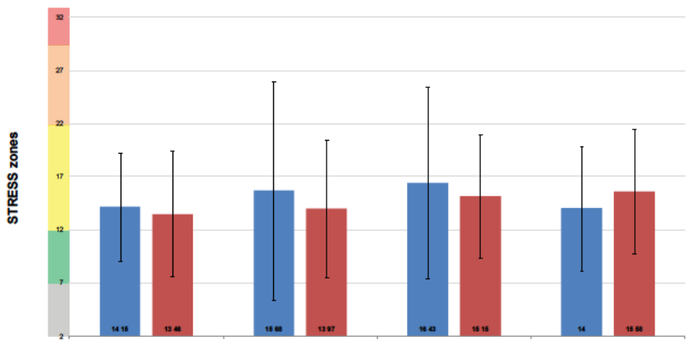
In general, during the *Waiting phase* (Fig.67), between Group B (M = 12.47; SD = +/- 5.51) and Group A (M = 13.01; SD = +/- 6.37) there was not a significant difference (p= 0.84).
As a result, no statistical evidence exists that medical alarms feedback provision has an effect on reducing stress levels.

From a non-statistical point of view (Fig.68) , it is possible to observe that despite both groups were exposed to the same situation, it is interesting to notice in Figure X that there are two different trends between the Control group (A) and the Experimental Group (B). In addition, it seems that the trend of Control group is similar to the conjectured trend from Context mapping during fieldwork research, thus confirming our initial hypothesis.

Figure X shows that, although Group B was more stressed than Group A at the beginning, since the *Waiting phase* to the *Separating phase*, their stress levels never exceed the level of the *Waking Up phase*; on the contrary, Group A exceeded the stress level registered in the *Waking up phase* twice in the *Waiting phase*.

In the *Interacting phase*, instead, stress levels of Group B are higher than the Control group; apparently, the progress indicator on the interface (which shows the time left before the arrival of a nurse), added more stress, especially in the last section when the nurse is almost opening the door.

In general, despite both groups experienced elevated stress, Group B had less elevated stress levels also at the end of the experience (Separating phase) where the use of Overcome seems to relieve participants despite the nurse had left the room.



	S2_Questionning			S3_Searching			S4_Submitting			S5_Interacting		
	Avg	StDv	p value	Avg	StDv	p value	Avg	StDv	p value	Avg	StDv	p value
Group A	14.15	5.068	0.782	15.68	10.312	0.662	16.43	9.010	0.710	14	5.868	0.553
Group B	13.46	5.905		13.97	6.488		15.15	5.776		15.58	5.817	

Figure 67. *HRv: Stress index. The values are related to the Waiting and Interacting phases.*

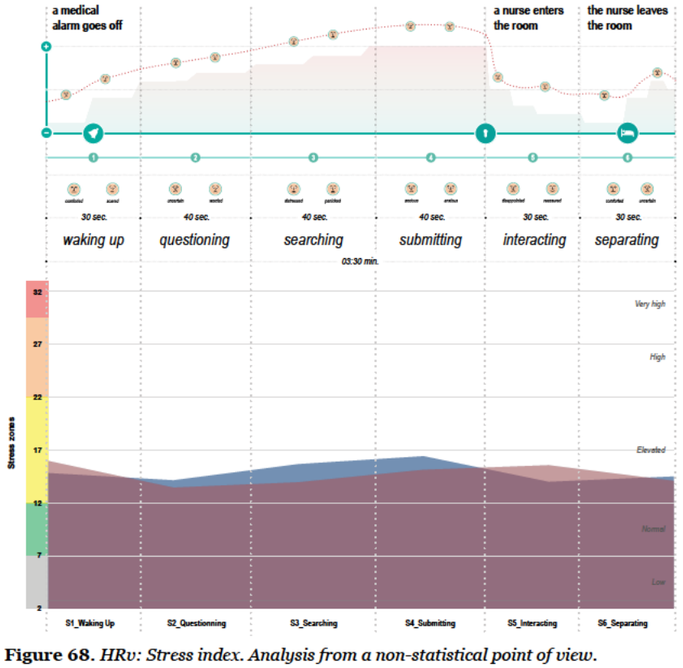


Figure 68. *HRv: Stress index. Analysis from a non-statistical point of view.*

Slider device - (N = 20)
Focusing only on the *Waiting phase* (Fig. 70), a t-test was conducted to determine the effect of medical alarms feedback provision on the anxiety people perceived during the experience.

Between Group B that was provided with feedback (M = 4.31; SD = +/- 3.16) and Group A with no feedback (M = 4.74; SD = +/- 2.68) there was not a significant difference (p= 0.74).

In addition, for each step characterizing the *Waiting phase* (Questioning, Searching and Submitting) a t-test was also conducted but it was not found a significant difference, as shown in Table X. As a result, no statistical evidence exists that medical alarms feedback provision has an effect on the anxiety people perceived during the experience.

However, from a non-statistical point of view, the graph X shows that, in general, people from Group B felt less anxious compared to Group A during the entire experience.

Although in the *Waiting phase*

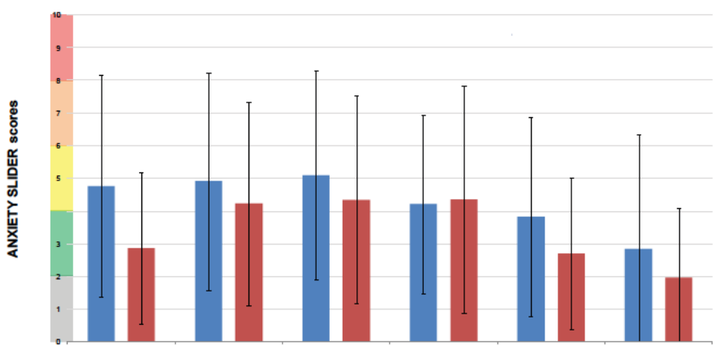


Figure 69. *(Anxiety) Slider scores. Full experience.*

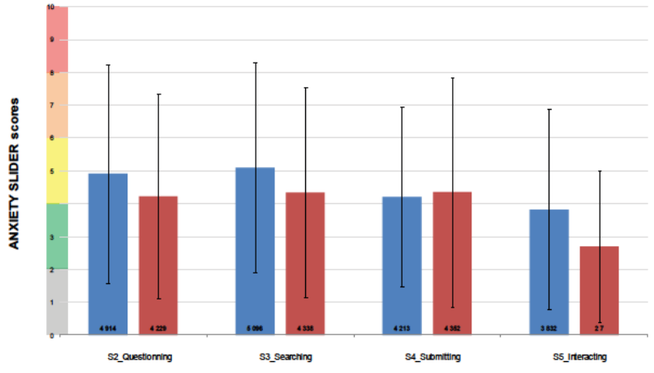


Figure 70. *(Anxiety) Slider scores. Waiting and Interacting phases.*

GROUP A	S1	S2	S3	S4	S5	S6
M	4.764	4.914	5.096	4.213	3.832	2.847
SD	3.389	3.326	3.203	2.731	3.041	3.500

GROUP B	S1	S2	S3	S4	S5	S6
M	2.868	4.229	4.338	4.352	2.7	1.971
SD	2.301	3.112	3.187	3.478	2.315	2.097

p-value	0.161	0.640	0.602	0.922	0.361	0.506

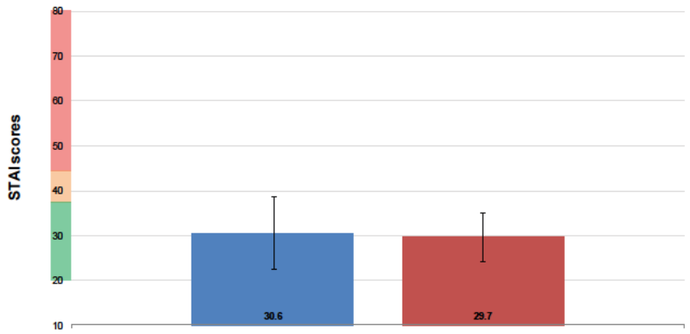


Figure 71. *STAI questionnaire. State of anxiety before the immersion in VR.*

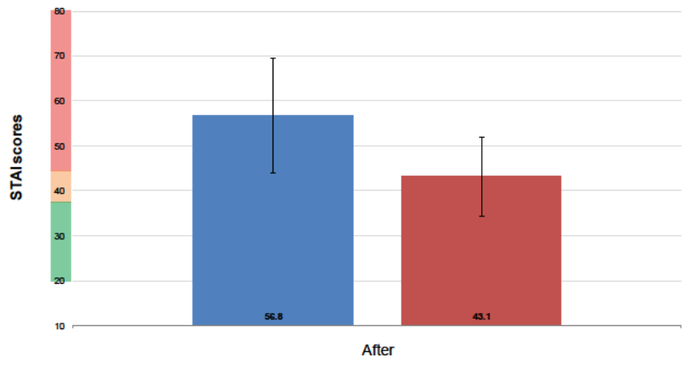


Figure 72. *STAI questionnaire. State of anxiety after the immersion in VR.*

BEFORE	A	B
Avg	30.6	29.7
StDv	8.168	5.396
p-value	0.774	

AFTER	A	B
Avg	56.8	43.1
StDv	12.796	8.787
p-value	0.012	

the levels of perceived anxiety increased compared to the *Waking Up phase* within the Group B, these values remained stable as well as lower than Group A which, in general, showed more elevated anxiety levels.

In the last step of the *Waiting phase* (Submitting step), levels of perceived anxiety were higher in Group B than in Group A; apparently, as already discussed before, the progress indicator had a negative influence on this experience influencing not only stress levels but also making people feeling more anxious.

In conclusion, the graph shows that in the phases of *Interacting* and *Separating*, Group B had less elevated anxiety levels. This finding might reinforce the conclusion about the fact that the use of Overcome reassures and comfort people also when alone.

State Anxiety Scale questionnaire - (N = 20)

In analysing the data, it was important to take into consideration that while the values of the *anxiety-present items* (3,4,6,7,9,12,13,14,17,18) must be taken as given, the values of *anxiety-absent items* (1,2,5,8,10,11,15,16,19,20) must be reversed (e.g. responses scored 1,2,3 or 4 must respectively be scored as 4,3,2 or 1).

After clarifying the scores, to obtain a score for the S-Anxiety scale, it was necessary to sum the given scores for the twenty items. Scores can range from 20 to 37 (no or low anxiety), from 38 to 44 (moderate anxiety), and from 45 to 80 (high anxiety) [59].

Lastly, a t-test was conducted to determine the effect of medical alarms feedback provision on the state of anxiety of participants.

Measurements were executed before and after the experience in VR. People were asked to score the items on the questionnaire considering how they felt at the specific moment the questions were asked.

Before the experience (Fig. 71), between participants from Group B (M = 29.7; SD = +/- 5.39) and Group A (M = 30.6; SD = +/- 8.17) there was not a significant difference (p= 0.77).

After the experience (Fig. 72), between participants from Group B who were provided with feedback (M = 43.1; SD = +/- 8.78) and Group A with no feedback (M = 56.8; SD = +/- 12.79) there was a significant difference (p= 0.01).

As a result, while evidence from the questionnaire filled out before the experience suggests that participants from Group A and B were in the same state of anxiety, results from the questionnaire filled out after the experience suggest, instead, that exists a statistical evidence that medical alarms feedback provision has an effect on the people state of anxiety.

Through this evaluation, it has been shown that despite both groups had elevated stress, Group B had less elevated stress after the experience. Thus Overcome has an impact on reducing anxiety on people.

Experience - (N = 20)
A t-test was conducted to determine the effect of medical alarms feedback provision on the experience of participants. Both groups were asked to evaluate the extent to which they felt acknowledged, informed, distracted, comforted and safe while being exposed to a medical alarm (Fig. 73). Besides, they were asked to score their overall experience (Fig. 74).

Level of acknowledging
Between Group B that was provided with feedback (M = 5.5; SD = +/- 1.27) and Group A with no feedback (M = 2; SD = +/- 0.67) there was a significant difference (p < 0.01) (Fig. 73).

Level of Informing
Between Group B (M = 5.2; SD = +/- 1.48) and Group A (M = 2.3; SD = +/- 1.25) there was a significant difference (p < 0.01) (Fig. 73).

Level of Distracting
Between Group B (M = 4.3; SD = +/- 1.83) and Group A (M = 2.9; SD = +/- 1.37) there was not a significant difference (p = 0.07) (Fig. 73).

Level of Comforting
Between Group B (M = 5.5; SD = +/- 0.98) and Group A (M = 2.3; SD = +/- 0.95) there was a significant difference (p < 0.01)

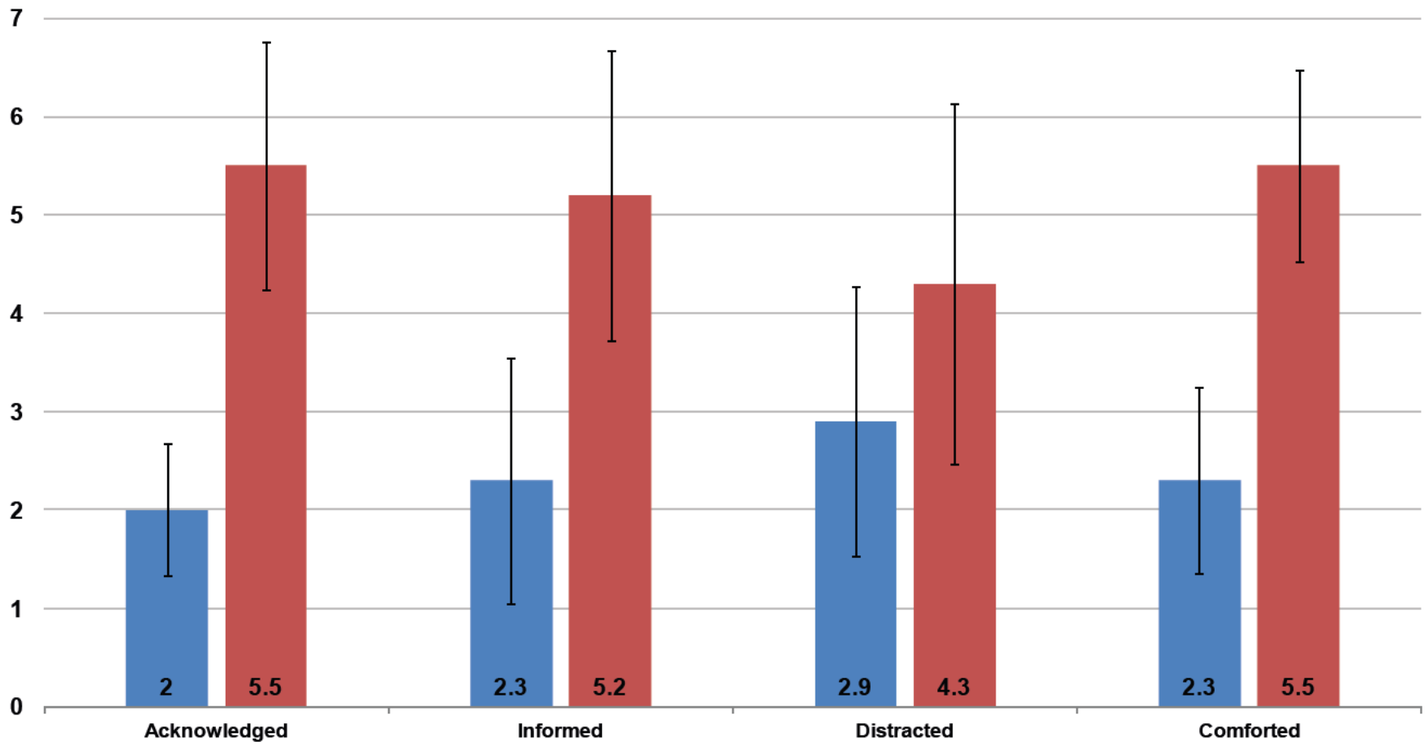
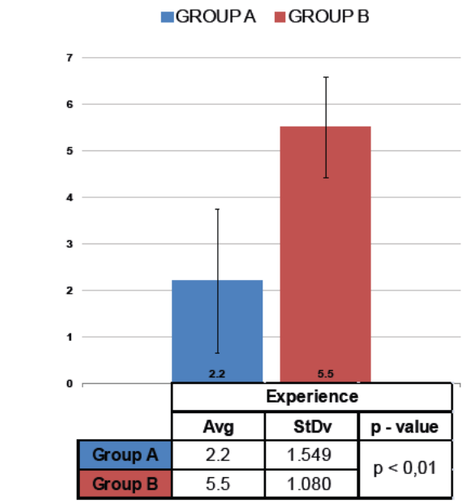


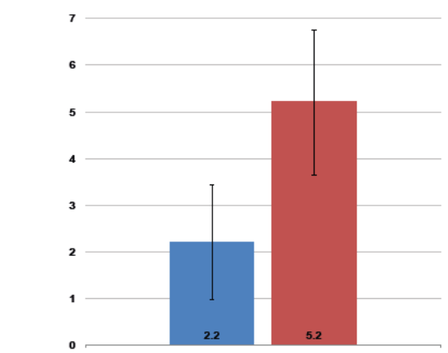
Figure 73. *Design goals.*

	Acknowledged			Informed			Distracted			Comforted		
	Avg	StDv	p - value	Avg	StDv	p - value	Avg	StDv	p - value	Avg	StDv	p - value
Group A	2	0.667	p < 0,01	2 3	1.252	p < 0,01	2 9	1 370	0.069	2.3	0.949	p < 0,01
Group B	5.5	1.269		5 2	1.476		4 3	1.829		5.5	0.977	

Figure 74. *Overall experience.*



	Experience		
	Avg	StDv	p - value
Group A	2.2	1.549	p < 0,01
Group B	5.5	1.080	



	Safe		
	Avg	StDv	p - value
Group A	2.2	1.229	p < 0,01
Group B	5.2	1.549	

Figure 75. *Perceived sense of safety.*

(Fig. 73).

Perceived Sense of Safety
Between Group B (M = 5.2; SD = +/- 1.55) and Group A (M = 2.2; SD = +/- 1.23) there was a significant difference ($p < 0.01$) (Fig. 75).

Overall experience
Between Group B that was provided with feedback (M = 5.5; SD = +/- 1.08) and Group A with no feedback (M = 2.2; SD = +/- 1.55) there was a significant difference ($p < 0.01$) (Fig. 74).

As a result, statistical evidence exists that medical alarms feedback provision, and on the levels of acknowledging, informing and comforting, improved the experience of participants, as well as their perceived sense of safety. Instead, results in the level of Distracting showed that there is no statistical difference between the two groups.

In general, these results suggest that interacting with Overcome can satisfy the need for patients for feeling safe when a medical alarm goes off.

To better understand the impact of Overcome on the experience of Group B, it is necessary to consider some of the behaviours participants form Group A had, especially during the Waiting phase.

Results from the statistical analysis on the *Level of Distracting* suggest that do not exists any statistical difference between the groups, thus demonstrating that both groups were similarly distracted from the medical alarm during the experience. But, what is important to understand is what distracted them from the medical alarm.

Persons belonging to the control group experienced a lack of information which pushed them to search for data that could have helped them to interpret the ongoing alarm. Indeed, most of them started to move their heads, and in a continuous way, from side to side of the room when the medical alarm went off.

"[...] I was looking around for signs or information that would tell me what was going on" [Group A -P20]

Basically, they were trying to figure out what was happening. In doing so, their attention was moved to the bedside monitor; moreover, between the Searching and Submitting steps, most of them were concentrated on the door, they were waiting for someone to show up, they were trying to understand whether a nurse was monitoring them or if there was someone aware about the ongoing situation.
"[...] I was watching the door and the monitor to see whether someone is coming and to understand what is happening [...] I was looking for information" [Group A - P07]

On the contrary, people from Group B were mostly focused on Overcome since the beginning of the experience; they did not move their heads from side to side of the room but they were focused on the feedback. However, when the progress indicator on the interface was almost at the end, most of the participants from Group B started to watch also at the door, mainly because they were checking if the nurse would arrive at the same time indicated on the interface.

As shown in *Table X*, Group A was less distracted than Group B from the medical alarm; therefore, Overcome captured and moved their attention from the auditory stimuli in a more effective way.

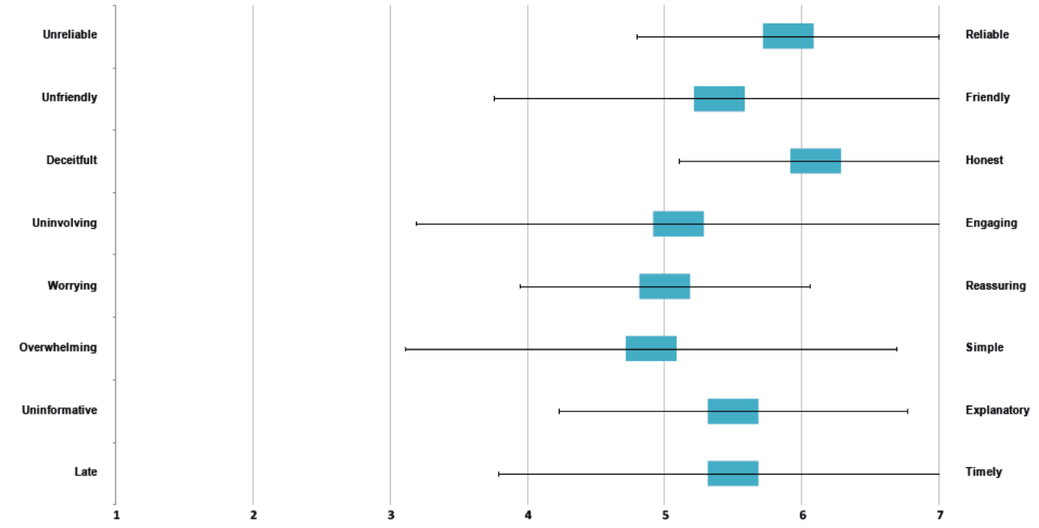


Figure 76. *Desing qualities.*

Design qualities - (N = 10)
The outcomes of the Design qualities questionnaire were compared on frequency. The scales of the design qualities were positioned with a negative adjective on the left and a positive one on the right. The mean score and standard deviation for each design quality were calculated to measure the spread of the data about the mean value .

In general (Fig. 76), the outcomes for the design qualities suggest that participants agreed more on the qualities Reassuring (M = 5; SD = +/- 1.05), Honest (M = 6.1; SD = +/- 0.99) and Reliable (M = 5.9; SD = +/- 1.10); while they had more different opinions on the qualities Simple (M = 4.9; SD = +/- 1.79) and Engaging (M = 5.1; SD = +/- 1.91). Lastly, for the qualities Timely (M = 5.5; SD = +/- 1.72), Explanatory (M = 5.5; SD = +/- 1.27) and Friendly (M = 5.4; SD = +/- 1.65), the majority of the opinions tend to the positive adjective, indeed only a small percentage of participants opted for a negative description.

"[...] the most important thing is that the info provided refer to the reality" [Group B - P11]

In conclusion, labels and most of the icons were easily understandable by all the participants who, in addition, trusted Overcome as the information provided referred to the reality and they were perfectly synchronized with the nurse reactions.

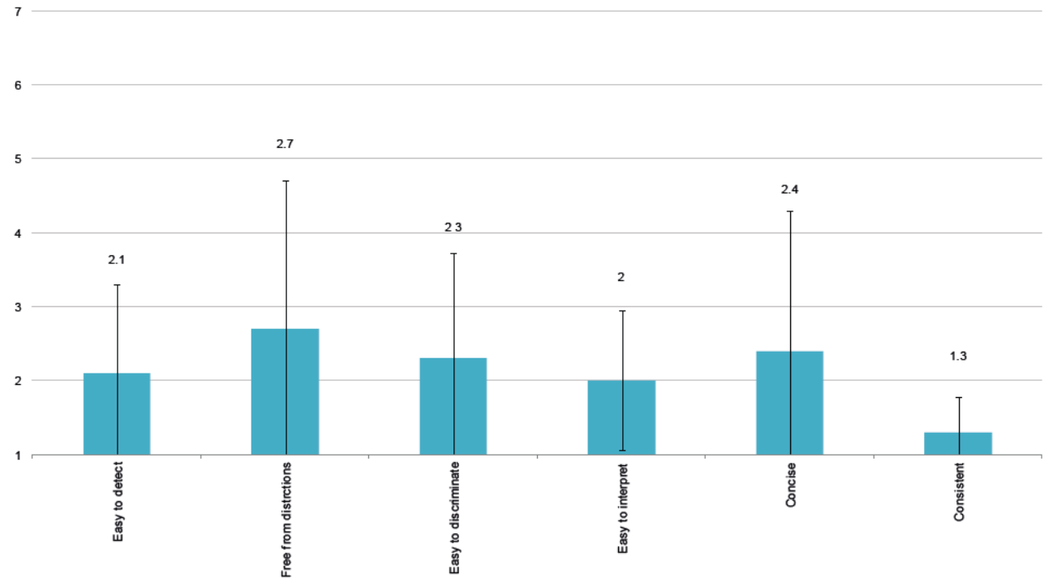


Figure 77. *Provision of Information.*

Provision of Information (N = 10)

The outcomes of the presentation of Information questionnaire were compared on frequency (Fig. 77). The scales of the items were positioned from 1 (Strongly Agree) to 7 (Strongly Disagree). The mean score and standard deviation for each pronciple were calculated to measure the spread of the data about the mean value.

In general, the outcomes for the provision of information suggest that participants agreed more on easy Detectability (M = 2.1; SD = +/- 1.20), easy Interpretability (M = 2; SD = +/- 0.94), Consistency (M = 1.3; SD = +/- 0.48) of the information presented; while they had more different opinions about the Freedom from distractions (M = 2.7; SD = +/- 2), easy Discriminability (M = 2.3; SD = +/- 1.42), and Conciseness (M = 2.4; SD = +/- 1.90).

However, the majority of the opinions related to the last three principles, clearly leaan to one side of the graph, which means that most of them were agree with the research questions.

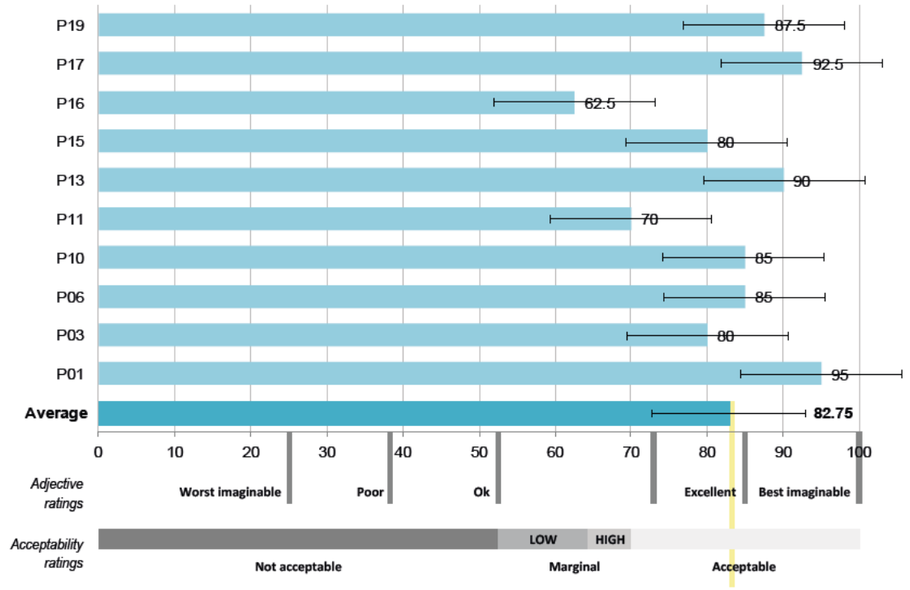


Figure 78. *System Usability Scale (SUS) scores.*

SUS - (N = 10)

To calculate the SUS score, first, the score contributions from each item needed to be clarified. These scores contributions range from 0 to 4. For items 1,3,5,7 and 9 (the positive statements in the scale) the score contribution is the scale position minus 1. For items 2,4,6,8 and 10 (the negative statements in the scale) the contribution is 5 minus the scale position.

To calculate the overall value of system usability, the sum of the scores needs to be multiplied by 2.5. The SUS score can range from 0 to 100 and can be rated using an adjective rating system [56, 57].

Regarding the usability, Overcome got an average SUS score of 82.75 (SD = +/- 10.1), which corresponds with an adjective rating of “Excellent” (Fig. 78). Therefore, it can be concluded that the usability of Overcome is good and acceptable.
Furthermore, from the results, it can be derived that users can easily learn how to use the device and they can quickly become familiar with it and making good use of its features and capabilities.

6.5 | Discussion

There were different aspects that could have influenced the outcomes of this test.

Sample
Firstly, the sample of users involved in the evaluation was not representative of ICU patients. They were mostly young students without or limited experience in hospitals, especially in the ICU. Few of them had knowledge about the ICU, while the biggest percentage did not know what an ICU is and which the reasons why people are admitted in ICUs. As a result, for participants was difficult to really empathise with an ICU patient whose medical conditions are critical, and the emotional state compromised by the fear of dying.

Broken immersion in VR
The use of the (Anxiety) Slider device could have broken the immersion in VR and affected the physiological measurements and the subjective evaluations of participants during the experience. Indeed, the interaction with the slider could have influenced the people perception of being in a different place than the testing room; furthermore, while in the video the arms and hands of the patients were mostly in the same position until the end, the left hand and arm of the participants was constantly in movement.

Furthermore, in the video, the patient attached an SPO2 sensor to his finger (right hand) and between the Waking up and the Waiting phases, the sensor detach due to a sudden movement of the patient's right hand. The detachment of the sensor and the movement of the patient's hand were clearly visible to the participants who, instead, were not wearing the sensor nor experienced the detachment.

Also, the introductory video and the second video were not merged but two separate entities. In fact, between the end of the Introductory video and the start of the second video, there was a pause of 30seconds and a black screen shown to participants.

All these factors could have broken the immersion in VR and reduced the levels of anxiety and stress evoked in the introduction video and during the experience.

Readability and VR glasses
Although the resolution of the video was high (4K), for some participants was difficult to read the information provided by Overcome.
For some people, the VR glasses resulted as uncomfortable especially when they tried to focus; some people would have preferred to keep the VR glasses at a bigger distance from their eyes, others would have preferred to keep their own glasses while wearing the VR glasses; unfortunately, it was not possible to satisfy such needs, thus some participants had readability problems, especially in reading the text of the labels.

As a result, this problem could have influenced the outcomes of the test, especially in relation to the provision of information and usability.

Video
The audio volume of the video, especially the medical alarm volume, was described as too soft from some participants. Actually, in the ICU the alarm volume is higher than the alarm volume in the video. As a result, the too soft medical alarm volume could have reduced the "surprise effect" that, in general, an alarm cause thus eliciting anxiety and stress in the patients.

Also, the Introductory video was designed to elicit anxiety and increasing stress levels on participants at a level similar to ICU patients.

However, it could be possible that the length of the video and the background voice were not enough to elicit such emotion and stress. Images showing an incident or the parents worried about the condition of the participant/patient could have helped better in reaching the levels of stress and anxiety expected.

Finally, in the video, the detachment of the sensor could have influenced the participants' levels of stress and anxiety. Indeed, the detachment of the sensor could have been associated with a not dangerous situation, and the alarm appraised as not a threat.

6.6 | Conclusions

For the evaluation of the design, Virtual reality (VR) revealed big potentiality, especially because I was able to simulate a context which, otherwise, was not possible to access. VR gave to people involved in the test, the possibility to experience the ICU from the perspective of a real patient and better empathise with them. However, evoking the emotions that usually patients experience during ICU stay when a medical alarm goes off, was difficult.

In this study, the possibilities to resolve or escape from (fight-or-flight response) the threat (medical alarm) were unlimited for participants, they were able to choose whether or not to stop the experiment and return to their reality; instead, patients are forced to submit to the events, and this limitation (lack of control) has emotional and physiological consequences difficult to replicate.

As a result, to really understand the impact of Overcome on the reduction of anxiety is necessary to test the design with real users, such as former ICU patients who could better understand the problem and be, in a more realistic way, emotionally involved.

However, recreating a hospital room was a good choice because participants were able to better immerse themselves on the experience and identify with the patient. Especially, the use of a hospital bed gave them the sensation of being really inside the VR room, as the position of their body was the same as the body shown on the video.

Despite the people involved in this study were not a good representation of my target group, involving them as potential users was necessary to test my design and to collect evidence that could have proved my hypotheses. VR offered me a great opportunity for seeing how my design fits into the context and, especially, to collect data that potentially reflect similar physiological and emotional reactions to an ICU patient to medical alarms.

Data on HRv show that no statistical evidence exists that medical alarms feedback provision has an effect on reducing stress levels, and there are several reasons that could explain such a result; for instance, the design did not work; the experiment was not strong enough to evoke the expected reactions towards a medical alarm; the sample of people was too small; participants had different personalities (some were more sensitive to the stressor than others / some are anxious person); participants cognitively regulate their body reactions.

However, by comparing stress levels of both Groups, and from not a statistical point of view, it was observed that stress levels of Group B were lower than Group A. In addition, results from the State Anxiety Scale questionnaire revealed that exists a statistical evidence that medical alarms feedback provision has an effect on the people state of anxiety.

As a result, it can be concluded that there is a correlation between physiological and subjective measurements, but further investigations are needed to statistically prove it; for instance, a bigger group of people who have similar characteristics, such as heart functions and personality, should be recruited.

From a not statistically point of view, it is interesting to notice that by comparing the results from the HRv, Slider Device and STAI there is a trend in the data showing that Group B was less stressed and anxious than Group A during the whole experience.
In general, the experience of Group B was better than Group A.

"[...] with the device I felt less lonely and not in a ball as usual patients feel [...] you did not lose the contact with the world, is reassuring" [Group B - P11]

It seems that, despite there are no significant effects on HRv, Overcome tends to keep people stress levels stable even when there is a reason for an increase in anxiety. As a result, putting in communication nurses with patients by a distance might benefit the psychological well-being of patients who feel ignored or abandoned and not in a safe situation, especially when a nurse delays to intervene when a medical alarm goes off.

In conclusion, the design of Overcome worked well in terms of usability, provision of information, quality of interaction and for the reduction of anxiety. However, some additional changes in the design are necessary to optimize the interface more in the future.

6.7 | Recommendations

Based on the test, recommendations to improve the usability, content and layout of Overcome were formulated. In addition, an evaluation of the design approach is given.

Colour
The used colours for the background and the user-interface elements are not in a good contrast with each other. Low contrast reduced the Detectability, Interpretability and Discriminability of the presented information, especially the progress indicator.

To minimize the problem, colours should be reconsidered in terms of Discriminability (e.g. by choosing colours that are widely distributed in hue and saturation, or by changing the luminance difference [73]).

For example, by correcting the colour of the background from a high saturated to a low saturated blue, the contrast with the progress indicator (which is one of the element that needs to be distinguishable), could be maximized and Discriminability improved.

In addition, to draw the attention of users on the animated icons in the input/output area, colours should be the brighter and the more highly saturated on the screen [73]. It is recommended to investigate this topic further.

Icons
More information about the medical alarms
Most of the participants would have preferred to receive more information about the medical alarm, such as the reasons for the alarm, its meaning and whether or not it is solvable.

"[...] more transparent info, like explaining to me how to put the sensor back also to understand what is happening" [Group B - P16]

As a result, it seems that the implementation of the Level of Instructing, which was designed for promoting medical alarms understanding and increase collaboration with the nurses, could satisfy such needs and improve the experience.

Animated lines
Some animations move too fast, competing with other elements and overwhelming users, such as the moving lines placed between the label and the animated icons. Indeed, it seems that the lines do not support users, but they distract them from the most important information. As a result, such lines should be removed.

Animated check-mark
The animated checkmark was considered too fast in terms of presentation and lasted too short after its completion. As a result, this animation should last longer and be more evident, especially because for the users it was a relevant piece of information the comforted them after the alarm went off.

Animated bell
The animated bell placed behind the icons captured totally the attention of the users distracting them from the other pieces of information. As a result, it should be positioned in another area of the interface, such as on the top-right corner and in line with the icon of the pulsing nurse.

Progress indicator
The progress indicator increased the expectations of the participants who, also, expected the arrival of the nurse before the indicator reached the end. Although initially, it reassured the participants, in the end, it added stress.

In general, users seem to expect that a progress indicator increases its speed towards the end [A]; as a result, to create more satisfaction and reduce frustration, the progress indicator of Overcome should proceed with a constant speed or go faster towards the end, to make the waiting time more pleasant. However, because the speed of the indicator varies with the variation of the speed of the nurse, it could be better to show patients the nurses' progress without time indications. Indeed, showing only steps could be enough for patients to form, at least, an estimation of the waiting time and also it might reduce the risks of adding stress [A] .

To further minimize the problem, the progress indicator could be positioned on the bottom part of the interface, just under the animated icons, and the shape changed in a horizontal indicator.

Pulsing nurse
In Overcome, the pulsing nurse icon is continuously shown and, only in the case of an alarm, it decreases in size and moves on the top-left corner of the screen thus allowing to the other information to be shown.

In general, the icon gave participants the feeling of being monitored (*"I felt like there is someone watching at me [...] you know someone is taking action"*), but the continuous pulsing frequently disrupted such a feeling, thus leading to misinterpretations and the belief that there was a problem in the connection with the nurse (*"it gives me the impression that there is a process going on [...] it seems that a nurse is taking time too much time to doing something" - " it seems like it is taking a lot of time to connect"*).

As a result, the icon should be redesigned. It should be more static and the circles removed; perhaps, an online status indicator could be added to show that the nurse is currently connected.

Cold interaction
Participants would have preferred to place a picture of the nurse who was monitoring them inside the icon of the pulsing nurse to make the interaction less impersonal, and more on a human level. Such an intervention could generally make the interaction with Overcome more friendly and reassuring; indeed, people might feel more connected to another human being (the nurse), rather than with just a computer.

Terminology
Improving the terminology of the labels could help in minimize the aforementioned problem. Indeed, messages should be more informal, less technical and straight forward (e.g. A nurse has been assigned to you).

6.8 | Future directions

To further develop Overcome into a tool that can be implemented in the ICU, some work on the design and the technology need to be done. Possibilities for implementation of Overcome concept seem promising, especially in this transition phase in which the removal of medical alarms from patients' rooms is still far away. Indeed, Overcome can play a role in improving the ICU patients' experience, as well as empowers the patient-nurse relationship, by reducing the detrimental effect medical alarms have on their psychological well-being and giving nurses the possibility to timely and properly support their patients.

Overcome is a resource that can support ICU patients in coping with medical alarms; indeed, it can help to properly appraise an alarm avoiding the rise of stress levels and the development of a state of anxiety.

A discussion at the EMC with the head of the ICU and my professors from Tu Delft about Overcome led to interesting insight about the possibility for further research.

Firstly, further research should be done to develop the content of medical alarm feedback provision, not only information related to the detachment of a sensor (e.g. SPO2) should be shown but, for instance, also on blood pressure, an empty pump, missing drugs, etc.; as a result, patients might be informed that the end of the drug was scheduled and be able to distinguish an analgesic from an antibiotic.

In addition, further research to categorize high priority and low priority alarms should be done and tests conducted to understand how clinically relevant alarms should be shown to patients.

The tool could be used also for keeping patients update about their healing process and the activities that need to be done during the day, thus psychologically preparing patients about the interactions that are going to happen in advance.

Furthermore, attention should be put on the development of the network in which connecting Overcome to the nurses' pager system. Nurses should be given the possibility to control Overcome and make choices on the provision of feedback deciding which information to share with a patient to provide those that the most suit with the personality and needs of the latter. Such development should take into account the implementation of functions to change the language on which the feedback is provided. In addition, nurses should give patients the possibility to choose whether or not to use Overcome during hospital stay.

I believe that the use of visual design for the provision of feedback should be employed also in future versions of Overcome. People can easily comprehend such information without effort and the need for someone who explains to them the meanings.

However, after the admission in the ICU, patients, as well as family members and friends, should always be introduced about the features and capabilities of Overcome by nurses. Patients' relatives could benefit from Overcome too, especially it could reduce their overreactions when a medical alarm goes off. Moreover, the needs of using Overcome might reduce in patients who are hospitalised for a long period of time because the longer is the stay, the higher are the possibilities to learn how to recognize and interpret a medical alarm, as well as the nurses' reactions.

In conclusion, in further research, it should be taken into consideration the use of a bigger TV screen or a dedicated screen to place closer to the patients' bed. Indeed, the elderly and people with limited vision abilities might find difficult to effectively read information from a 40 inch TV screen placed at a distance of about three meters from their eyes. These considerations should be also extended for people with colour vision deficiency; as a result, it is necessary that a redesign of Overcome takes into consideration the possibility to adequate the interface to people with such conditions.

Acknowledgements

I love my job. I love my job because I can help people and improve the quality of their life.

Overcome for me is not just a product, but represents me as a designer and as a person. The journey I had in this graduation project was a mixture of surprises, knowledge, innovation, People, hope, love, passion and nights spent awake thinking about how, as a designer, I can contribute to making the life of people in critically ill conditions more pleasant in such complex environment where professionals from many fields continuously interact not only to save people life but also to give them and their families hope. I want to express my gratitude to Elif for her time, trust, support, motivation and to have given me the opportunity to enter, for the first time in my life, inside an ICU. I want to express my gratitude to Joos for his time, support and to have continuously motivating me. You have both taught me a lot, and I am really honoured to have worked together with you.

I want to express my gratitude to Dr Diederick for his time, the honest point of view on my job and to have opened the doors of the Department of Intensive Care at the Erasmus MC where, for more than a year, I have been welcomed and I had the chance to do my researches.

I want to express my gratitude to Mrs Marianne for her kindness and to have welcomed me at the IC connect organization where I met really brave people: Mrs Diana and Mrs Hans. Thank you to all of you to have open you heart and share with me your incredible experience at the ICU.

I want to express my gratitude to the ICU nurses at the Erasmus mc for your comprehension, time and patience. I want to particularly thanks Mrs Erna, Mrs Margo and Zoran.

I want to express my gratitude to Arno for his time, availability and support in my experience with Virtual reality. I want to thanks Jeron for his support and to be a really good friend even if we were just two strangers.

I want to express my gratitude to my flatmates and colleagues, you are good friends. You always had time for me, to talk about work and about life, I want to thank you guys for all your support and for all the beautiful smiles you shared with me.

Last but not least, I want to express my gratitude to my Parents, my Sister and my love, Clara. Your love and support have been essential in all this time during this amazing experience here in the Netherlands at TU Delft, without you all of this could not have been possible but just a dream.

Reference

1. Byers J.F., Smyth K.A. Application of a Model of Stress and Coping with Critically Ill Patients. Dimension Critical Care Nursing. Nursing Diagnosis. VOL.16, November-December. 1997, 292 - 300.

2. Johansson L., Bergbom I., Lindahl B. Meanings of Being Critically Ill in a Sound-Intensive ICU Patient Room - A Phenomenological Hermeneutical Study. The Open Nursing Journal. 2012, 6, 108-116.

3. Peplau H.E. Peplau's Theory of Interpersonal Relations. Nursing Science Quarterly. 1997, 162 - 167.

4. Min Cho, Ok & Kim, Hwasoon & Lee, Young Whee & Cho, Insook. Clinical Alarms in Intensive Care Units: Perceived Obstacles of Alarm Management and Alarm Fatigue in Nurses. Healthcare Informatics Research. 2016.

5. Topcu S., Alpar S.E., Gulseven B., Kebapci A. Patient experience in intensive care units: a systematic review. Patient Experience Journal. 2017. Vol. 4. Issue 3. Art. 17.

6. Ozcan E., Birdja D., Edworthy J.R. A Holistic and Collaborative Approach to Audible Alarm Design. Biomedical Instrumentation & Technology, November/December, 2018, 422-432.

7. Scott A. Managing anxiety in ICU patients: the role of pre-operative information provision. British Association of Critical Care Nurses, Nursing in Critical Care, 2004. Vol. 9 No 2.

8. Van Mol M.M.C. et al. Joined forces in person-centered care in the intensive care unit: a casa report from the Netherlands. Journal of compassion Health Care. 2016.

9. Fleischer S., Berg A., Behrens J., Kuss O., Becker R., Horbach A., Neubert T.R. Does an additional structured information program during the intensive care unit stay reduce anxiety in ICU patients?: a multicenter randomized controlled trial. BMC Anaesthesiology 2014, 14:48.

10. Blackwood B., Albarran J.W., Latour J.M. Research priorities of adult intensive care nurses in 20 European countries: a Delphi study. Journal of Advanced Nursing (JAN). Balckwell Publishing Ltd. 2010. 550-560.

11. Frazier S.K., Moser D.K., Riegel B., McKinley S., Blakely W., Kim K.A., Garvin B.J. Critical Care Nurses' Assessment of Patients' Anxiety: Reliance on Physiological and Behavioral Parameters. American Journal of critical care. Jan. 2002. 11(1): 57-64.

12. Bhutkar G., Deshmukh S. Vital Medical Devices in Intensive Care Unit. Medical Equipment & Automation. Mar-Apr 2012. 44-47.

13. Svenningsen H., Langhorn L., Agard A.S., Dreyer P. Post-ICU symptoms, consequences, and follow-up: an integrative review. British Association of Critical Care Nurses, 2015. Vol. 22, No. 4.

14. Devlin JW. The pharmacology of over sedation in mechanically ventilated adults. Curr Opin Crit Care. 2008;14:403–7.

15. Christensen M, Dodds A, Sauer J, Watts N. Alarm setting for the critically ill patient: a descriptive pilot survey of nurses' perceptions of current practice in an Australian Regional Critical Care Unit. Intensive Crit Care Nurs 2014;30(4):204-10.

16. Chambrin M.C. Alarms in the intensive care unit: How can the number of false alarms be reduced? Crit Care 2001; 5:184–188.

17. Pugh R.J., Jones C., Griffiths R.D. The Impact of Noise in the Intensive Care Unit. Intensive Care and Emergency Medicine, 2007.

18. Purbaugh T., Alarm Fatigue: A roadmap for mitigating the Cacophony of beeps. Dimension Critical Care Nursuing. 2014;33(1):4-7.

19. Siebig S., Kuhls S., Imhoff M., Gather U., Scholmerich J., Wrede C.E., Intensive care units alarms: how many do we need? Critical Care Medicine 2010, Vol.38, No.2, 451-456.

20. Cvach M., Dang D., Foster J., Irechukwu J. Clinical Alarms and the Impact on Patients Safety. Initiatives in Safe Patient Care. Saxe Healthcare Communications. 2009.

21. Bell L. Monitor alarm fatigue. Am J Crit Care 2010; 19(1):38.

22. Bridi A.C., da Silva R.C.L., de Farias C.C.P., Franco A.s., dos Santos V.deL.Q. Reaction time of health care team to monitoring alarms in the intensive care unit: implications for the safety of seriously ill patients. Res Bras Ter Intensiva. 2014; 26 (1): 28-35.

23. Chambrin MC, Ravaux P, Calvelo-Aros D, et al: Multicentric study of monitoring alarms in the adult intensive care unit (ICU): A descriptive analysis. Intensive Care Med 1999; 25:1360–1366.

24.Balogh D, Kittinger E, Benzer A, et al. Noise in the ICU. Intensive Care Med 1993; 19:343–346.

25.Imhoff M., Kuhls S. Alarm Algorithms in Critical Care Monitoring. International Anesthesia Research Society, 2006;102:1525–37.

26.Wilson-Barnett J. Patients' emotional reactions to hospitalization: an exploratory study. Journal of Advanced Nursing. Vol. 1 (5). 1976.

27. emotiontypology.com/typology/list/anxiety. Delft Instituite of Positive Design.

28. Inokuchi R., Sato H., Nanjo Y., Echigo M., Tanaka A., Ishii T., Matsubara T., Doi K., Gunshin M., Hiruma T., Nakamura K., Shinohara K., Kitsuta Y., Nakajima S., Umezu M., Yahag N. The proportion of clinically relevant alarms decreases as patient clinical severity decreases in intensive care units: a pilot study. BMJ Open, September 2013.

29. Novaes M.A.F.P., Aronovich A., Ferraz M.B., Knobel E. Stressors in ICU: patients' evaluation. Intensive Care Med. 1997. 23:1282-1285.

30.Wade D., Howell D. What can psychologist do in intensive care? ICU management & practice. VOL.16. Issue: 4. 2016. 242-244.

31. Hatch, R., Young, D., Barber, V. et al. Anxiety, Depression and Post Traumatic Stress Disorder after critical illness: a UK-wide prospective cohort study. Crit Care 22, 310. 2018.

32. Blair K.T.A, Eccleston S.D., McCarthy M.S. Improving the patient experience by implementing an ICU diary for those at risk of Post-intensive care syndrome. Journal of patient experience. 2017. Vol. 4(1) 4-9.

33. Peris A., Bonizzoli M., Iozzelli D. et al. Early intra-intensive care unit psychological intervention promotes recovery from post traumatic stress disorders, anxiety and depression symptoms in critically ill patients. Critical Care. 2011. Vol. 15(1): R41.

34. The Joint Commission. Advancing Effective Communication, Cultural Competence, and Patient- and Family-Centered Care: A Roadmap for Hospitals. Oakbrook Terrace, IL: The Joint Commission, 2010.

35. Castillo M.I., Cooke M.L., Macfarlane B., Aitken M.L. In ICU state anxiety is not associated with posttraumatic stress symptoms over six months after ICU discharge: A prospective study. Australian Critical Care. Vol. 29, Issue 3, 2016. 158-164.

36. Lazarus R.S., Folkman S. Stress, Appraisal, and Coping. New York. Springer Publishing Co, 1984.

37. McLeroy K. R., Gottlieb N. H., and Heaney C. A. Health Promotion in the Workplace. Albany, New York: Delmar, 2001.

38. Agneessens F., Waege H., and Lievens J. Diversity in Social Support by Role Relations: A Typology. Social Networks, 2006, 28, 427–441.

39. Blanchard C. G., et al. The Role of Social Support in Adaptation to Cancer and Survival. Journal of Psychosocial Oncology, 1995, 13, 75–95.

40. Stappers, P. J. Teaching principles of qualitative analysis to industrial design engineers. In DS 74: Proceedings of the 14th International Conference on Engineering & Product Design Education (E&PDE12) Design Education for Future Wellbeing. 2012. 109–114.

41. Corbin, J. M., & Strauss, A. Grounded Theory Research: Procedures, Canons, and Evaluative Criteria. Qualitative Sociology, 1990. 13(1), 3–12.

42. House, J. S. Work Stress and Social Support. Reading, Mass.: Addison-Wesley, 1981.

43. wikipedia.org

44. Schokkin M. Sound cultures of critical care: how design could tune sound-related practices of intensive care nurses. Master thesis. Delft University of Technology. Delft. 2019.

45. Mulhall, A. In the field: Notes on observation in qualitative research. Journal of Advanced Nursing. 2003. 41(3), 306–313.

46. servicedesigntools.org

47. Mazza D. Reducig Cognitive Load and Supporting Memory in Visual Design for HCI. CHI 2017, May 6-11, Denver, CO, USA.

48. Kluger A. N., DeNisi A. The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. Psychological Bulletin, 119(2). 1996. 254–284.

49.Hermsen S., Frost J., Renes R.J., Kerkhof P. Using feedback through difital technology to disrupt and change habitual behaviour: A critical review of current literature. Computers in Human Behavior. 2016. Volume 57, 61-74.

50. Mai L. M., Freudenthaler R., Schneider F. M., Vorderer P. "I know you've seen it!" Individual and social factors for users' chatting behavior on Facebook. Computers in Human Behavior, 49. 2015. 296-302.

51. ISO 9186-1:2014. Graphical symbols - Test methods. Methods for testing comprehensibility.

53. ISO 9241-112:2017. Principles for the presentation of information.

54. Tarvainen M. P., Lipponen J., Niskanen J-P., Ranta-aho P. O. Kubios HRV (ver. 3.3). User's guide. 2019.

55. Spielberg D. Stait-Trait Anxiety Inventory for Adults. Manual, Instrument and Scoring Guide. Mind Garden. Consulting Psychologists Press, Inc. 1983.

56. Brooke J. SUS: A retrospective. Journal of Usability Studies. 8 (2), 29-40. 2013.

57. Bangor A., Kortum P.T., Miller J.T. Determining what individual SUS scores mean: Adding an adjective rating scale. Journal of Usability Studies, 4(3), 114-123. 2009.

58. Taelman J., Vandeput S., Spaepen A., Van Huffel S. Influ-

ence of mental stress on heart rate and Heart rate variability. 4th European Conference of the International Federation for Medical and Biological Engineering. IFMBE Proceedings, Vol. 22.. 2009.

59. Kayikcioglu O., Bilgin S., Seymenoglu G., Deveci A. State and Trait Anxiety Scores of Patients Receiving Intravitreal Injections. Biomed Hub. 2(2). 2017.1-5.

60. Chambrin M.C., Storme L., Lemoine D., Usselio A. Les alarmes des parametres monitores: principes generaux et gestion. Editions scientifiques et medicales Elsevier SAS. 2000; 9: 432/438.

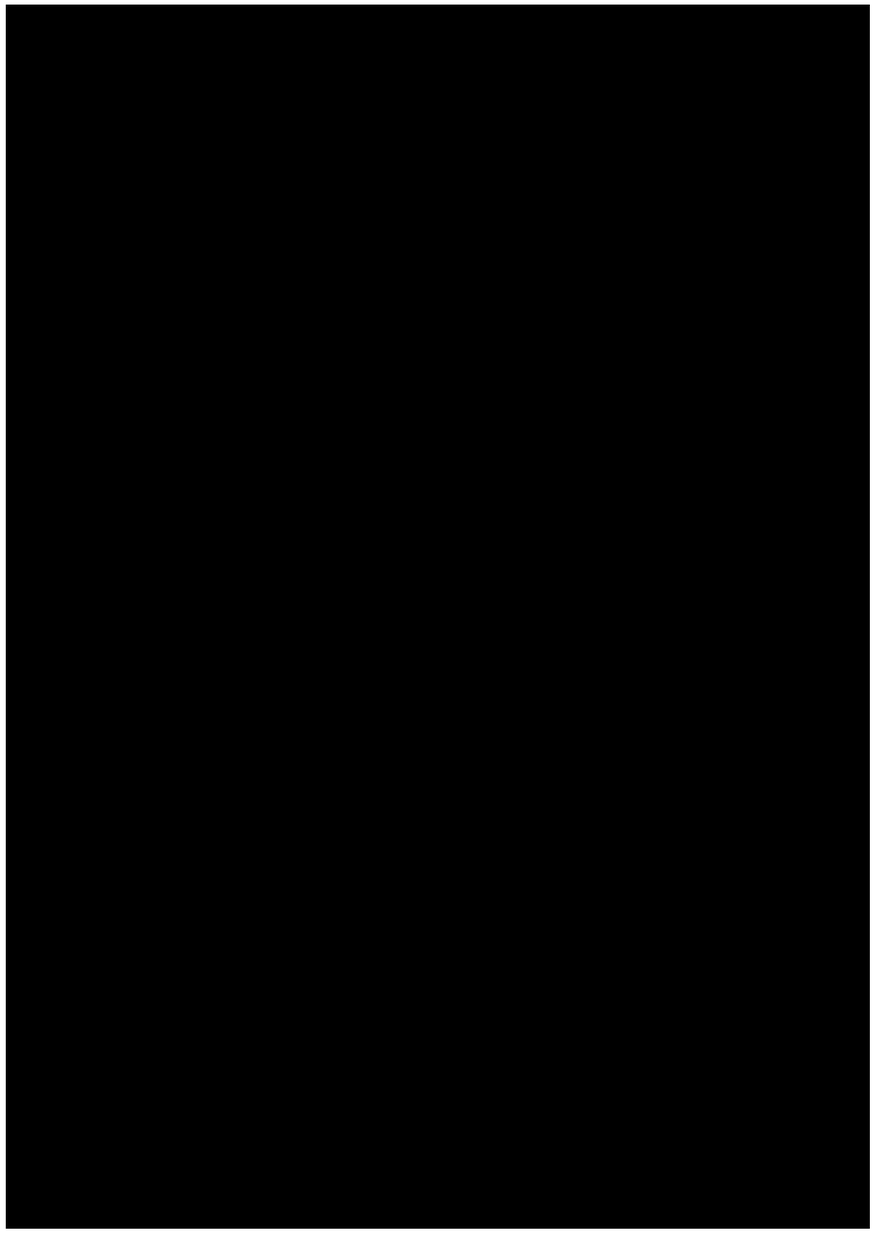
61. Glanz K., Rimer B.K., Viswanath K. Health Behaviour and Health Education: Theory, Education, and Practice. Jossey-Bass. 4th edition. 2008.

62. mayoclinic.org

63. Philips. Experience flows: understanding people and their experiences to deliver meaningful innovations. Philips Design & Innovation Communications. 2014.

Appendices

Appendix B - Recruitment process



5. Research TU Delft into impact alarms on the IC

Critical Alarms Lab

We would like to bring Salvo Cucinella's research to the attention of former ICU patients and loved ones.

"Hello, my name is Salvo and I am from Italy. I am a Master's student in User Experience Design at TU Delft. For my graduation project I work at the IC of the Erasmus MC, where I investigate how the sounds (alarms, etc.)) affects the mental well-being of IC patients.

Staying in the IC is an overwhelming experience and its effects may linger long after discharge from the hospital. Sound plays a major role in this, because they can prevent the patient from recovering from serious illness. It not only has a negative influence on the quality of sleep, but it also often scares people in the IC because it is so unpredictable and it is not clear what the sound is for.

For my research I ask help from former ICU patients and their families because with their experience we can get a better picture of what effects sounds have on the mental well-being of the patient. Together we can define guidelines that caregivers can apply to improve the experience of IC patients. "

Do you want to participate?
S.L.Cucinella@tudelft.student.nl
+39 320 1890 113

01_Newsletter : recruiting participants

“Hello, my name is Salvo and I am from Italy. I am a Master’s student in Design for Interaction at TU Delft. For my graduation project I am investigating on the effects medical alarms have on ICU patients’ psychological well-being.

Staying in the ICU is an overwhelming experience and its effects may linger long after discharge from the hospital. Medical alarms play a major role in this because they can prevent the patient from recovering from serious illnesses. They do not only have a negative influence on the quality of sleep but they also often scare patients and thus increase the risks to develop psychological issues, such as anxiety disorders.

We want to get an understanding of the contextual factors that influence the behaviours and opinions on medical alarms in nurses and patients. I ask help from ICU nurses and who have experience in single-bed rooms and (former) patients who were conscious during hospital stay. They will be involved in four activities: sensitizing (1 hour), one interview (1hour), one group session (2 hours) and one users test (1 hour)”.

Do you want to participate?
S.L.Cucinella@tudelft.student.nl
+39 320 1890 113

02_Invitation to the study email

H e l l o !

I am Salvo from the *Delft University of Technology*.

I am conducting a study at the *Critical Alarms Lab* (TU Delft) in collaboration with the *Department of Intensive Care* (Erasmus MC), the *IC Connect organization* and the *V&VN Intensive Care association* about the anxiety induced by medical alarms on patients. The aim of the study is to understand the experience of (conscious) ICU patients with medical alarms in relation to the support provided by nurses. Nurses are considered the main resource for patients to cope with medical alarms. We believe this is a very important topic that needs to be explored and addressed to understand the gaps in the interaction, and you can help.

The first phase of the study involves three activities with former ICU patients who were conscious during the hospital stay. I will send you a Booklet that you can complete over a week and each activity would take 5/10 minutes per day to prepare you for the interview; a one-on-one interview that would be no

more than 1 hour long; a group session that would be no more than 2 hours long. No identifying information will be shared. These activities will help us understand the needs and values of patients and will serve as a basis for exploring a future solution.

To guarantee physical and emotional safety, participants are invited to perform the one-on-one interview and the group session at the *Delft University of Technology* or at the *Erasmus MC*; however, participants are allowed to choose the location where they want to be.

If you are interested in participating, please contact me at **S.L.Cucinella@student.tudelft.nl** or **(+39)3201890113**.

In the attachment, you can find the Study Information with more details about the research and the Informed Consent. Please, read these documents carefully, and if you have questions, please, call or send an email to me or the supervisory team.

While waiting for your reply, I send you my best greetings.

03_Welcome to the study email

TUDelft · Critical Alarms Lab · Erasmus MC · IC Connect · vsvn

Welcome to the study

Dear *Mrs XXXX*!

Welcome to the study *"Coping with medical alarms in the ICU: reduce the anxiety on ICU patients by improving the communication with nurses"*. The first phase of the study involves a *Booklet* and a *one-on-one interview*.

- *The Booklet*. You will receive it by post. I would like to ask you to complete the *Booklet* before the interview. In this way, you can reflect on your experience following the questions as a guide. Completing the *Booklet* requires about five/ten minutes per question. You can complete a question per day.

- *The Interview*. We will discuss the questions on the *Booklet* together. We will do some activities using elements designed to trigger associations and/or memories. The interview lasts about an hour.

Why do we want to involve you?

You are the expert, and therefore we consider your experience and knowledge precious and meaningful.

The primary goal of the study is to understand the experience of ICU patients with medical alarms in relation to the support provided by nurses. We are interested in understanding which emotions alarms evoke on conscious patients and the meanings they attribute to them. We are interested in understanding what hinders the interaction between patients and nurses and which needs have to be satisfied to improve comfort when a medical alarm goes off.

You will be involved in the design process in order to ensure that we can meet the needs and dreams of conscious ICU patients for designing a future experience.

What do I need?

- An address to send you the *Booklet*;
- Arrange a date for the interview: *are you available between the 19th and the 23rd of August?*
- Settle the location where I can meet you for the interview.

If you have questions, please contact me at ***S.L.Cucinella@student.tudelft.nl*** or ***(+39) 3201890113***.

I am looking forward to meeting you and to know each other better.

I really appreciate your help.
Thank you for your consideration and your time.

Sincerely,

Salvo

04_Confirmation to participation

Dear *Mrs XXXX*,

Thank you for your reply!
Hereby I confirm the date, time and location of the interview:

Time
10:00 am
Day
21st of August 2019
Location
Arthur van Schendelplein 62
2182 ZJ Hillegom

Please, if you prefer to have the interview sooner / later than 10 am, send me an e-mail with the time more convenient for you.

You will receive the *Booklet* by Post NL between Monday the 12th and Tuesday the 13th of August. Please, let me know if you do not receive it.

Thank you for your consideration and your time.
Sincerely,
Salvo

Study information

Coping with medical alarms in the ICU : reduce the anxiety on ICU patients by improving the communication with nurses.

Salvatore Luca Cucinella, MSc in Design for Interaction, Critical Alarms Lab (CAL), Faculty of Industrial Design Engineering, TU Delft, The Netherlands

---

TU Delft · Critical Alarms Lab · Erasmus MC · IC Connect · V&VN

Purpose of the study

The research is a qualitative study that uses a method developed in TU Delft called Contextmapping. The aim of the study is to get an understanding of the contextual factors that influence the behaviours and opinions on medical alarms in ICU nurses and (former) patients. We will investigate the meanings users attribute to medical alarms and the emotions they arouse, as well as on the interactions between nurses and patients in coping with medical alarms.

The purpose of this research is to generate insights into the experience of ICU nurses and (former) patients to have an understanding of anxiety caused by medical alarms. The research is for a graduation project developed at the *Critical Alarms Lab* (TU Delft) and in collaboration with the *Department of Intensive Care* of the *Erasmus MC* (Rotterdam), the *IC Connect organization* and the *V&VN Intensive Care association*.

Benefits and risks of participating in the study

During this research, the main risk for the participants is to feel uncomfortable due to activities that might evoke negative memories could and provoke psychological stress due to the time they have spent in the ICU.

Comfort and safety of participants are considered of primary importance and the research will be timely interrupted if one of these aspects is not assured. Participants will be invited to stop the activities and quit the study at any time they want. Participants are free to not share their own memories or opinions if they feel uncomfortable. To guarantee physical and emotional safety, all participants will be allowed to choose the location where they want to be and where they feel safer for the interview. It is expected the participants will choose quiet spaces, such as homes or other spaces (e.g., library, community centre, etc.). For the workshop and the follow-up study (users' test) participants will be invited at the Delft University of Technology or the Erasmus MC.

The benefits of this research are to generate knowledge regarding the meanings users attribute to medical alarms. Talking about the stress provoked by medical alarms can help (former) patients to become more aware about the problem, as well as nurses that might learn more about how their patients are emotionally involved and which are the most effective strategies to apply to reduce anxiety. Knowledge acquired might benefit clinical staff by increasing their empathic understanding regarding patients and influencing the way care is delivered, making it more humanised.

At the end of the study, participants will be informed about the results.

Research activities

If participants will accept to take part of the study, they will be involved in three activities:

1. ***Sensitizing*** | September 2019 | Individual activity

   Participants will be provided with a *Booklet* by post. A Booklet is a small book with exercises, containing text and graphics. The aim of the Booklet is to prepare the participant to the *Interview*. Completing the Booklet requires about five/ten minutes per question. Participants have a week to complete it.

2. ***One-on-one interview*** | September 2019 | Individual activity

   During the interview participants will be asked to take part in four activities. The location will be determined according to the participant preference. The interview lasts around one hour.

   The *interview* is structured as follow:

   - *Introduction | Knowing each other (10 min)*
     The researcher and the participant will introduce themselves. More detailed information regarding the project will be also provided.
   - *Activity 1 | Reflecting on the Booklet (10 min)*
     The researcher will ask the participant to reflect on the answers given in the Booklet together.
   - *Activity 2 | Discussing Medical Alarms (15 min)*
     The researcher will ask the participant to talk freely about the medical alarms.
   - *Activity 3 | Talking about Comfort (15 min)*
     The researcher will start a conversation with the participant regarding their experience in the ICU with medical alarms and comfort.

- *Activity 4 | Future experience (10 min)*
  The researcher will ask the participant to provide ideas to generate new insights.

3. ***Workshop*** | October 2019 | Group activity

   Participants will be invited to participate in a group activity at the Erasmus MC. During the Workshop, participants will be update regarding the progress of the research and involved in creative activities to generate together with the researcher ideas regarding the future experience of ICU nurses and patients in reducing anxiety when a medical alarm goes off. The workshop will last around two hours.

4. ***Follow-up study*** | November 2019 | Individual activity

   Participants will be invited at the Delft University of Technology for a hour session. During this session, they will interact with a prototype developed by the researcher and questions about Usability will be asked. The aim of the activity is to gather feedback and validate the design.

More details regarding the activities will be provided participants during the course of the study periods and before each activity.

Personal information collected

During the research, written notes, pictures and audio recordings will be captured. The researcher will use some quotes and pictures that depict important moments of the activities proposed to explain how the research was conducted during presentations, in the report, and the portfolio.

To guarantee the privacy to participants, names, as well as faces of the participants in the pictures, will not be shown in any of the presentations, report or portfolio. Collected Data will be safeguarded physically and will be accessible only to the supervisory team involved in this research. Data will be de-identified. Names of the participants will be coded (*Participant 01)* and faces on the pictures will be blurred in all the situations of use described before. Finally, audio recordings will be destroyed after six months.

Participants can always contact the researcher and the supervisory team to ask questions about the study if any doubts arise.

Participants will be allowed to access their own data if requested. To the participants that will request the data, the researcher will provide a copy of all the materials produced by themselves during the multiple activities, including the voice recordings and pictures that depict only the person interested.

Contacts

Researcher		
S. L. Cucinella		*S.L.Cucinella@student.tudelft.nl*
Supervisory team		
Dr. Ozcan Vieira E.	*Director of the Critical Alarms Lab*	*E.Ozcan@tudelft.nl*
Dr. Kraal, J.J.		*J.J.Kraal@tudelft.nl*
Prof. Dr. D. Gommers	*Head of Intensive Care Unit*	*d.gommers@erasmusmc.nl*

Informed consent

Confirmation of permission to participate in the study:

Coping with medical alarms in the ICU: reduce the anxiety on ICU patients by improving the communication with nurses.

Herewith I confirm, the undersigned, that I give permission to participate in the aforementioned study.

In connection with this, I declare the following:

Please tick the appropriate boxes	Yes	No
Taking part in the study		
• I have read and understood the study information.	○	
• I have had sufficient time to decide on participation in the study.	○	
• I am sufficiently informed about the nature, purpose and procedures of the investigation.	○	
• I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	
• I understand that taking part in the study involves that information will be captured using a Booklet, audio recordings, pictures and written notes.	○	
• I agree to be photographed while taking part in the study	○	○
• I agree to be audio recorded while taking part in the study	○	○
• I give permission that I can be approached for a follow-up study	○	○
Risks associated with participating in the study		
• I am aware that taking part in the study could stress me and evoke negative experiences and memories regarding the medical alarms.	○	
Use of the information in the study		
• I understand that the information I provide will be used to depict important moments of the activities to explain how the research was conducted during presentations, in the report, and in the portfolio	○	
• I understand that personal information collected that can identify me will not be shared beyond the supervisory team.	○	
• I agree that my information can be quoted in research outputs.	○	

Appendix C - Contextmapping tools

Future use and reuse of the information by others

- I give permission for the materials generated in this study to be archived in TuDelft repository so it can be used for future research and learning. ○

□

Signature

For the participant

I have read the information sheet carefully and understand what I freely agree with.

Date Participant's name Participant's signature

---------- ---------- ----------

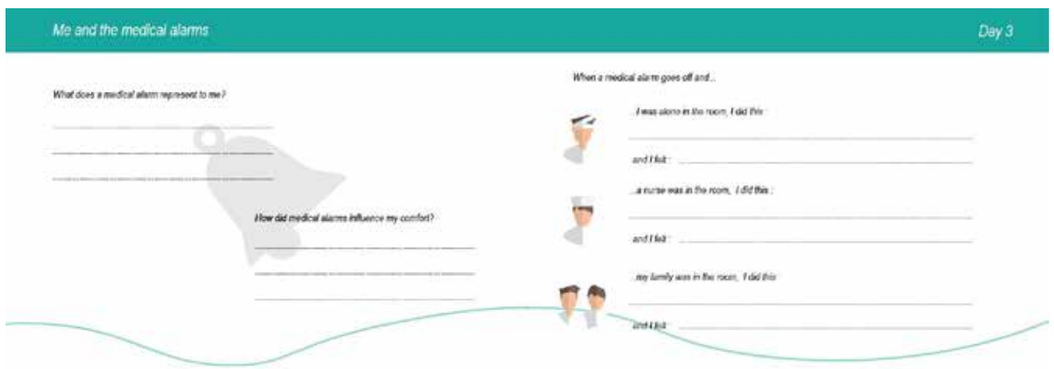
For the researcher

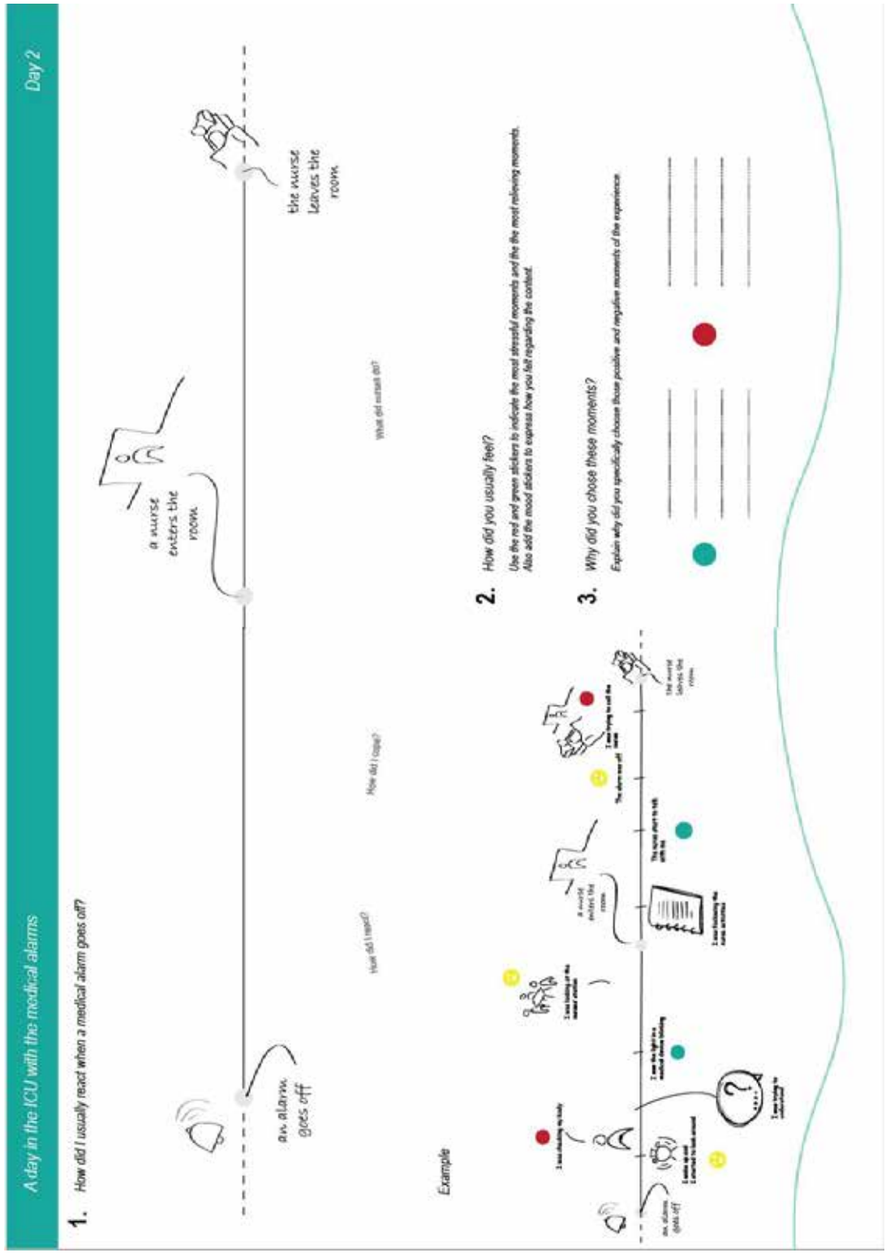
I hereby certify, the undersigned, that I have fully explained to the above-mentioned patient the nature, purpose and procedures of the examination, that I have given them a copy of the corresponding "patient information" and that they have volunteered to participate to the investigation.

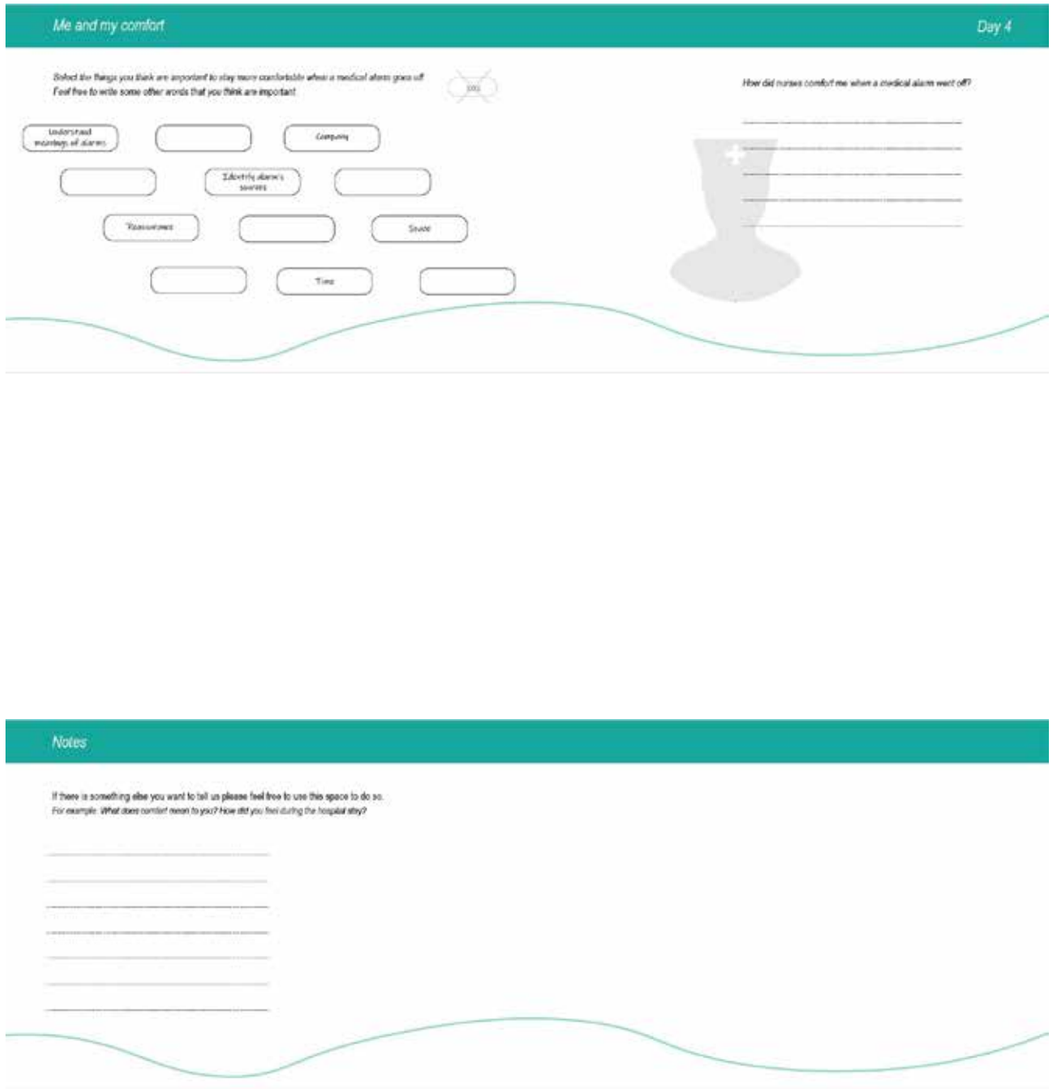
Date Researcher's name Researcher's signature

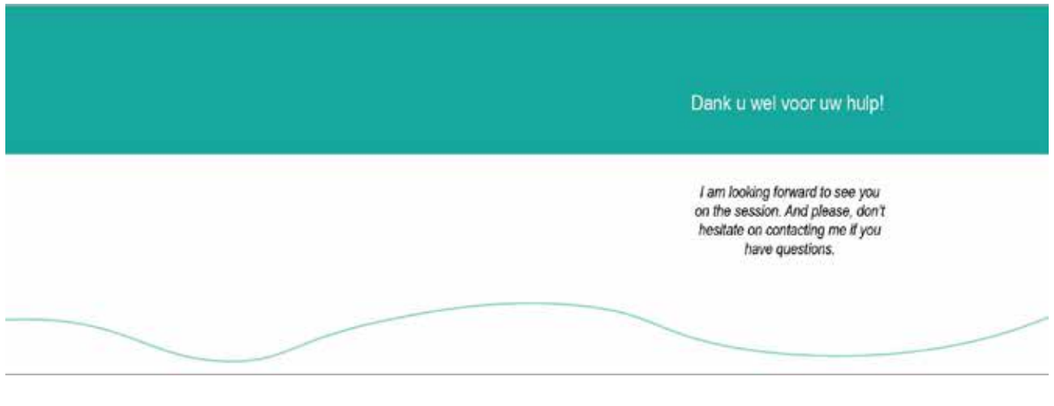
---------- ---------- ----------


Being a patient
Day 1
Who am i?
Something about me as a former ICU patient...
My age is
I was admitted at the ICU on the
I spent a total of
days in the ICU
I was
conscious
unconscious
My hospital was
I was in a
single-bed room
multi-beds room
What is it important to you for a patient in the ICU?

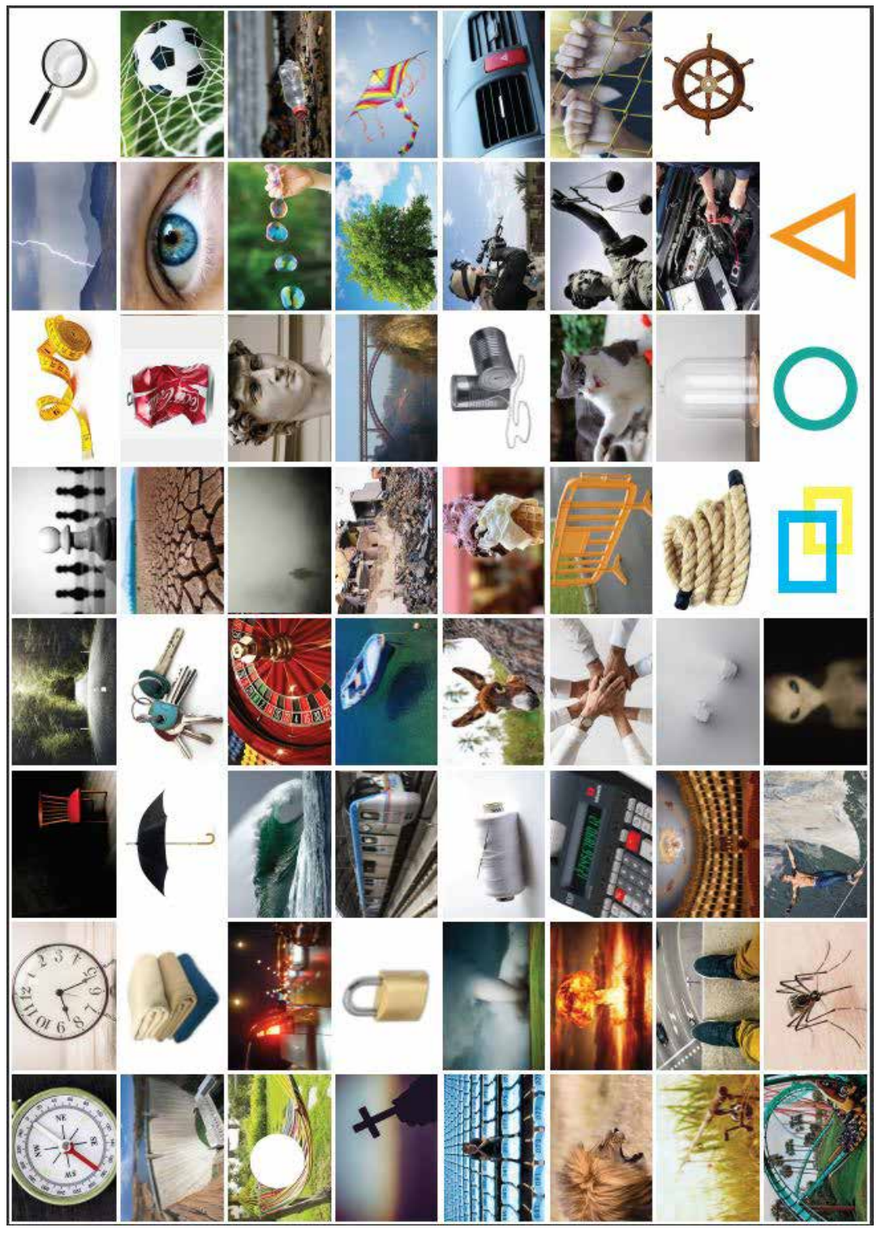

Me and the medical alarms
Day 3
What does a medical alarm represent to me?
How did medical alarms influence my comfort?
When a medical alarm goes off and...
...I was alone in the room, I did this:
and I felt:
...a nurse was in the room, I did this:
and I felt:
...my family was in the room, I did this:
and I felt:

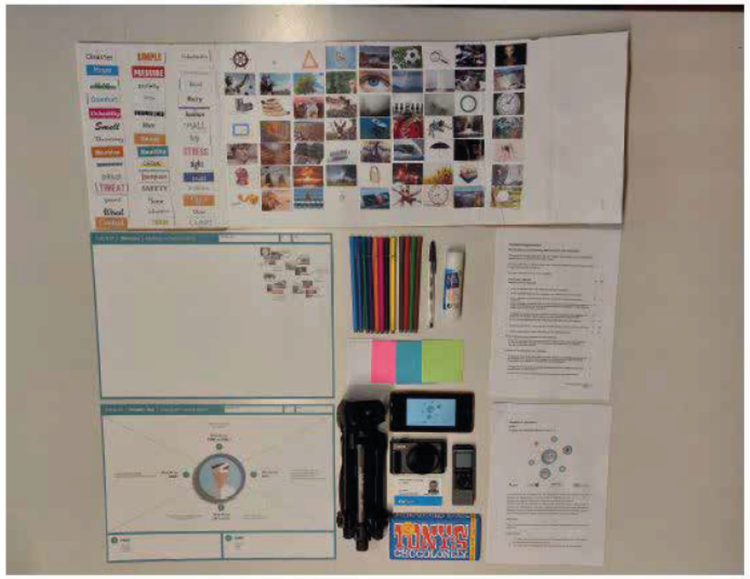

A day in the ICU with the medical alarms
Day 2
1. How did I usually react when a medical alarm goes off?
an alarm goes off
a nurse enters the room
the nurse leaves the room
Example
How did I react?
What did nurses do?
2. How did you usually feel?
3. Why did you chose these moments?

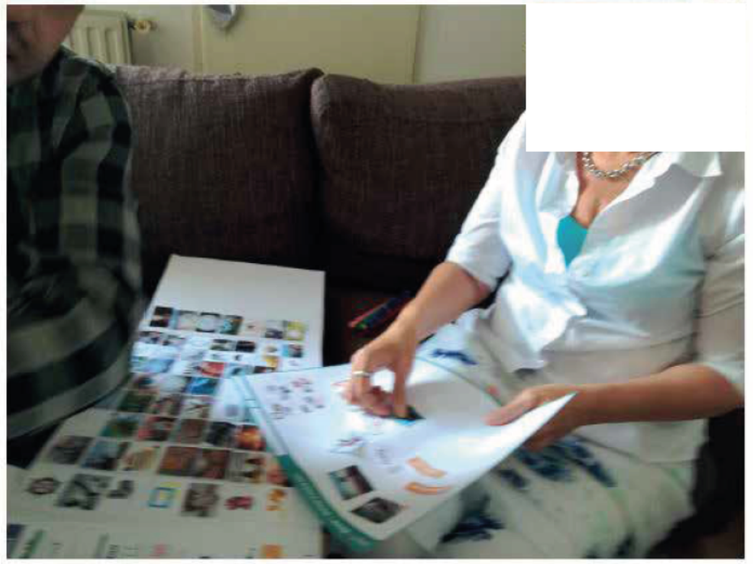

Me and my comfort
Day 4
Select the things you think are important to stay more comfortable when a medical alarm goes off
Feel free to write some other words that you think are important
Understand meanings of alarms
Company
Identify alarm's sources
Reassurance
Speak
Time
How did nurses comfort me when a medical alarm went off?
Notes
If there is something else you want to tell us please feel free to use this space to do so.
For example: What does comfort mean to you? How did you feel during the hospital stay?


Dank u wel voor uw hulp!
I am looking forward to see you on the session. And please, don't hesitate on contacting me if you have questions.

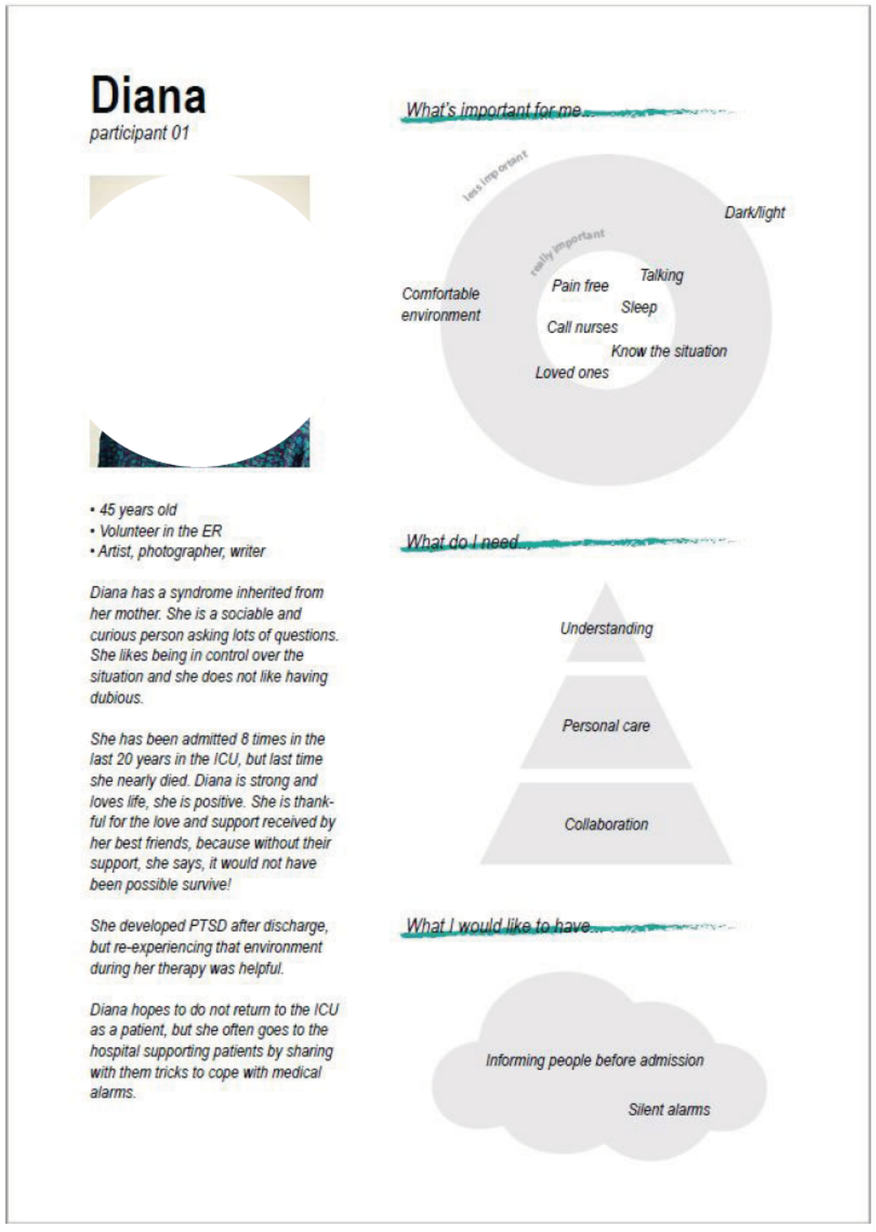
Smell	Visit	Choice	
SMALL	Problem	Control	
tight	Information	Help	
Light	TEAM	STRESS	
DISCOVERY	Ghost	Noisy	
Understanding	SAFETY	TRAP	
Communication	Home	ignored	
trust	Comfort	OVERWHELMED	
human	Disaster	anxiety	
SIMPLE	Uncertainty	FEAR	
Wired	Victim		
Healthy	THREAT		
Emergence	CRIME		
Difficult	Machine		
Unhealthy	PRESSURE		
Hope	Bound		

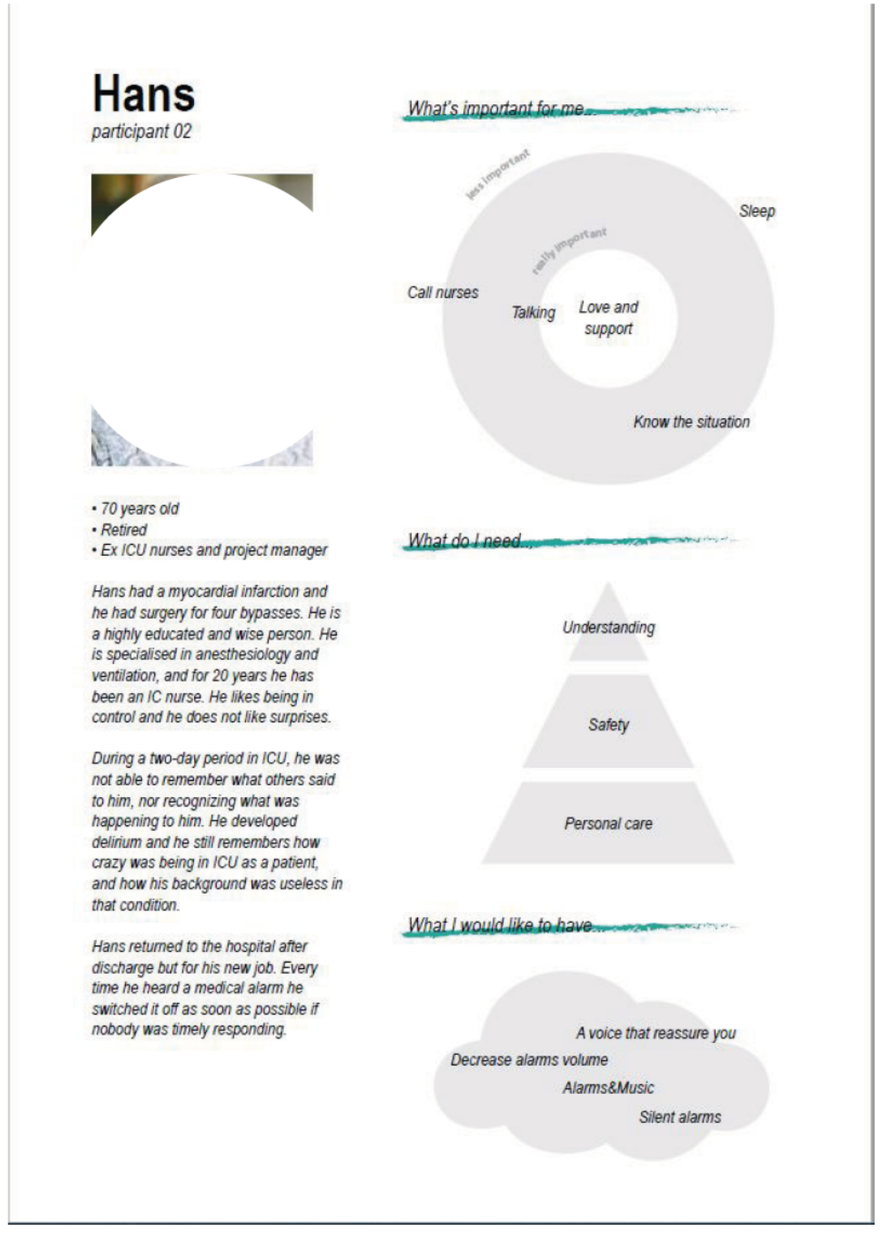




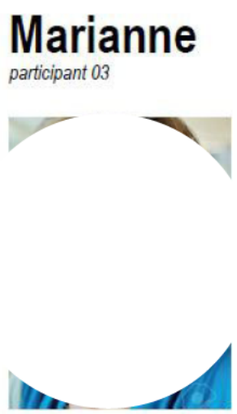


Appendix D - Personas





Appendix E - User Interfaces



Marianne

participant 03

- *75 years old*
- *Retired*
- *Chairman IC Connect, former ICU patient, former Youth Healthcare doctor*

Marianne had a chronic severe and autoimmune disease. She is an ambitious and independent person who always has been full of responsibilities and in control.

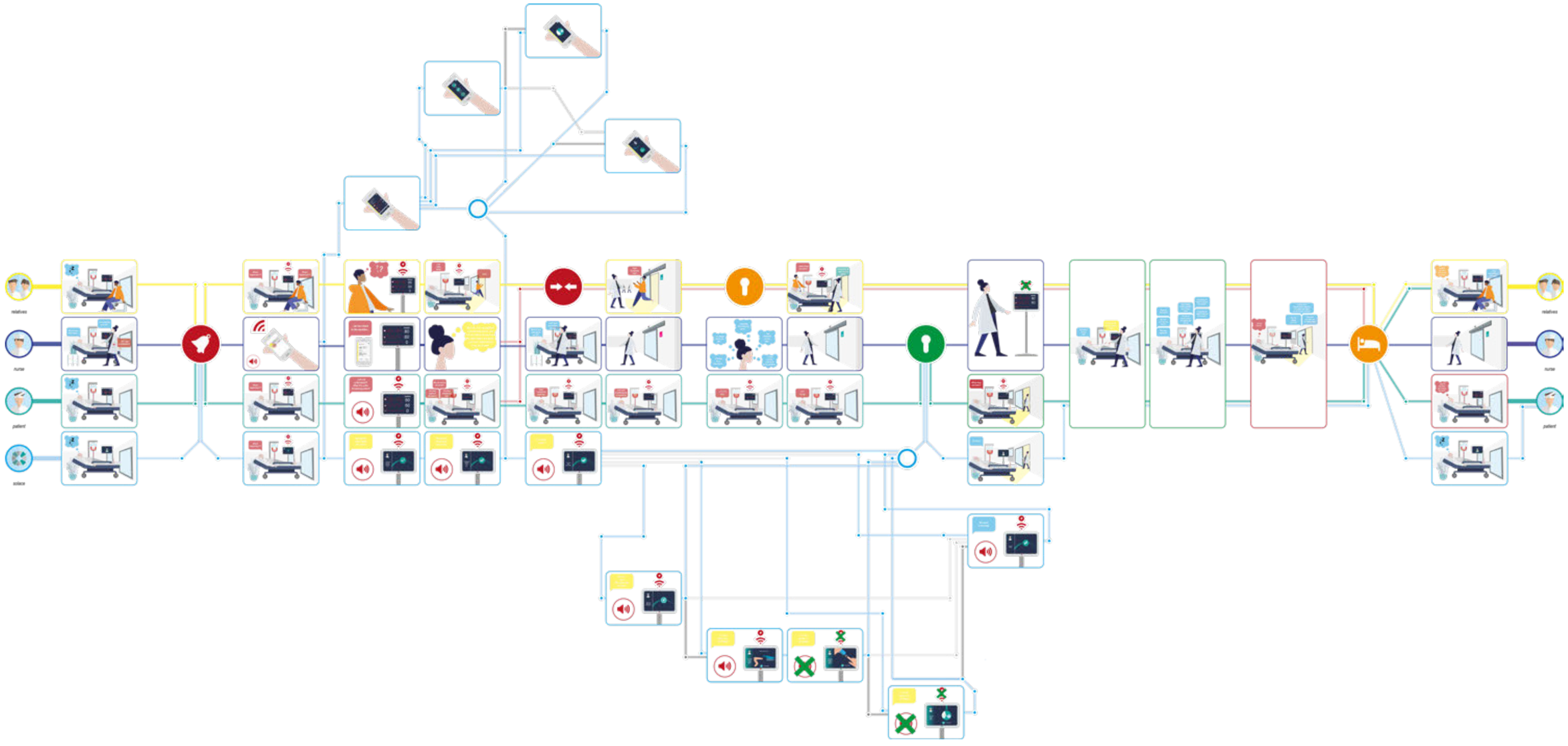
Marianne woke up in the ICU after 10 days of coma. She remembered only the last 4 days in ICU and when she was conscious. Her husband has been always next to her and his technical and emotional support was fundamental for her recovery.

In ICU, she got delirium because of lack of sleep and the stress caused by lack of care, the noisy environment and the inability to talk and move.

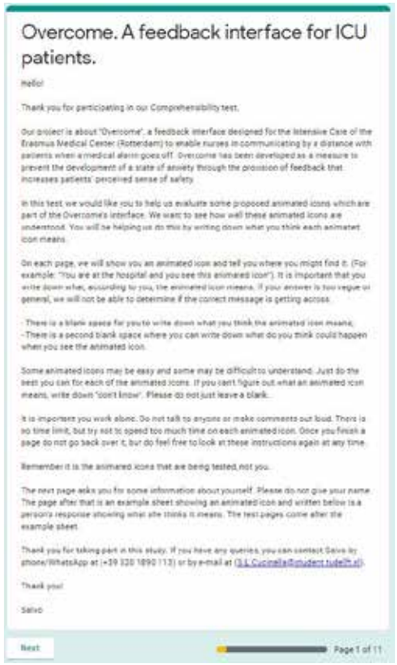
After 11 years, Marianne still deals with her PTSD. She can not tolerate crowded and noisy situations. Every sound bothers and agitates her.

Marianna wants to help as much as possible (former) ICU patients and relatives in her organization.

Appendix F - Experience flow



Appendix G - Questionnaire- Testing comprehensibility


Overcome. A feedback interface for ICU patients.

Hello!

Thank you for participating in our Comprehensibility test.

Our project is about "Overcome", a feedback interface designed for the Intensive Care of the Erasmus Medical Center (Rotterdam) to enable nurses in communicating by a distance with patients when a medical alarm goes off. Overcome has been developed as a measure to prevent the development of a state of anxiety through the provision of feedback that increases patients' perceived sense of safety.

In this test, we would like you to help us evaluate some proposed animated icons which are part of the Overcome's interface. We want to see how well these animated icons are understood. You will be helping us do this by writing down what you think each animated icon means.

On each page, we will show you an animated icon and tell you where you might find it. (For example: "You are at the hospital and you see this animated icon"). It is important that you write down what, according to you, the animated icon means. If your answer is too vague or general, we will not be able to determine if the correct message is getting across.

- There is a blank space for you to write down what you think the animated icon means;
- There is a second blank space where you can write down what do you think could happen when you see the animated icon.

Some animated icons may be easy and some may be difficult to understand. Just do the best you can for each of the animated icons. If you can't figure out what an animated icon means, write down "don't know". Please do not just leave a blank.

It is important you work alone. Do not talk to anyone or make comments out loud. There is no time limit, but try not to spend too much time on each animated icon. Once you finish a page do not go back over it, but do feel free to look at these instructions again at any time.

Remember it is the animated icons that are being tested, not you.

The next page asks you for some information about yourself. Please do not give your name. The page after that is an example sheet showing an animated icon and written below is a person's response showing what she thinks it means. The test pages come after the example sheet.

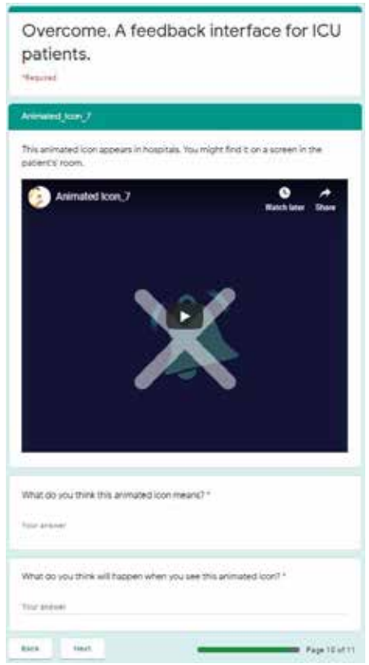
Thank you for taking part in this study. If you have any queries, you can contact Salvo by phone/WhatsApp at (+39 320 1890 113) or by e-mail at (S.L.Cucinella@student.tudelft.nl).

Thank you!

Salvo

Next

Page 1 of 11


Overcome. A feedback interface for ICU patients.

*Required

Animated_Icon_7

This animated icon appears in hospitals. You might find it on a screen in the patient's' room.

Animated Icon_7

Watch later

Share

What do you think this animated icon means? *

Your answer

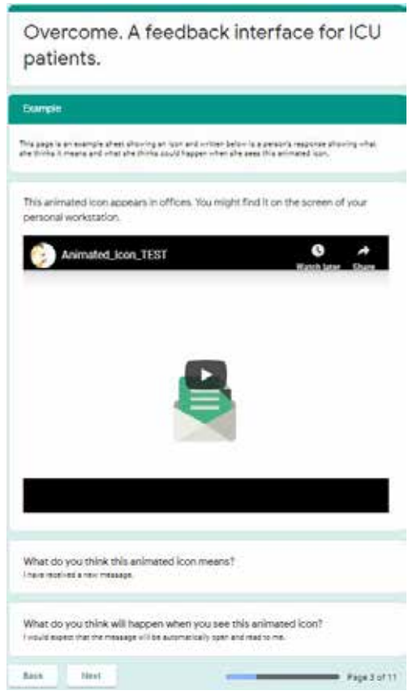
What do you think will happen when you see this animated icon? *

Your answer

Back

Next

Page 10 of 11


Overcome. A feedback interface for ICU patients.

Example

This page is an example sheet showing an icon and written below is a person's response showing what she thinks it means and what she thinks could happen when she sees this animated icon.

This animated icon appears in offices. You might find it on the screen of your personal workstation.

Animated_Icon_TEST

Watch later

Share

What do you think this animated icon means?

I have received a new message.

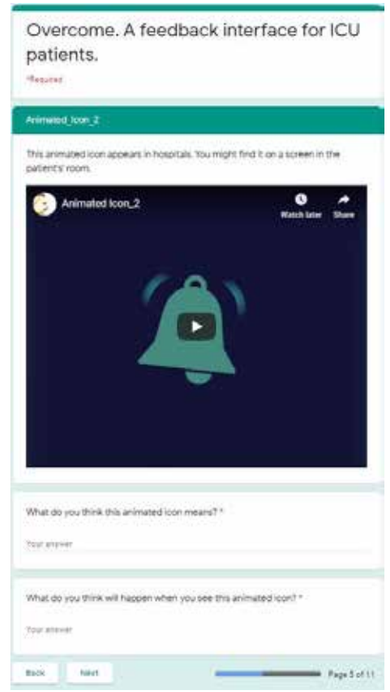
What do you think will happen when you see this animated icon?

I would expect that the message will be automatically open and read to me.

Back

Next

Page 3 of 11


Overcome. A feedback interface for ICU patients.

*Required

Animated_Icon_2

This animated icon appears in hospitals. You might find it on a screen in the patient's' room.

Animated Icon_2

Watch later

Share

What do you think this animated icon means? *

Your answer

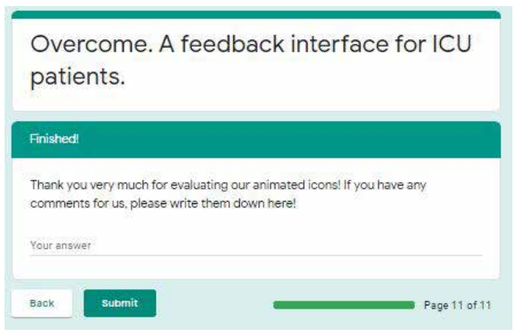
What do you think will happen when you see this animated icon? *

Your answer

Back

Next

Page 5 of 11


Overcome. A feedback interface for ICU patients.

Finished!

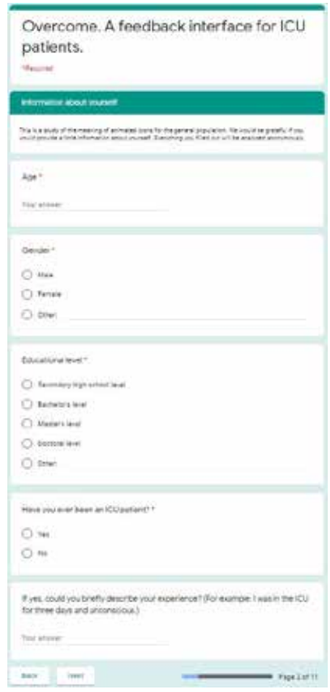
Thank you very much for evaluating our animated icons! If you have any comments for us, please write them down here!

Your answer

Back

Submit

Page 11 of 11


Overcome. A feedback interface for ICU patients.

*Required

Information about yourself

This is a study of the meaning of animated icons for the general population. We would be greatful, if you would provide a little information about yourself. Everything you'll read on will be analyzed anonymously.

Age *

Your answer

Gender *

Male

Female

Other

Educational level *

Secondary high school level

Bachelor's level

Master's level

Doctoral level

Other

Have you ever been an ICU patient? *

Yes

No

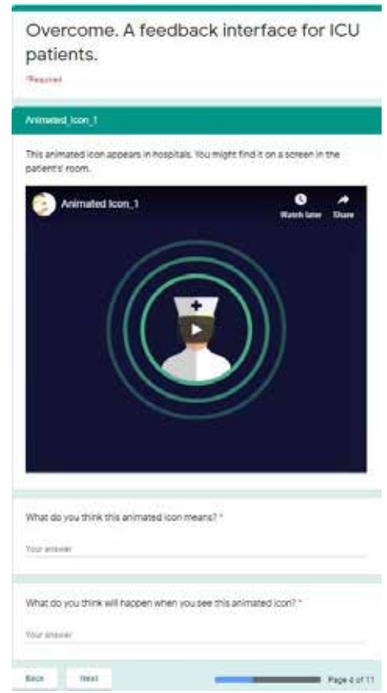
If yes, could you briefly describe your experience? (For example: I was in the ICU for three days and unconscious.)

Your answer

Back

Next

Page 2 of 11


Overcome. A feedback interface for ICU patients.

*Required

Animated_Icon_1

This animated icon appears in hospitals. You might find it on a screen in the patient's' room.

Animated Icon_1

Watch later

Share

What do you think this animated icon means? *

Your answer

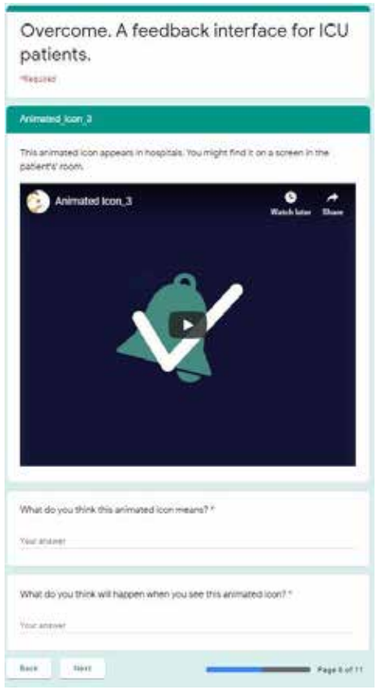
What do you think will happen when you see this animated icon? *

Your answer

Back

Next

Page 4 of 11


Overcome. A feedback interface for ICU patients.

*Required

Animated_Icon_3

This animated icon appears in hospitals. You might find it on a screen in the patient's' room.

Animated Icon_3

Watch later

Share

What do you think this animated icon means? *

Your answer

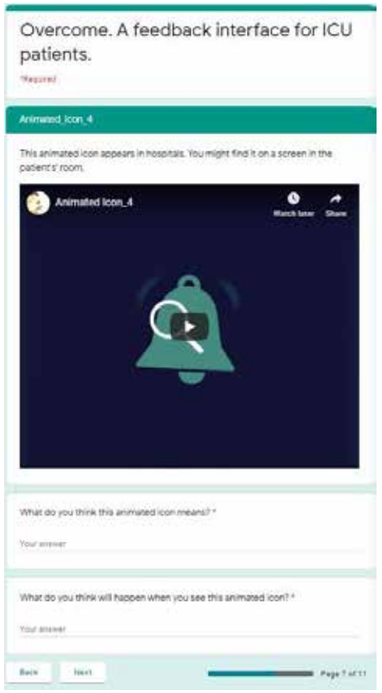
What do you think will happen when you see this animated icon? *

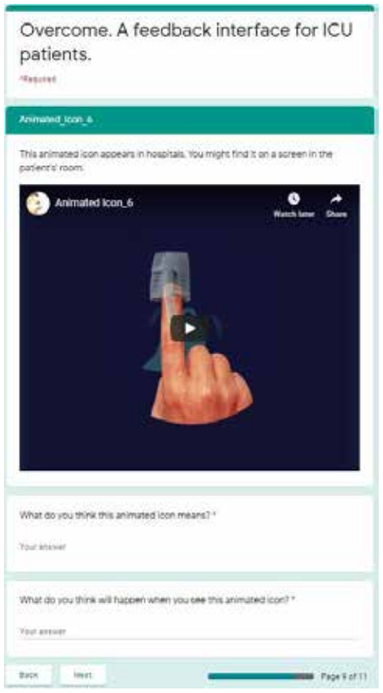
Your answer

Back

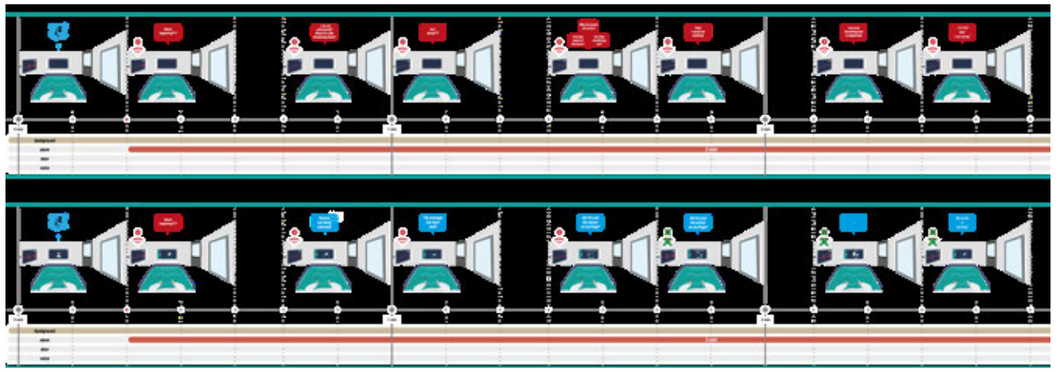
Next

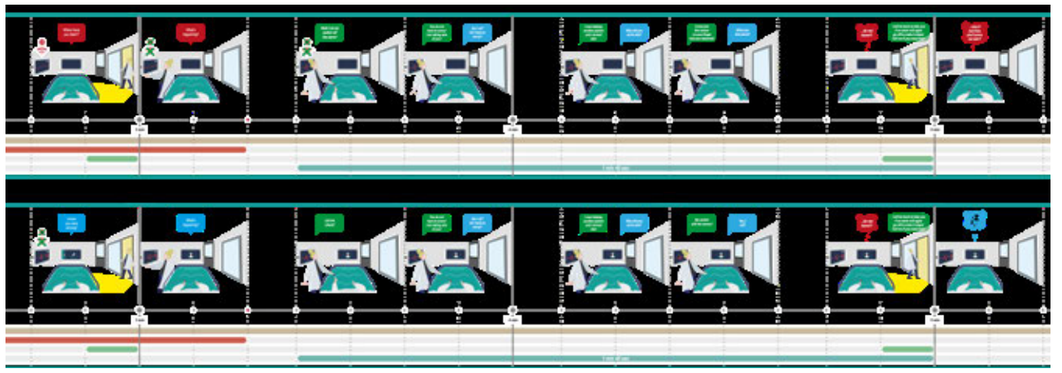
Page 6 of 11





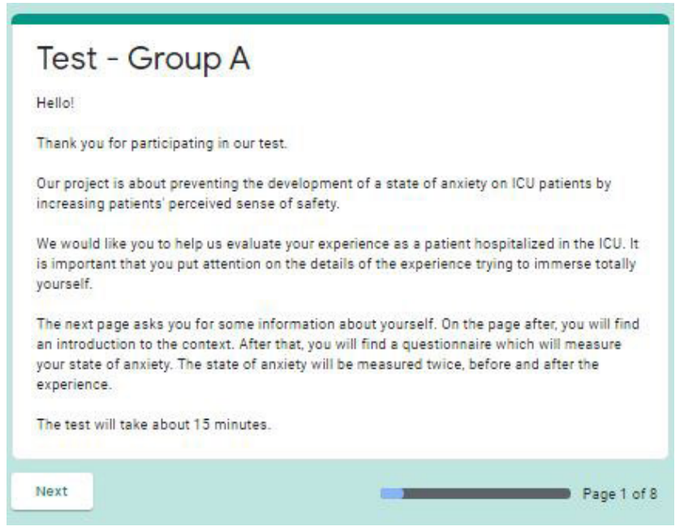
Appendix H - Virtual reality video storyboard

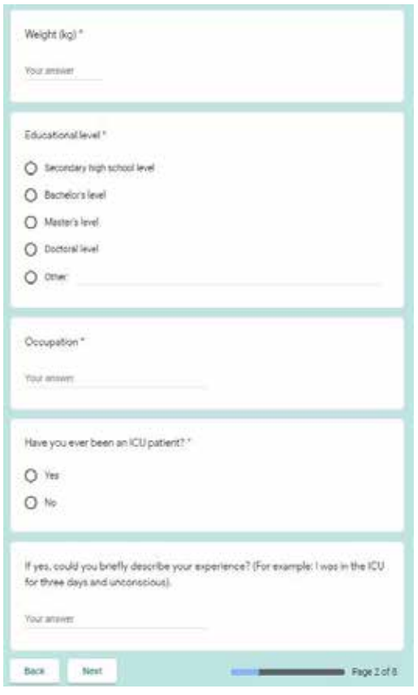




Appendix I - VR flyer for recruitment

Appendix L - Questionnaire - Evaluating the design





Test - Group A

*Required

Self-evaluation questionnaire - State Anxiety Inventory

A number of statements which people have used to describe themselves are given below. Read each statement and then blacken the appropriate circle to the right of the statement to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

When you are taking the test try to think aloud.

In this study the items are scored on a 4-point scale (1) NOT AT ALL, (2) SOMEWHAT, (3) MODERATELY SO, (4) VERY MUCH SO

I feel calm *

I feel secure *

I am tense *

I feel strained *

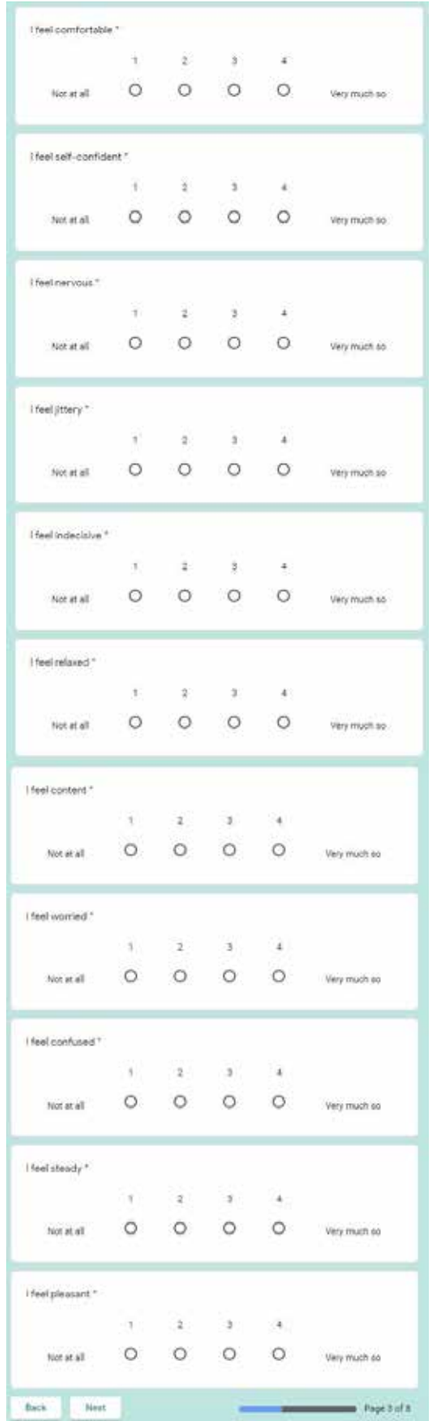
I feel at ease *

I feel upset *

I am presently worrying over possible misfortunes *

I feel satisfied *

I feel frightened *



I feel comfortable *

I feel self-confident *

I feel nervous *

I feel jittery *

I feel indecisive *

I feel relaxed *

I feel content *

I feel worried *

I feel confused *

I feel steady *

I feel pleasant *

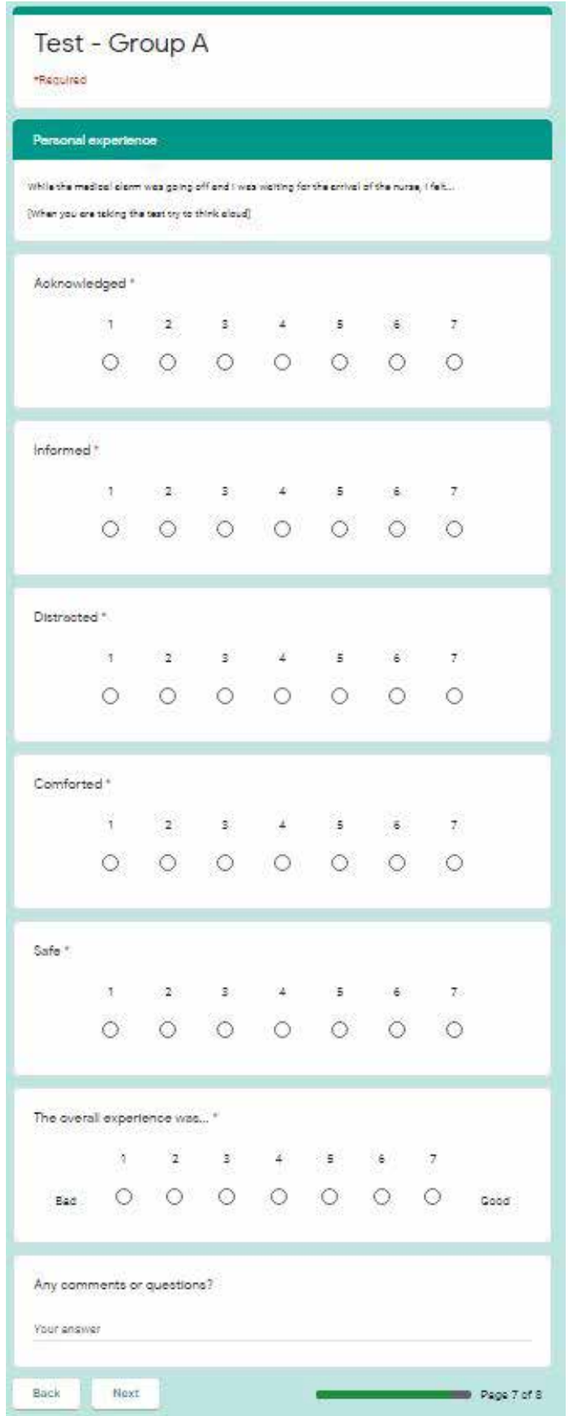
Not at all

Very much so

Back

Next

Page 3 of 8



Test - Group A

*Required

Personal experience

While the medical alarm was going off and I was waiting for the arrival of the nurse, I felt...

[When you are taking the test try to think aloud]

Aoknowledged *

Informed *

Distracted *

Comforted *

Safe *

The overall experience was... *

Bad

Good

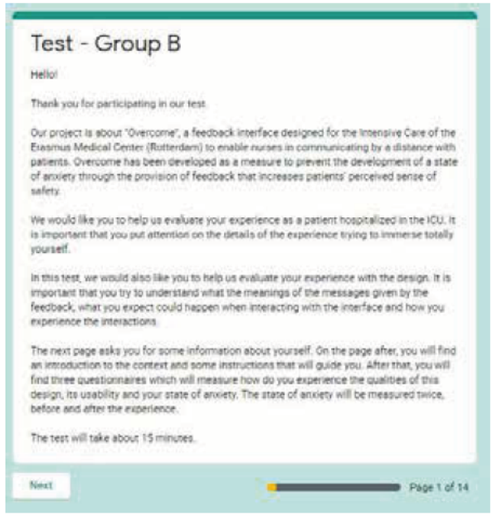
Any comments or questions?

Your answer

Back

Next

Page 7 of 8



Test - Group B

Hello!

Thank you for participating in our test.

Our project is about "Overcome", a feedback interface designed for the Intensive Care of the Erasmus Medical Center (Rotterdam) to enable nurses in communicating by a distance with patients. Overcome has been developed as a measure to prevent the development of a state of anxiety through the provision of feedback that increases patients' perceived sense of safety.

We would like you to help us evaluate your experience as a patient hospitalized in the ICU. It is important that you put attention on the details of the experience trying to immerse totally yourself.

In this test, we would also like you to help us evaluate your experience with the design. It is important that you try to understand what the meanings of the messages given by the feedback, what you expect could happen when interacting with the interface and how you experience the interactions.

The next page asks you for some information about yourself. On the page after, you will find an introduction to the context and some instructions that will guide you. After that, you will find three questionnaires which will measure how do you experience the qualities of this design, its usability and your state of anxiety. The state of anxiety will be measured twice, before and after the experience.

The test will take about 15 minutes.

Next

Page 1 of 14

Test Group B

*Required

Information about yourself

These questions are solely to analyse the measurements. Everything you filled out will be analyzed anonymously.

Date *

Your answer

Name *

Your answer

Gender *

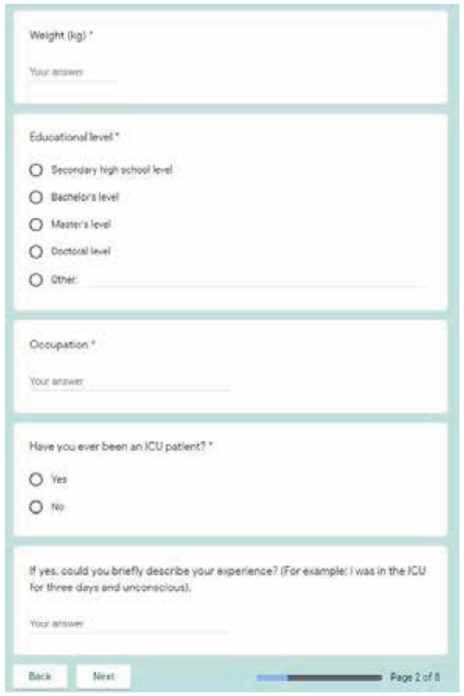
- Male
- Female
- Other:

Date of Birth (dd/mm/yy) *

Your answer

Height (cm) *

Your answer



Weight (kg) *

Your answer

Educational level *

- Secondary high school level
- Bachelor's level
- Master's level
- Doctoral level
- Other:

Occupation *

Your answer

Have you ever been an ICU patient? *

- Yes
- No

If yes, could you briefly describe your experience? (For example: I was in the ICU for three days and unconscious).

Your answer

Back Next

Page 2 of 8

Test Group B

*Required

Self-evaluation questionnaire - State Anxiety Inventory

A number of statements which people have used to describe themselves are given below. Read each statement and then blacken the appropriate circle to the right of the statement to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

When you are taking the test try to think aloud.

In this study the items are scored on a 4-point scale (1) NOT AT ALL, (2) SOMEWHAT, (3) MODERATELY SO, (4) VERY MUCH SO

I feel calm *

I feel secure *

I am tense *

I feel strained *

I feel at ease *

I feel upset *

I am presently worrying over possible misfortunes *

I feel satisfied *

I feel frightened *

1 2 3 4

Not at all — Very much so

I feel comfortable *

I feel self-confident *

I feel nervous *

I feel jittery *

I feel indecisive *

I feel relaxed *

I feel content *

I feel worried *

I feel confused *

I feel steady *

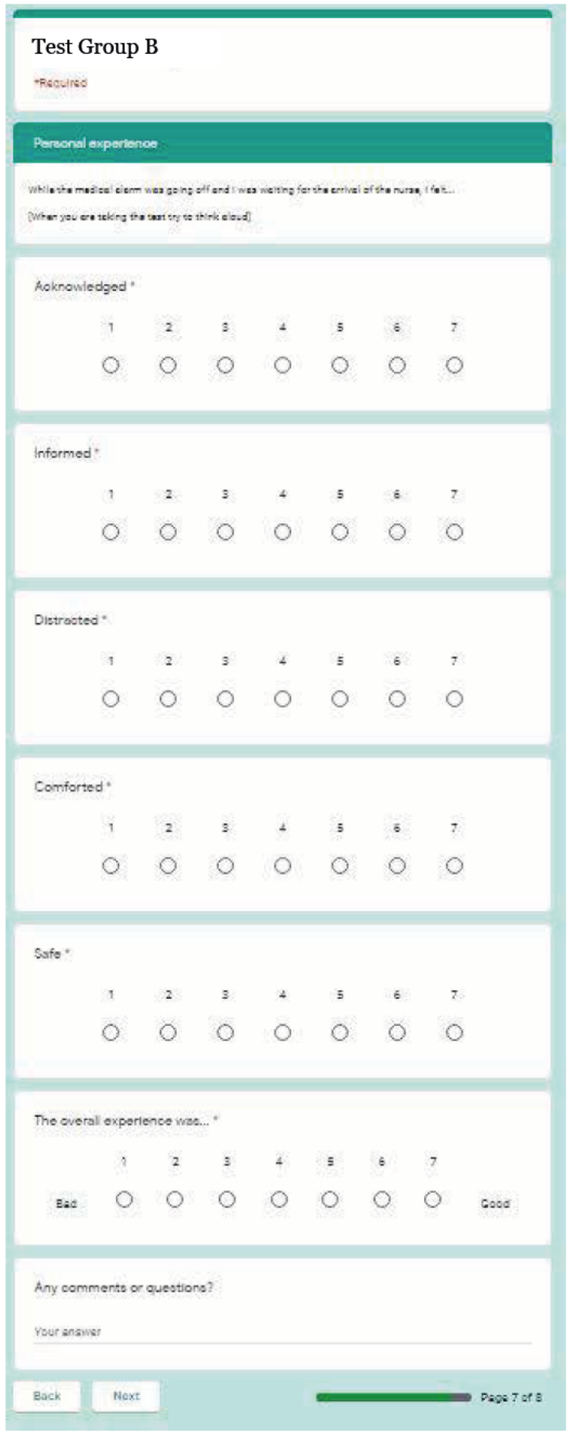
I feel pleasant *

1 2 3 4

Not at all — Very much so

Back Next

Page 3 of 8



Test Group B

*Required

Personal experience

While the medical alarm was going off and I was waiting for the arrival of the nurse, I felt...

(When you are taking the test try to think aloud)

Aoknowledged *

1 2 3 4 5 6 7

Informed *

1 2 3 4 5 6 7

Distracted *

1 2 3 4 5 6 7

Comforted *

1 2 3 4 5 6 7

Safe *

1 2 3 4 5 6 7

The overall experience was... *

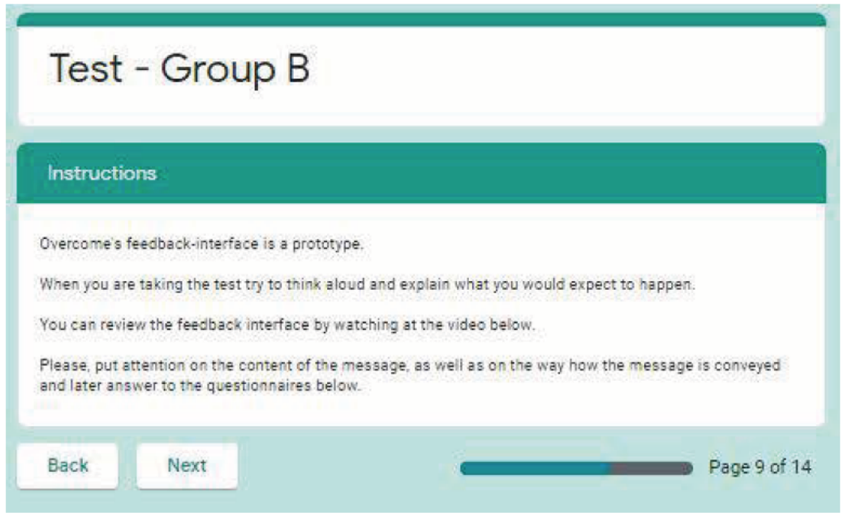
1 2 3 4 5 6 7

Bad Good

Any comments or questions?

Your answer

Back Next Page 7 of 8



Test - Group B

Instructions

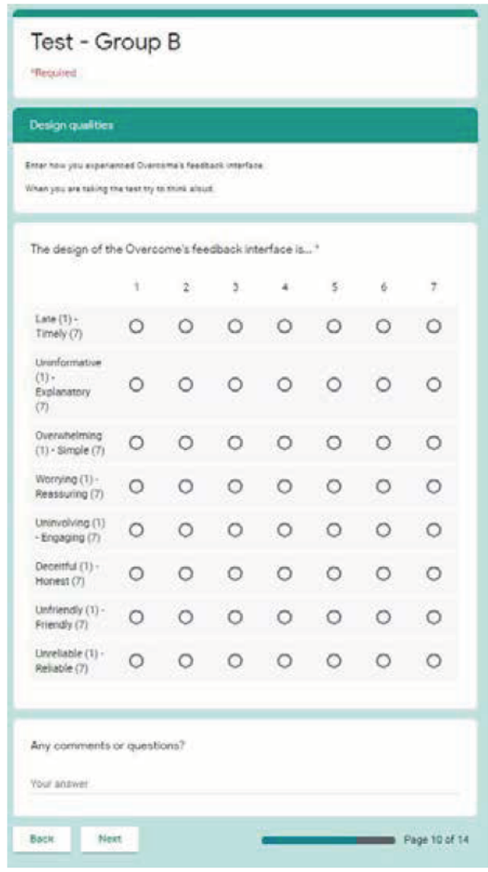
Overcome's feedback-interface is a prototype.

When you are taking the test try to think aloud and explain what you would expect to happen.

You can review the feedback interface by watching at the video below.

Please, put attention on the content of the message, as well as on the way how the message is conveyed and later answer to the questionnaires below.

Back Next Page 9 of 14



Test - Group B

*Required

Design qualities

Enter how you experienced Overcome's feedback interface.

When you are taking the test try to think aloud.

The design of the Overcome's feedback interface is... *

	1	2	3	4	5	6	7	
Late (1) - Timely (7)								
Uninformative (1) - Explanatory (7)								
Overwhelming (1) - Simple (7)								
Worrying (1) - Reassuring (7)								
Uninvolving (1) - Engaging (7)								
Deceitful (1) - Honest (7)								
Unfriendly (1) - Friendly (7)								
Unreliable (1) - Reliable (7)								

Any comments or questions?

Your answer

Back Next Page 10 of 14

Test - Group B

*Required

Presentation of Information

The general principles for the presentation of information are given. Read each statement and then blacken the appropriate circle to indicate whether or not you agree or disagree. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present experience best.

When you are taking the test try to think aloud.

In this study, the items are scored on a 7-point scale (1) STRONGLY AGREE to (7) STRONGLY DISAGREE.

All the information on the Overcome's feedback interface was easy to detect. *

1 2 3 4 5 6 7

Strongly Agree ○ ○ ○ ○ ○ ○ ○ Strongly Disagree

All the information on the Overcome's feedback interface was free from distractions. *

1 2 3 4 5 6 7

Strongly Agree ○ ○ ○ ○ ○ ○ ○ Strongly Disagree

All the information on the Overcome's feedback interface was easy to discriminate/distinguish. *

1 2 3 4 5 6 7

Strongly Agree ○ ○ ○ ○ ○ ○ ○ Strongly Disagree

All the information on the Overcome's feedback interface was easy to interpret. *

1 2 3 4 5 6 7

Strongly Agree ○ ○ ○ ○ ○ ○ ○ Strongly Disagree

All the information on the Overcome's feedback interface was concise. *

1 2 3 4 5 6 7

Strongly Agree ○ ○ ○ ○ ○ ○ ○ Strongly Disagree

All the information on the Overcome's feedback interface was consistent. *

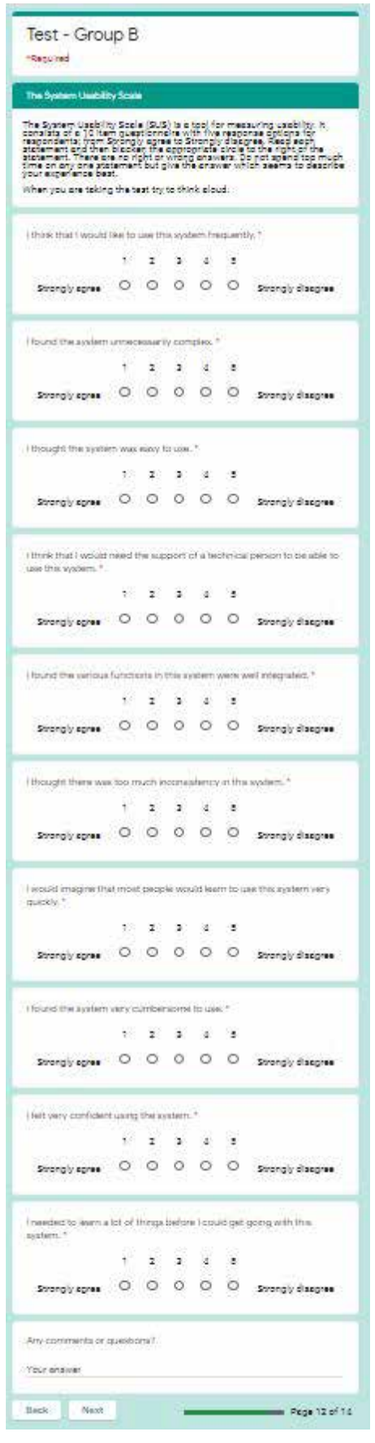
1 2 3 4 5 6 7

Strongly Agree ○ ○ ○ ○ ○ ○ ○ Strongly Disagree

Any comments or questions?

Your answer

Back Next Page 11 of 14



Test - Group B

*Required

The System Usability Scale

The System Usability Scale (SUS) is a tool for measuring usability. It consists of a 10 item questionnaire with five response options for respondents; from Strongly agree to Strongly disagree. Read each statement and then blacken the appropriate circle to the right of the statement. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your experience best.

When you are taking the test try to think aloud.

I think that I would like to use this system frequently. *

1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

I found the system unnecessarily complex. *

1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

I thought the system was easy to use. *

1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

I think that I would need the support of a technical person to be able to use this system. *

1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

I found the various functions in this system were well integrated. *

1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

I thought there was too much inconsistency in this system. *

1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

I would imagine that most people would learn to use this system very quickly. *

1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

I found the system very cumbersome to use. *

1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

I felt very confident using the system. *

1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

I needed to learn a lot of things before I could get going with this system. *

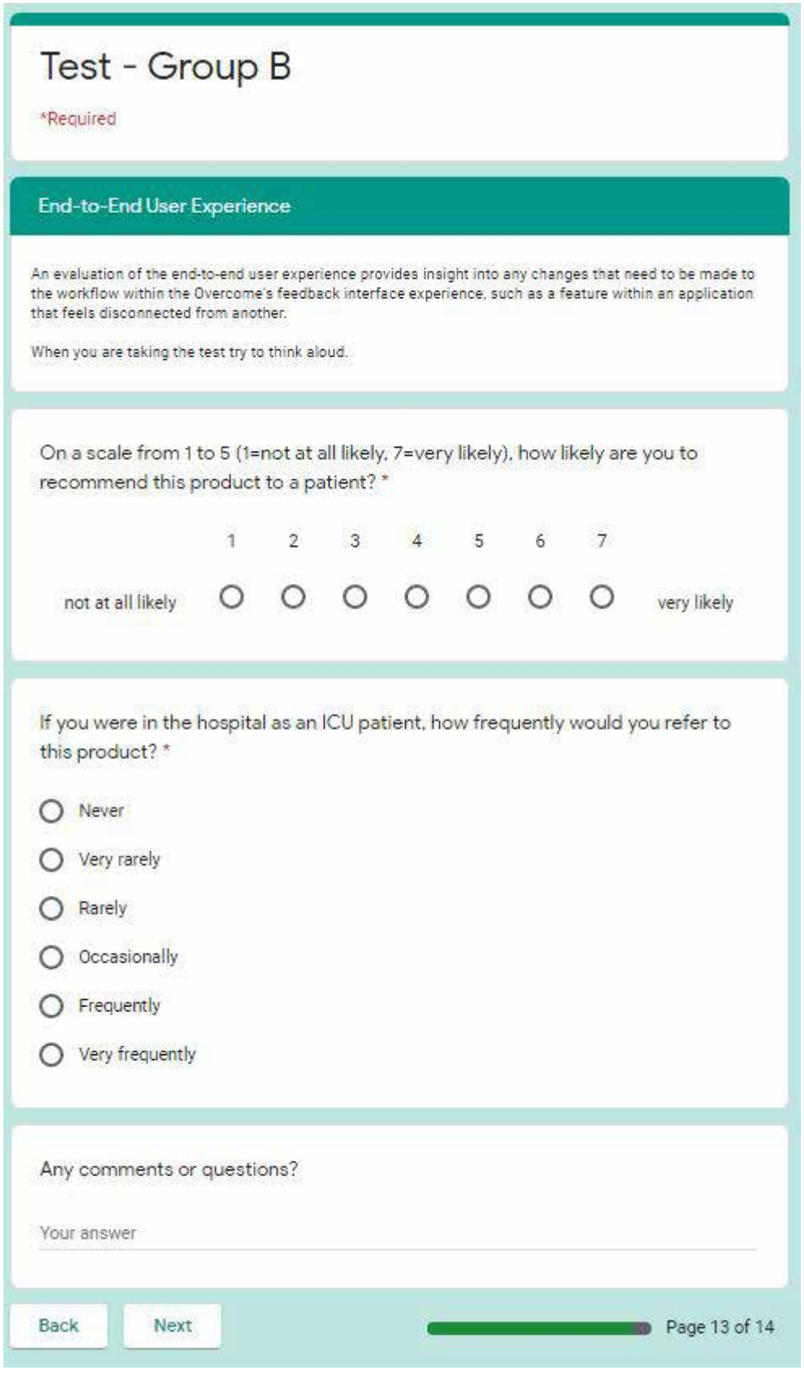
1 2 3 4 5

Strongly agree ○ ○ ○ ○ ○ Strongly disagree

Any comments or questions?

Your answer

Back Next Page 12 of 14



Test - Group B

*Required

End-to-End User Experience

An evaluation of the end-to-end user experience provides insight into any changes that need to be made to the workflow within the Overcome's feedback interface experience, such as a feature within an application that feels disconnected from another.

When you are taking the test try to think aloud.

On a scale from 1 to 5 (1=not at all likely, 7=very likely), how likely are you to recommend this product to a patient? *

1 2 3 4 5 6 7

not at all likely ○ ○ ○ ○ ○ ○ ○ very likely

If you were in the hospital as an ICU patient, how frequently would you refer to this product? *

- ○ Never
- ○ Very rarely
- ○ Rarely
- ○ Occasionally
- ○ Frequently
- ○ Very frequently

Any comments or questions?

Your answer

Back Next Page 13 of 14