# ACD FINAL REPORT

## NOISE-FREE ICU

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# INDEX

# 1 INTRODUCTION

This section will provide an overview of the original assignment, characteristics of the user and the vision that was created at the start of the concept phase.

## 1.1 ASSIGNMENT

As part of a renovation plan, the Erasmus MC is implementing a new type of intensive care unit. The problem with current ICU is the multitude of alarm sounds causing stress among patients. The sounds can also lead to alarm fatigue for caregivers, causing them to respond less consistently to alarms, which may lead to life-threatening situations (Sendelbach and Funk (2013). Erasmus MC has commissioned to design solutions for the noise free ICU.

## 1.2 ICU PATIENTS

Patient ending up in the ICU recover from severe surgeries and are often on heavy medication. Data on cognitive capabilities suggest that approximately one third of the ICU patients develop ongoing and persistent cognitive impairment after their ICU stay (Gordon et al., 2004) . When designing for ICU patients, the cognitive limitations that patients might have during their stay need to be taken into account such as:

- Decreased (visual) memory
- Decreased attention & concentration
- Decreased processing speed (Gordon et al., 2004)

## 1.3 DESIGN VISION

In the first part of the project research revealed that currently the sounds of machinery and alarms are, next to the negative effects, an important source of feedback. This feedback is expected to disappear, as pager and nursery warning systems are becoming more smart, leading to the alarms only be heard by the designated people and no longer disturb patients.

Therefore the focus in the second part of the project was not so much on finding solutions for reducing noise, but rather on finding a solution for the lack of feedback that will arise when the ICU rooms are becoming silent, preferably in a silent way. The vision used during this project can be summarized in the following sentence:

*"Reassure patients in the silent environment by providing information and feedback concerning events within the ICU and the time of arrival of the nurse"*

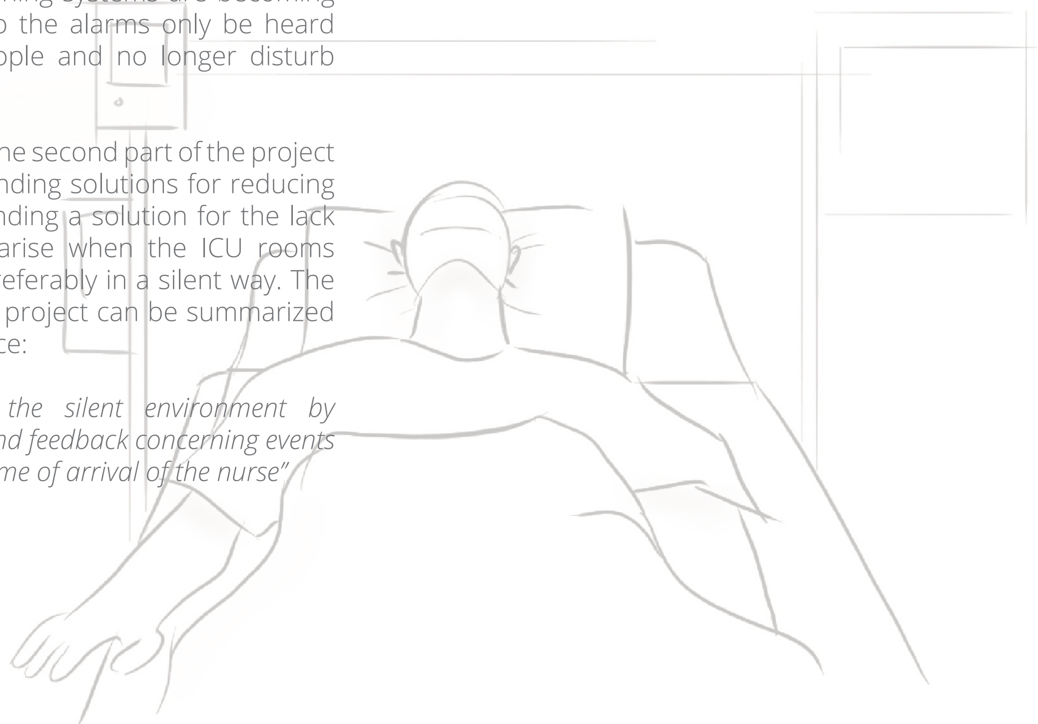

*Figure 1: ICU patient*

## 1.4 FOCUS POINTS

As designing for the noise free ICU is a broad topic, this section will explain the focus points of the project and the main issues that were tackled.

*Current situation*

The problems that arise currently in case patients are exposed to an unfamiliar noise are illustrated in figure 2. In the current situation, in case of an alarm or unfamiliar noise, the patients does not know the meaning of the sound and might questions if and when a nurse will be arriving.
Patients uncertainty plays a big part in the development of stress within the ICU. Research showed that patients not knowing or understanding the whole story from the beginning can even lead to patients refusing treatments and feeling frightened. (Hupcey, 2000). To be able to reassure patients in these situations, patients need to know whether a nurse took notice of the alarm in the ICU or a call for help, and get an indication of how long it's going to take for help to arrive.

*Feeling involved and attached*

The effects of enabling patient to receive this information should lead to the patients perceiving a stronger bond with and trust in the nurse . Besides this could lead to patients feeling more involved in the recovery process, which is a desire of the majority of ICU patients. (Alasad, Tabar and Ahmad ,2015).

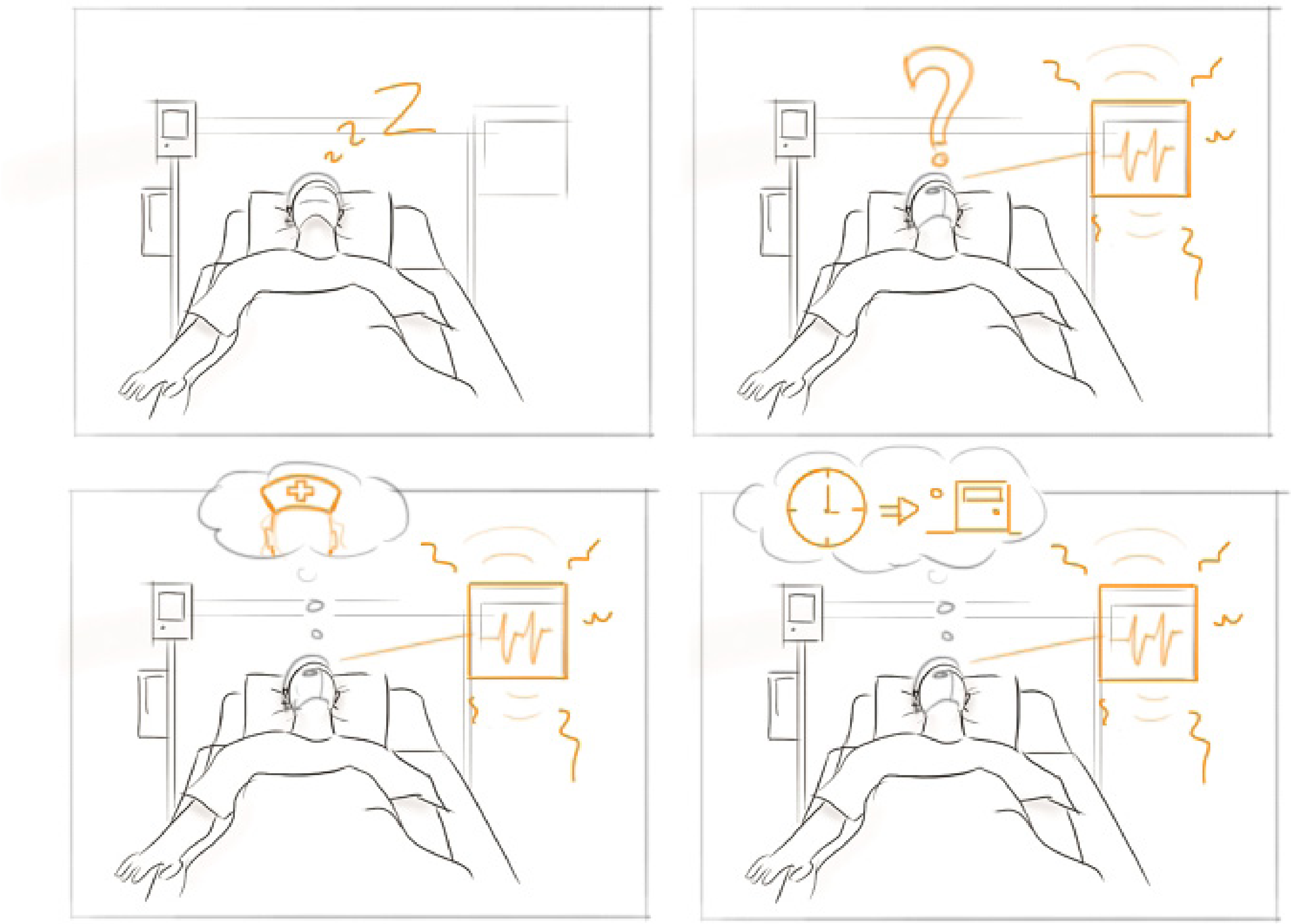

*Figure 2: Current situation*

# 2 THE CONCEPT

The following chapter will explain the concept that should solve the problems described in the previous chapter. The working principle and the feedback of all the components of the system will be addressed. Although the system consist out of a patient and nurse device, the project scope leads to a main focus on the patient device in the concept phase.

## 2.1 IDEATION AND CONCEPT CHOICE

The research done into standard guidelines when working in ICU ,and the focus points described before, lead to a general list of requirements used for the ideation and concept phase (appendix A). In the end one concept has been chosen to develop further into detail and in the end a prototype. This process will be described in the next chapter, a summary of the ideation and concept phase can be found in appendix B.

## 2.2 CONCEPT SUMMARY: THE HAND-e

The HAND-e is a handheld device that informs patients about events within the intensive care unit. The device is connected to an armband attached to the upper arm of the nurse. Depending on physical and cognitive capabilities of the patient, the device informs patients when a nurse took notice of an event and gives an indication about the estimated time of arrival of help by giving either vibration or light signals. Additionally, the patients is able to squeeze the middle part of the device in case of pain and send a message to the nurse in charge.

In both the case of an event or a patient indicating pain, a message is sent to the armband of the nurse and translated into a vibration signal (see section 2.5). When the nurse indicates she took notice and is on her way, the HAND-e will confirm this to the patients and possibly prepare for hospital staff entering the room. In case the patients is not able to hold the device or preferes to have both hands free, the HAND-e can be stored in the bedside compartment. Like this, the user will still be able to receive the feedback, while at the same time charge the device.

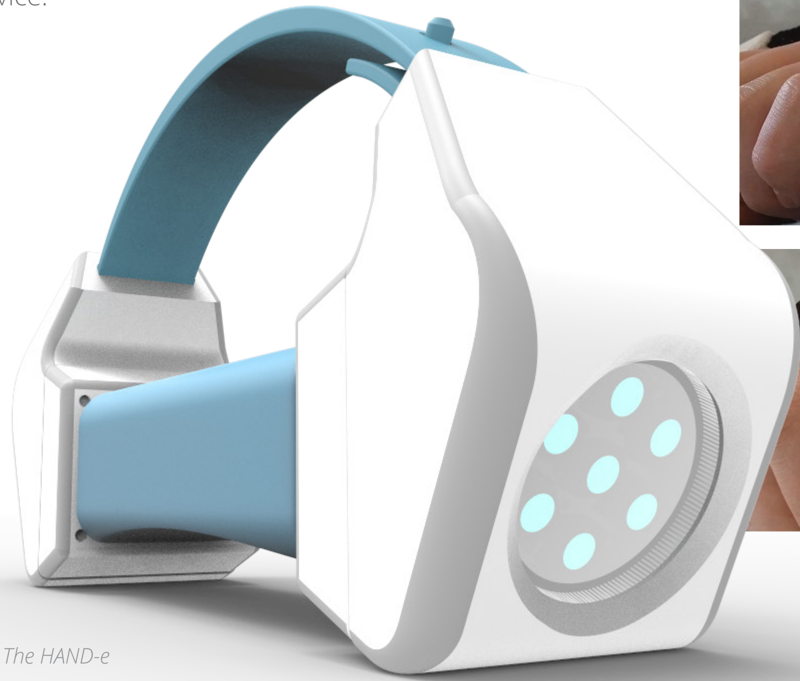

*Figure 3: The HAND-e*

## 2.3 COMPONENTS

To able to describe the working principle in detail, the most important components of the HAND-e and their function will be shortly described.

1. Casing: holding together the different components of the HAND-e patient device
2. Strap: makes sure the HAND-e doesn't get lost in bed when the patient is asleep
3. Grip: place where the patient can hold and squeeze in case of pain.
4. Vibration motor: the vibration motor provides feedback in the first stages of the recovery process ( see patient feedback, page 8)
5. LED ring: the ring provides feedback in the second stage of the recovery process ( see patient feedback, page 8)
6. WIFI module: the module that connects the product to the system and the nurse armband
7. Gyroscope: detecting movement of the arm to help decide the recovery stage of the patient
8. Pressure sensors: the sensors that can detect pain when the grip is pressurized.
9. Chargeable battery: powering the system
10. Lens: diffusing the light cominf from the LED and protecting the internal parts of the HAND-e

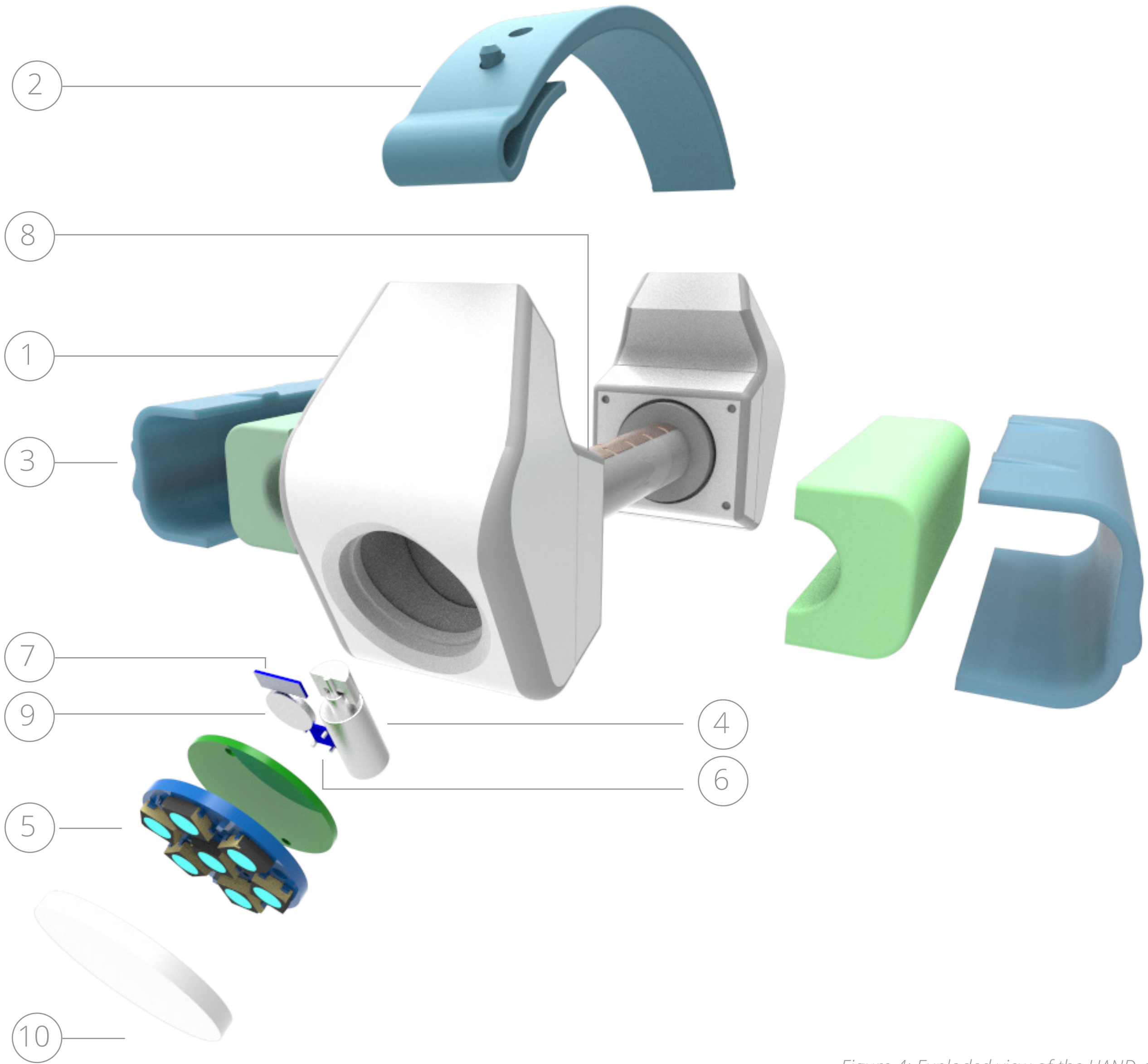


*Figure 4: Exploded view of the HAND-e*

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## 2.4 PATIENT FEEDBACK

The amount and type of feedback that is provided to the patients depends on both the stage of recovery of the ICU patients, as the type of event, which can either be a patient's call for emergency or an automatic message sent by machinery. The HAND-e should only be used after the patient is able to undergo a short introduction concerning the functionalities and meaning of the feedback the patient will receive. The procedure during an event or pain indication will be described in this section, the reason behind the specific types of feedback are explained in the grey sections.

### 2.4.1 FEEDBACK DURING AN EVENT

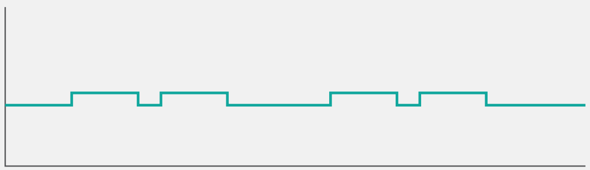
During an event or alarming situation, which can be either something that has to do with the patient's values that are being monitored or machinery and equipment, the patient might perceive feelings of doubt or anxiety. The following procedure should guide the patient through this experience and provide feedback to achieve a feeling of reassurance.

*Warning stage*

In case the system recognizes an event that requires the nurse to come over, a message will be sent to the nurse armband over the WIFi network. To report this to the patient, the grip of the HAND-e will start vibrating gently in a rhythm that comforts the patient and possibly wakes the patient up when sleeping.

Figure 5: Warning feedback

*To comfort the patient, the vibration in the warning stage will simulate a standard breathing pattern of a person in rest : 12 to 16 breaths per minute ( Health Encyclopedia University of Rochester, ). The signal will gradually increase in strength to awake the patient and prepare for a nurse about to arrive.*

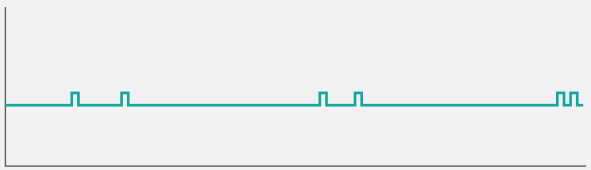


*Confirmation stage*

As soon as the nurse indicates the took notice of the situation in the ICU room, the pattern of vibration will change to indicate this confirmation. The vibration will now give an indication about the time left before the nurse will enter the room.

Figure 6: Confirmation feedback

*The pattern indicating the time up till arrival of the nurse has been tested in the ergonomic research ( see chapter 4). Based on the general time the typical event would normally take, the time between two vibrations will become shorter as the nurse approaches. In the user test this was prefered over an indication of the amount of minutes left.*



*Advanced feedback stage*

As soon as the physical state of the patients allows for movement of the arm, the visual feedback can be activated. This will activate the LED ring and visualize the time up till arrival of the nurse by means of light instead of vibration. Where the vibration pattern can be seen as intuitive, the meaning of different color signals can be hard to process and remember for ICU patients with a low cognitive and physical state. People that are not able to move their arms are most likely in a state of low physical and cognitive capabilities. Therefore the choice has been made to only enable this feedback for the more active patients, this way, the feedback change also resembles the next stage in the recovery process of the patient. The LED ring will start with a blue pulsating light to comfort the patient and will gradually change to green as the nurse approaches.

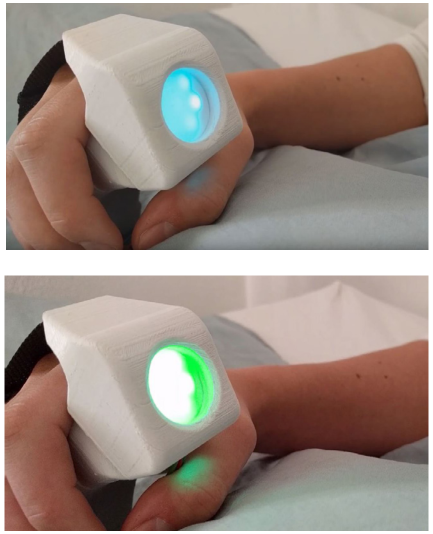


*Figure 7: Advanced feedback*

*Research investigating the effects of red, green and blue light has showed that blue light (n=x) has the most positive effect on bodily values such as heart rate and temperature which are important in the development of stress (Litscher et al., 2013). The green color on the other hand can be associated with something good about to happen, in this case, the arrival of help from the nurse.*

## 2.4.2 FEEDBACK DURING PAIN

In case the patient squeezes the middle part of the HAND-e, the device will give the same gentle vibration as in the case of an automatic event to indicate a message has been sent to the responsible nurse. The confirmation and advanced feedback stage will be identical.

*Figure 8: Pain indication*

*To possibly predict the severity and need for assistance and prevent nurses from receiving an overload of help requests, the systems that gathers the pressure data and monitored values needs to be able to distinguish standard events from emergencies. (See chapter 5 : conclusions & recommendations)*

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## 2.5 NURSE FEEDBACK

In the new ICU configuration of Erasmus MC , a nurse will take responsibility over 2 patients at a time. Preferably the armband does not conflict with current routines and improves the workflow by taking away the necessity to check a pager and the overload of noises

### 2.5.1 FEEDBACK DURING AN EVENT

In case there is need for action for the nurse ,like an abnormal change in the patient's values, the nurse is warned by a vibration signal typical for a specific event. As the nurse signal might be coming from one of the two patients, the area that needs to be stroked is color coded by means of light. Each patient of the two patients and their rooms are represented by a color, so the nurse can quickly recognize which patients is in need of help.

*Currently an important standard in ICUs used for specification of alarms is the IEC 6060128, which standardized particular sounds and sound patterns for particular physiological functions (Edworthy, 2006). Since the patient device was the main focus, deciding the specific vibration signals was out of the scope for this project. However, the guidelines that these standards use for alarms prove the possibility to link signals of a specific order and frequency to a certain physiological event, and should be taken into consideration in the design of the vibration signals.*

### 2.5.2 FEEDBACK DURING PAIN

In case the patient squeezing the middle part of the HAND-e, the pressure sensors measure the force and predict the possible severity and need for assistance. The nurse armband will vibrate accordingly and provide the nurse with a more accurate indication than a standard emergency button would do.

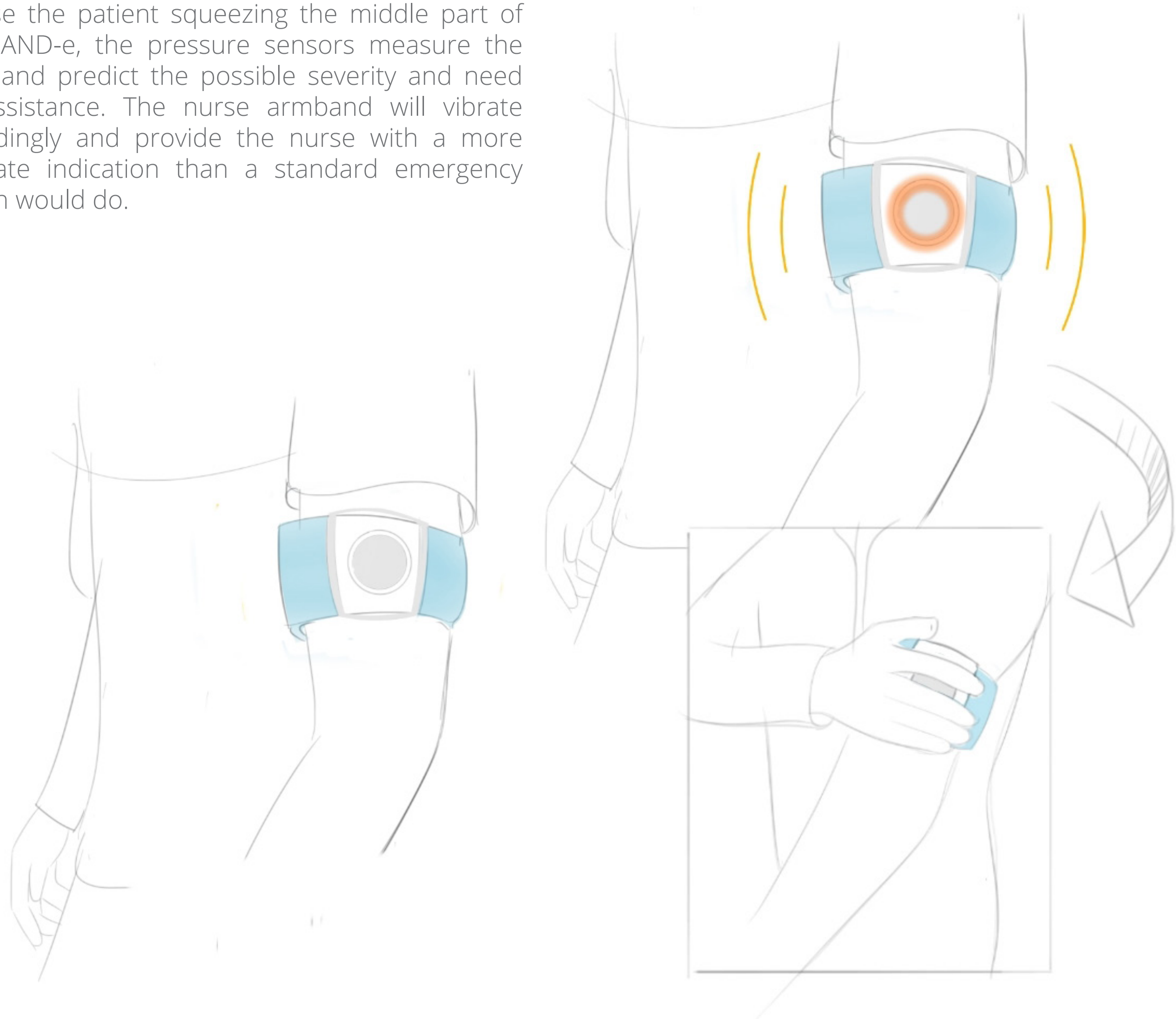

*Figure 9: Nurse armband interaction*

## 2.6 RECOVERY MONITORING

Additional benefits of the system include improved monitoring of patients recovery by looking into the data gathered by the HAND-e. Besides this data, the increase in strength can be measured along the recovery process.

As an extra feature, the HAND-e could be used for patients to test their own strength by squeezing the middle part as hard as they can and receive a visual response from the LED ring. This mode can be activated by shaking the HAND-e. As this interaction fits more with patients that are in a further stage of the recovery, it could be explained when patients are moved from the ICU to the normal ward. Like this, the different stages of vibration feedback, visual feedback and testing the strength resemble the patients recovery. This way, the functionalities of the HAND-e grow with the capabilities of the patient along the way.

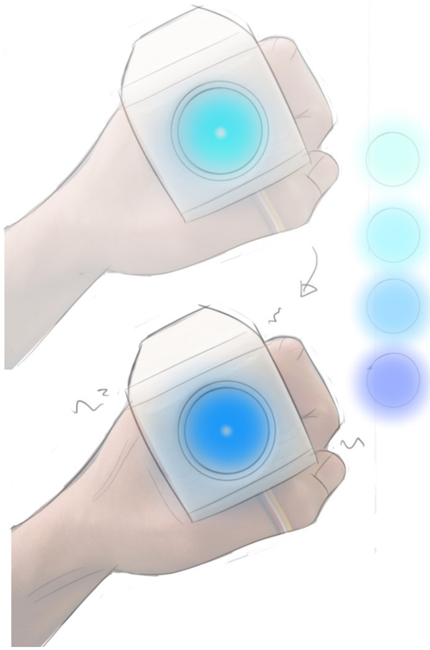
*Figure 10: Enabling strength test*

## 2.7 EFFICIENCY

As the systems recognizes when a nurse has entered the room and is about to solve the event she has been notified for, the estimation of the time it takes a nurse to arrive to the room in this specific event can be optimized. By gathering this data the Erasmus can get an overview of the efficiency of hospital staff during a specific event and discover possible bottlenecks.

## 2.8 SYSTEM & NETWORK CONFIGURATION

To be able to transfer message from the ICU station of two rooms towards the central monitoring system and , in the end, the nurse armband, the two rooms should be equipped with a data processor or gateway which is already used in most dutch hospitals. The HAND-e, nurse armband and machinery act as nodes in the WiFi network. The processor decodes the incoming data such as the values measured by machinery or indications of pain and warns the central monitoring station and nurse armband in case there is need for assistance.

After a nurse indicated she is processing the request, the data collect identifies when a nurse has entered the room by checking the proximity of the signal. The data that is gathered can be stored in a database of the central monitoring unit to provide insights in the recovery of the patient and efficiency of hospital staff.

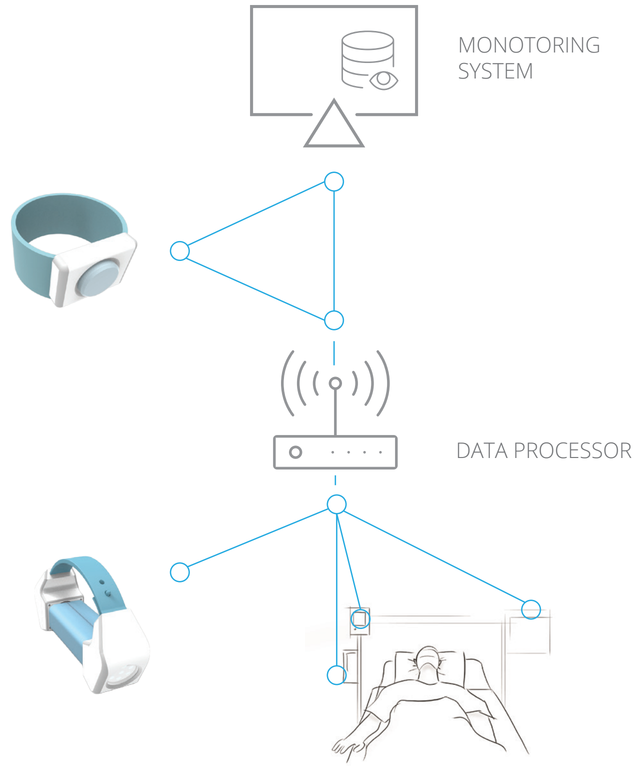

*Figure 11: Network configuration*

# 3 PRODUCT DETAILS

This section will explain design choices that have been made concerning egonomics, aesthetics , materials and composition of the different components.

## 3.1 ERGONOMICS

The dimensions of the HAND-e are based on standard dimensions of the human hand extracted from the DINED database (DINED, 2017). Most important dimensions are the dimensions from the grip which will decide the comfort of the device.

The width of the middle axis is based on the width of the hand without thumb and is expected to leave space for all patients with a width of 90 millimeters. Next to the width, the diameter of the axis is important to enable the patients to squeeze the grip and pressurize the pressure sensors. The mean measure of grip circumference that dutch adults are able to achieve is 129 millimeters. To enable patients to squeeze their hand around the grip, the outer diameter of the grip is estimated on 30mm resulting in a circumference of around 95 millimeters.

The space between the hand and the strap is based on the average thickness of the hand. As DINED suggests that in the extreme case a hand has a thickness of about 35 millimeters, the space between the grip and hand should be 45 millimeters to make sure the patients is able to take the hand out easily when desired while providing enough restriction during sleep to prevent the device from getting lost in bed.

As the outer shell of the grip will be made out of a soft polyurethane ,(see section 3.4) the material will shape towards the specific grip of each patient and make sure holding the device is a comfortable experience.

Since the weight of all the components does most likely not exceed 200 grams (appendix E), moving the arm while holding the device is not expected to lead to problems for the patients with low physical capabilities.

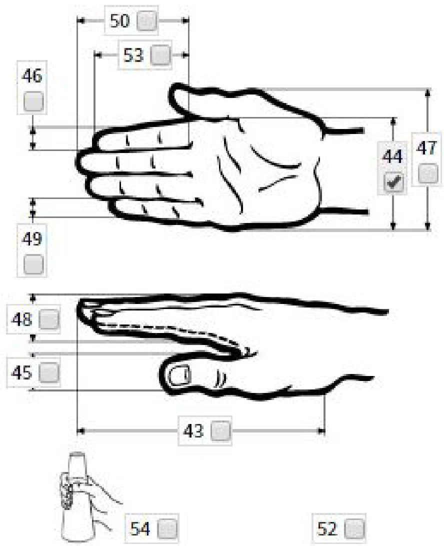


*Figure 12: DINED Hand ergonomics*

## 3.2 AESTHETICS

By making the HAND-e express values in its aesthetics that fit with the function of the product, the chance of acceptance among the user is expected to increase. Since the user is in a state of low cognitive capabilities , the device should express simplicity to underline the ease of use.

Besides, the HAND-e will become an important tool for communication when going through though moments, meaning the device should have a trustworthy appearance that allows patients to be confident the HAND-e is doing its job. Both values and corresponding product characteristics have been captured in a collage that was used during the concept phase and the development of the final concept (see appendix C).


*Figure 13: Style collage*

## 3.3 ASSEMBLY AND CLEANING

To ensure the hygiene of the HAND-e to patients, the main components of the device are detachable. To do so, the strap can be loosened, and the grip can be unscrewed by turning one side of the casing. This will allow for the cloth to come off and be washed (figure 15). Besides, the whole casing body is now easy to reach and clean if necessary.

The two main components of the HAND-e casing are designed to fit all the electric components and sensors on one side. In case the device deals with battery or sensor failures, the casing can be opened by loosening the four screws in the corners of the casing (figure 14).

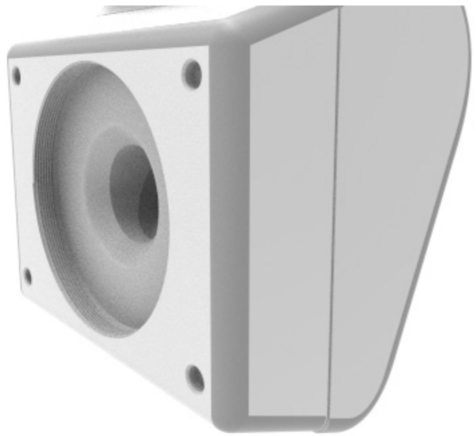

*Figure 14: Casing close up*

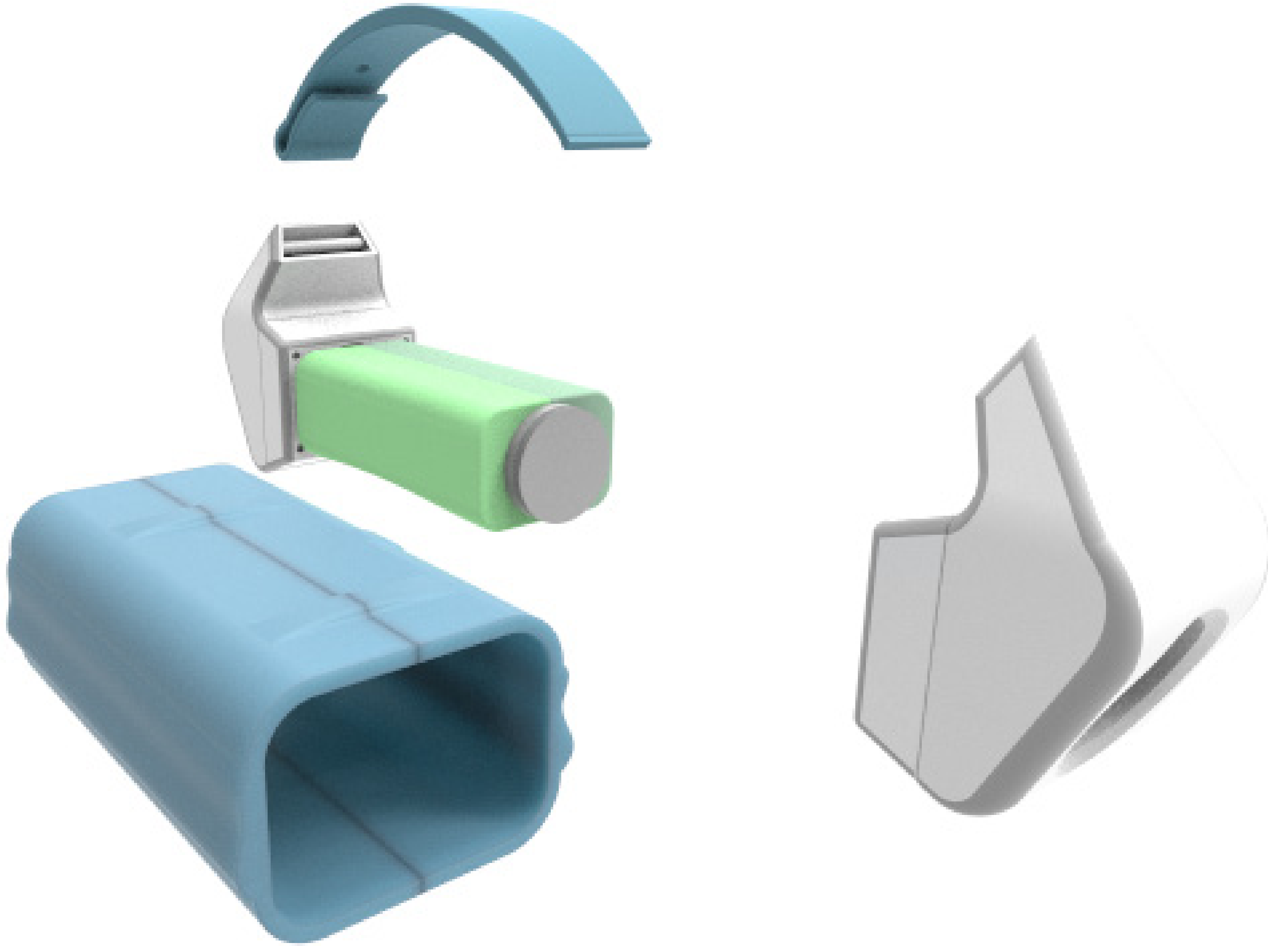

*Figure 15: Decomposition of the HAND-e*

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### 3.4 MATERIALS AND PRODUCTION

The two casing parts will be made out of ABS plastic, which is relatively cheap and suitable for casting and injection molding due to its low melting point (CES Edupack, 2015). The plastic is surrounded by a medical grade silicone coating that is easy to clean and ensures a soft feel, the same material is used for the hand strap.

The grip of the HAND-e is made out of three materials: an ABS core on which the pressure sensor are placed, a soft polyurethane that shapes towards the shape of the squeezing hand, and a siliconized polyester cloth which surrounds the whole. Siliconized polyester is often used in medical products for its chemical resistance and strength (McKeen, 2014).

An summary of the production methods used to manufacture the HAND-e can be found in appendix E. The rough estimation of the component and manufacture costs lead to a estimated price of 125 euros for the patient device and an additional 45 for the nurse armband.

*Figure 16: Different materials of the HAND-e*

ADVANCED EMBODIMENT DESIGN

# 4 EVALUATION

This section will explain the user research that was performed with a prototype.

## 4.1 PROTOTYPE

To verify the dimension as well as the patient interaction of the concept, a prototype has been made. The casing and grip of the HAND-e were 3D printed and combined with a nylon strap. With help of an Arduino microcontroller, a vibration motor and Neopixel ring were programmed to mimic the vibration and visual feedback in the patient confirmation stage.

## 4.2 USER RESEARCH

Next to verifying the dimensions and appearance of the prototype as far as possible, the vibration feedback was tested on efficiency during user research. The main goal of this research was to find out whether the user would be able to link the vibration signal to the time left for the nurse to arrive to the room, and if so, which vibration pattern would be more suitable for this:

- A pattern indicating the amount of time units of 20 seconds left before arrival (figure 17).
- A pattern symbolizing the distance between patient and nurse every 20 seconds (figure 18).

Participants were asked to indicate when they expected the nurse to be half way and almost arriving to the room. Besides, each vibration pattern was valued using a five point scale on clarity and reassurance.

From the seven participants that were tested, all 7 indicated to be able to link both vibration patterns to the time of arrival in some way. Looking at the indications made on the scales for clarity and reassurance, the majority of the participants (n=5) indicated to prefer the second pattern. Main reasons that participants gave for this where the fact the second signal is more intuitive and the first signal starts too heavily, which might lead to stress when being in the ICU. Secondly, the change of the pattern in the first signal was hard to recognize and link to time units.

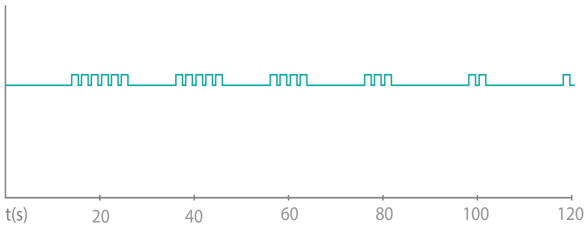

*Figure 17: Vibration pattern 1*

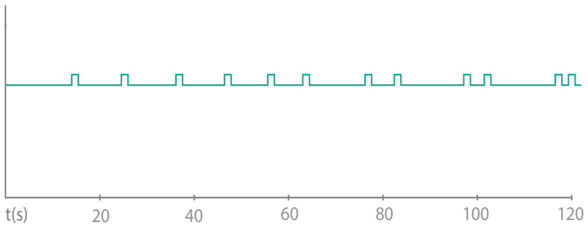

*Figure 18: Vibration pattern 2*

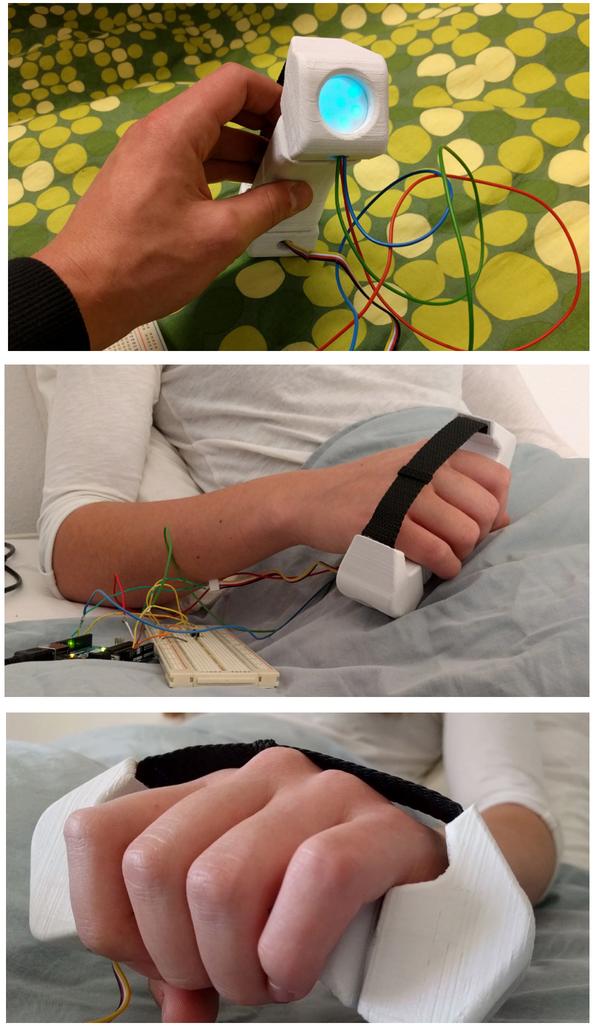
*Figure 19: Prototype user test*

# 5 CONCLUSION & RECOMMENDATIONS

The original design brief of Erasmus MC asked to give insights into the problematic areas of current ICU's and explore solutions for multisensory information design to improve patients wellbeing in the future.

The HAND-e is a product that tries to deal with a problem in the ICU that is currently present, and is expected to become even bigger in a noise free environment: patient being in doubt and uncertainty. As described in this report, feedback and information in case of an event are believed to be vital for a high well being of ICU patients. By using vibration and visual stimuli, the HAND-e provides this feedback and tries to inform and prepare patients while freeing the nurse from the audio overload.

To predict the possible success of the concept, the concept and feedback provided to nurse and patient need to be tested in the real context. The solution provided will not be the solution for all ICU patients, but for those who are recovering and becoming aware of their surroundings and the meanings of machinery signals. For those people the feedback should be understandable and intuitive, something that was hard to verify within the scope of this project.

As the patient device is always within reach, and the chance patients perceive heavy pain in the ICU is high, nurses should be prevented from being exposed to an overload of pain indications on their armband. The system that determines the need for immediate assistance is key to this. Other data such as muscle activity might be necessary to determine the severity of a pain event and distinguish in which occasions help is required. More research in the field of pain and the way the human body reacts to this is needed to improve this interaction.

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# 7 APPENDICES

## APPENDIX A: GUIDELINES

After the research done in the first quarter and the start of the second quarter, some general guidelines could be drawn up for the ideation and conceptualization phase.
The sensory modality that might substitute for the lack of sound should conform to some general guidelines that can be found for current ICU alarms (Edworthy,2006):

- Easy to localize
- Resistant to masking by other sensory modalities
- Allow communication
- Easy to learn and retain

Looking at the current negative and positive contributions of sound the feedback device should:

- Not disturb sleeping patients for events with low importance
- Wake patients up gradually for events with high importance
- Inform patients about upcoming events that require people to enter the room
- Looking at the ICU environment of the patients the feedback device should:
- Not contain sharp edges
- Not be able to entangle with machinery tubing or wiring.
- Not Interfere with current routines in the ICU
- Be easy to clean

To further increase the feeling  that help is nearby and strengthen the bond with the nurse, a wish is that the device:

- Allows the patient to communicate pain to reponsible nurse

## APPENDIX B: CONCEPTS

CONCEPT 1

*Target group*

This concept is focused on patients with low physical and cognitive capabilities.

*Focus problems*

- Patient not getting feedback on whether something is wrong with machinery or their condition, especially since there are no alarms anymore
- Patient not knowing whether he or she has been noticed by the nurse
- Patient not getting an indication of when people are about to come in to their room
- Nurse does not know whether patient is awake before entering the room

*Working*

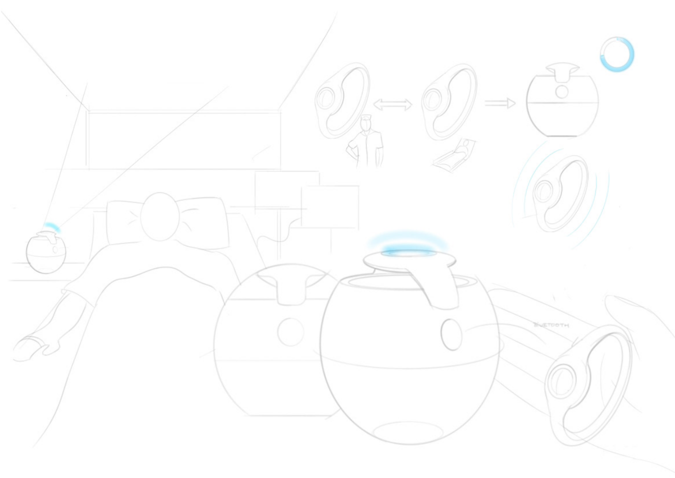
The first concept lets the patient experience of feeling of control over who is about to enter the room.
When an event in the room occurs that will require the nurse to come in, a light will be automatically activated that indicates the time until arrival. This light will be activated as soon as the nurse indicates on the pager that he or she took notice of the event and is preparing to come over. The color of the light can influence the state of the patient by changing to a different color and a higher intensity.
In addition, vibrational feedback will be incorporated that will be activated during events that require physical contact and are therefore are likely to wake the patient when sleeping.  A strap attached to the hand of the patient will start to vibrate and gradually increase in strength and rhythm. When the patient took notice, pressing the strap towards the bed can stop the vibration and provide the nurse with a sign of "approval" from to come in by a blinking LED on the outside of the room.  In case the patient is sleeping, the vibration can gradually wake the patient up.
The time it takes for before the nurse enters the room can be based on the data that is received on the pager. The amount and types of events that the nurse has to handle at a certain time, result in an estimation of the time it will take for the nurse to help the patient. Data of arrival times can be gathered to further define and optimize the estimation.

*Pros*

- Patient and nurse can communicate on distance and let each other know whether and event has been noticed and nurse can adapt to the situation.
- Patient is prepared beforehand by lighting in a semi active state and vibrations when sleeping which increases their feeling of control and privacy.

*Cons*

- Times of arrival are hard to predict precisely
- Extra steps for the routine of the nurse



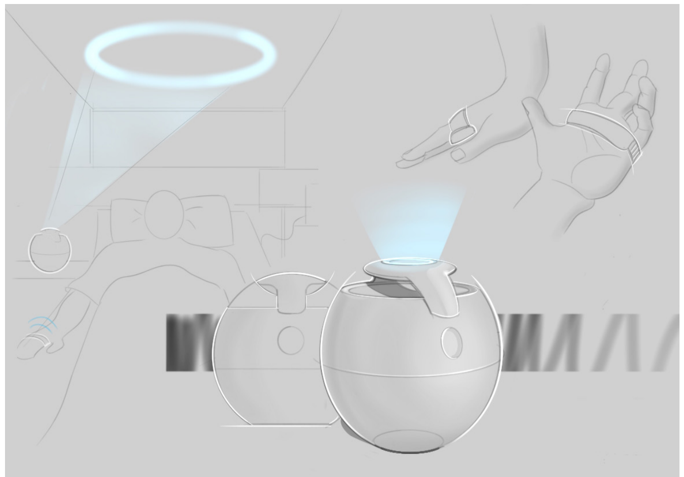


*Figure 20: Concept 1*

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CONCEPT 2

*Target group*

This concept is focused on patients with a more active state and higher physical and cognitive capabilities.

*Focus problems*

- Patients not in control over day planning and being disturbed in the silence environment unnecessarily.
- Patients losing their sense of time during the day or week

*Working principle*

The second concept lets the user perceive a feeling of control by providing them with information about the daily schedule and give them the possibility to change the planning to their own preferences. Example of events that the patient can have control over are visiting times, dinner/food times and the moments were patients are washed, as this are the most basic things somebody has control over in the usual daily life:  food, hygiene and company.

The patient is provided a handheld device which allows him to physically move events over the course of the day with help of circular sliders around the device. Moving the slider forwards or backwards will change the daily schedule and preferences will be transferred to the person responsible.

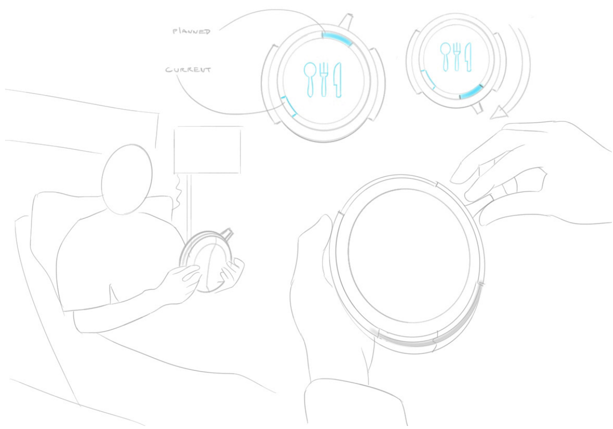
On the outside of the room the preferred daily schedule of the patient could be presented so patient are not obligated to explain for example why they are not in the mood for company.

*Pros*

- Patients get control over their daily schedule which increases their feeling of being in charge
- Preferences can prevent interference from nurses or visitors on moments were the patient prefers silence in the room
- Patient preferences are expressed outside of the room so no verbal expression is necessary.
- One central device for simplified information on time and planned events

*Cons*

- Amount of control is limited
- Daily planning for food and care will be more complex



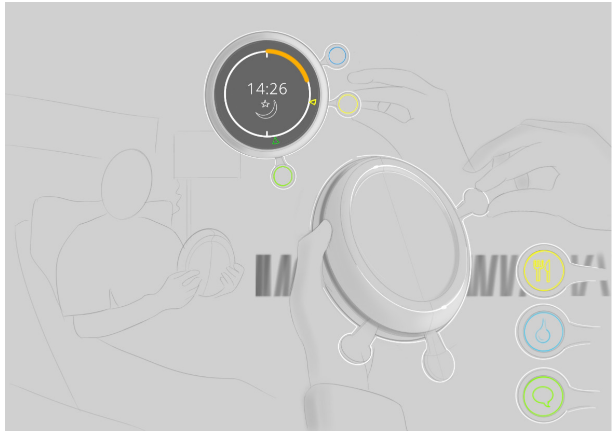



*Figure 21: Concept 2*

CONCEPT 3

*Target group*

This concept is focused on patients with a more active state and higher physical and cognitive capabilities.

*Focus problems*

- External sounds like TV, outside noise, talking frustrating the patients
- No control over sound

*Working principle*

The third concept provides the patient with a feeling of control by enabling the patient to mute sounds in the ICU room.

A pillow is able to vibrate and transfer anti-noise through the pillow and the human skull to be able to let users mute certain sound in the ICU. A device containing a microphone could listen to the most high frequencies and save these frequencies. After these frequencies have been identified, the user can choose to mute on of these sounds with a handheld device located in the bed. By turning the knob on this device, the patient can choose which sound is perceived as most obtrusive and mute these by placing the head on the pillow to receive the anti-noise by means of vibrations.

*Pros*

- Feeling of control over surrounding sound
- One sound can be muted
- Vital information can still be hears since only one sound is muted

*Cons*

- Frequencies of noises such as voices and tv are varying a lot , therefore providing anti-noise is for these sound is hard
- User has to keep the head in one position in order for both eyes to receive the signal, laying sideways is not an option

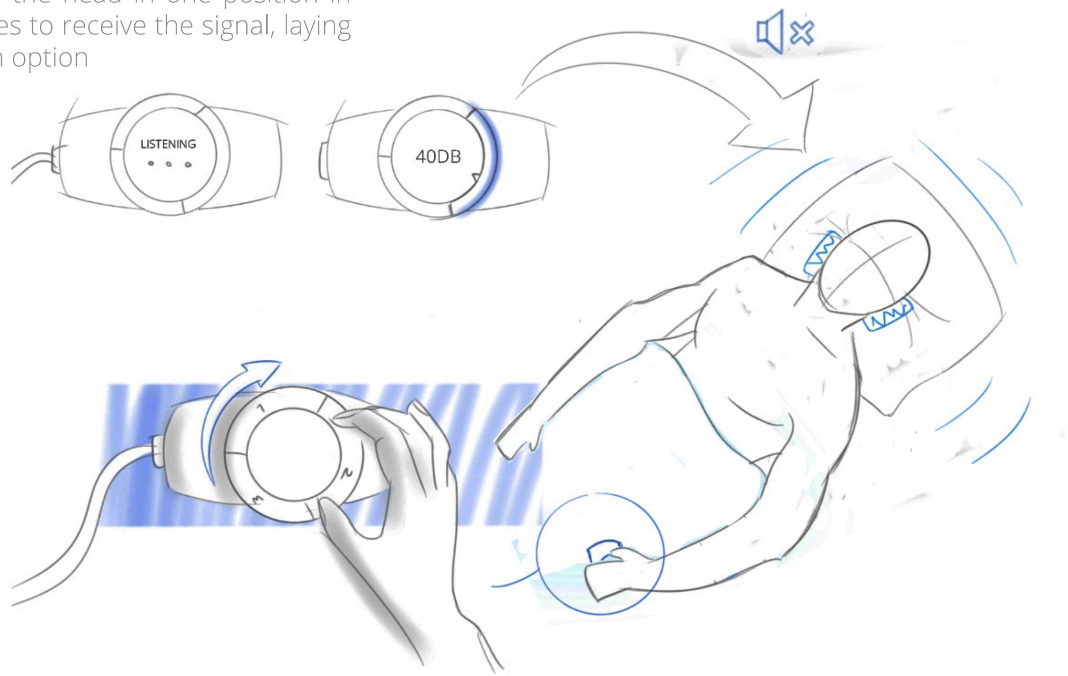



*Figure 22: Concept 3*

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## CONCEPT CHOICE

The concept choice for the first concept was mainly based on its ability to reach a bigger group of patients, meaning the ones that are in a somehow unconscious state. The second concept is more focused on active patients and might serve better at the normal hospital wards. Besides, people being that active might solve the problem of a lack of control already themselves by gaining control through personal devices.

## CONCEPT ELABORATION

The concept that was chosen can be described as a wearable that can communicate when the time in which nurses are about to arrive to their room as well as a communication tool that allows the nurse to see whether a patient is awake or not.

- Why is a button in the hand better than a standard button
- How can differences in pain or red button be monitored
- Why the light as you don't know if people can/ want to see this
- Graduation in information feedback fitting with the state of the patient

To get further develop the concept into a prototype, the patient-nurse communication and the use of light and vibration in the wearable had to be specified as well the positioning, aesthetics and material of the device. Furthermore, as patients recover during their stay in the ICU, their cognitive and physical capabilities might grow. Preferably, the communication between the patient and the nurse as well as the patient and the device grows accordingly.
To be able to assess the severity of pain a patient perceives and communicate this severity to a nurse as well as the need for a nurse to get to the patient as quickly as possible could be done in multiple ways. Taking into account the cognitive and physical capabilities of the, it should be something that does not require high physical or cognitive load. One of the main reactions of the human body on pain is the

## APPENDIX C - STYLE COLLAGE

After evaluating the goal of the concept and the values that would fit with the functioning, a style collage was made that could be used during the ideation and concept phase. The style collage tries to capture the values of simplicity (ease of use) and trustworthiness.

To be able to express the value of simplicity in the final concept, some product characteristics were extracted from the collage:

- Minimal amount of buttons
- Unity in shape
- Big feedback areas
- Use of color on interaction parts

As for simplicity, the trustworthiness could be reflected by including:

- No loose elements
- Rounded corners
- High material thickness


*Figure 23: Style collage*

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# APPENDIX D : USER TEST

## 1 Introduction

The use test was done to verify that patients could be able to link the pattern of vibration to the time left for a nurse to come over, and if so, which pattern would be more suitable.

## 2 Method

### *2.1 Participants*

The research was conducted with 7 students in the age of 21 to 25. Participants were recruited among the researcher's relatives and acquaintances that would be asked to imagine themselves in the context as good as possible. .

### *2.2 Stimuli*

Participants are confronted with the prototype which includes haptic and visual feedback. As it was not possible to reach the target group for this user test, participants were asked to listen to a sound fragment that would mimic the environment of the ICU.Besides, the particpants were asked to lay down in a bed. Next, two different types of vibration patterns lasting each a litte over two minutes were to be felt:

- A pattern indicating the amount of time left by starting with 6 vibrations (representing the 6x20 seconds left) and going down to 1.
- A pattern representing the proximity of the nurse, from which the time in between the two vibrations would get shorter every 20 seconds.

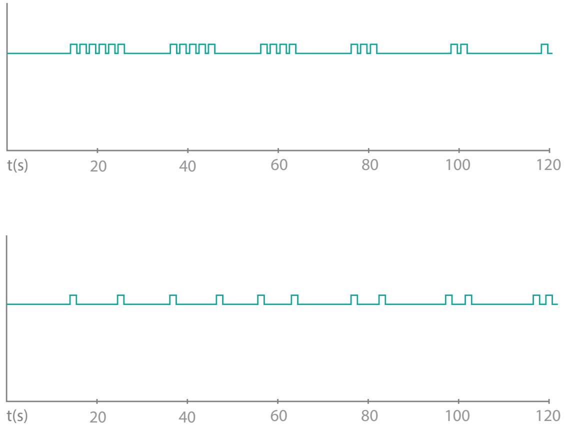


*Figure 24: Vibration patterns*

### *2.3 Apparatus*

Participants were asked to listen to ICU noises payed on a laptop (HP Elitebook 8560w) through headphones. The same laptop was used to keep track of the time and fill in the answers with a pencil on the printed research forms.

For the prototye, an Arduino microcontroller was needed to upload the different programs for vibrating patterns. Besides, a powerbank was used that would deliver the 5 volts needed for the Arduino and prototype to function.

### *2.4 Procedure*

Before starting the test, participants received a short explanation conerning the general goal of the vibrations.To get the patient more into the real context, they were asked to put on headphones with some ICU machinery noise, in this case, a ventilator.

Next, participants were asked to go through two minutes of vibration feedback, and indicate when during these two minutes they had the feeling the nurse was half way, and when she was almost coming in. They were asked to indicate this by raising a finger twice, once when they expected the nurse to be half way, and once when they expected the nurse to be almost entering. Afterwards, they were asked to indicate how clear and reassuring the feedback had been on a five point scale.

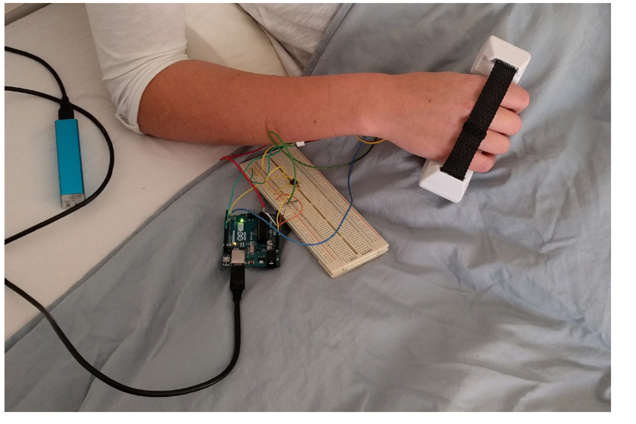

*Figure 25 Usert test*

### *2.5 Measures*

The measurements consisted of the time indications each participants gave when indicating the nurse could be half way or about to enter the room, the score on the five point scale on clarity and reassurance and the comments that were given to reason for this preference.

| Participant | VB-1 1st time (s) | VIB1 2nd time (s) | VB-2 1st time (s) | VB-2 2nd time (s) |
|---|---|---|---|---|
| 1 | 85 | 120 | 62 | 120 |
| 2 | 65 | 100 | 65 | 120 |
| 3 | 70 | 120 | 85 | - |
| 4 | 41 | 120 | 83 | 120 |
| 5 | 105 | - | 85 | - |
| 6 | 102 | - | 65 | 120 |
| 7 | 65 | 120 | 102 | 120 |

| Participant | VIB-1 Clarity | VIB-1 Reassur. | VIB-2 Clarity | VIB-2 Reassur. |
|---|---|---|---|---|
| 1 | 2 | 3 | 3 | 3 |
| 2 | 2 | 2 | 3 | 3 |
| 3 | 1 | 2 | 4 | 3 |
| 4 | 2 | 2 | 3 | 3 |
| 5 | 3 | 3 | 2 | 2 |
| 6 | 2 | 3 | 2 | 3 |
| 7 | 1 | 3 | 2 | 3 |

*Figure 26: Test results*

## 4 Discussion

The time indications indicate that it was possible for the participants to relate the changing vibration pattern to the time left up till arrival of the nurse, although some participants expected a final confirmation pattern to indicate the nurse had really arrived.

As can be seen in the scores, the second vibration pattern that represented the distance between the patient and nurse getting closer was , in general, prefered over the first pattern by five people. In the comments that were made to clarify the scores, two participants mentioned that the heavy start of six vibrations in the first pattern is what made it disturbing, as they experienced this as something that would happen if there is something wrong, like their phone alarm vibration in the morning. Secondly, three participants indicated that the change in the vibration pattern was more easy to recognize in the second signal, which gave them the feeling that there was actually something changing, and that help could be on the way.

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## APPENDIX E - COST PRICE ESTIMATION

Although the HAND-e is only a concept, and should be developed into detail in order to have a more precise idea of the cost price, a rough estimation will be made for the cost of the product in the first stages of the development.

*Production processes*

Most of the parts included in the HAND-e and the armband can can be bought such as the sensors , LED lights and vibration motor in both the patient as nurse device. Other parts, such as the HAND-e casing on both sides and the middle axis, need to be manufactured.

As long as the HAND-e is not a worldwide success, the amounts of product to be manufactured are not high enough for injection molding. Therefore these parts are most likely to be 3D printed or casted in the prototype stage, and when going towards the first batch for the test-phase. The batch size depends on the amount of hospitals that are willing to start a pilot. Assuming that the five biggest hospitals are willing to try the concept in 10 of their ICU rooms, the first batch of products would be around 50 to 75 products. The cost price will be calculated for this phase, where the parts are still 3D printed. It is assumed that the current network of the hospitals can be used so no additional routers are needed.

Taking into account the before mentioned statements, the costprice of the HAND-e is estimated on 125 euros. Taking the some material and component costs for the nurse arband would result in a price of 45 euros, which makes the total price for both devices 170 euros.

| Part | Weight (grams) | Material cost per kg | Costs | Manufacturing / Labour costs | Quantity | Costs |
|---|---|---|---|---|---|---|
| Casing | 17 | € 2,29 - 2,75 | € 5,- (*3) | € 25,- | 2 | € 30,- |
| Middle axis | 40 | € 2,29 - 2,75 | € 10,- (*3) | € 25,- | 1 | € 35,- |
| Strap | 10 | € 3,76 - 6,33 | € ≈0.05 | € 5,- | 1 | € 5.05,- |
| Lens | 10 | € 2,29 - 2,75 | € ≈0.05 | € 5,- | 1 | € 5.10,- |
| Polyurethane cushion | 45 | € 2,29 - 2,66 | € ≈0.10 | € 5,- | 1 | € 5.10,- |
| Polyester cloth | 10 | € 3,72 - 3,82 | € ≈0.05 | € 20 | 1 | € 20.05,-- |
| Pressure sensor *1 | 2 | | US $5.2-5.5 | | 1 | |
| Vibration motor *1 | 2 | | US $ 0.15-0.45 | | 1 | |
| LED-ring *1 | 2 | | US $ 3.5-5.5 | | 1 | |
| PCB *2 | 5 | | US $ 1.50 | | 1 | |
| Battery *1 | 1 | | US $1.1-1.5 | | 1 | |
| Wifi module *1 | 2 | | US $8-12 | | 1 | |
| Gyroscope *1 | 2 | | US $4-5 | | 1 | |
| Total costs | | | | | | **€ ≈125,-** |

*Figure 27: Cost calculation*

1. www.alibaba.com
2. http://circuitcalculator.com/wordpress/2006/01/31/pcb-trace-width-calculator/
3. www.shapeways.com