Co-designing a monitoring system to support patient safety in an Emergency Department

Safetrack

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This report is an output of a project undertaken by the Design and Arts Research Laboratory (LIDA).

POLITÉCNICO DE LEIRIA | ESCOLA SUPERIOR DE ARTES E DESIGN | LiDA

Contents

Design and Arts Research Laboratory (LIDA)

The Design and Arts Research Laboratory (LIDA being the Portuguese acronym), is an interdisciplinary research unit at the Polytechnic of Leiria's School of Arts and Design in Caldas da Rainha (ESAD.CR). LIDA is funded by Portugal's Science and Technology Foundation (FCT) and has created an open community where academics collaborate effectively with industrial and social partners, providing space for innovation and development in the creating of social, cultural, economic and environmental benefits. Their work will benefit Portugal's central region, as well as other locations.

Health and Care Design Research

Health and Care Design Research is a LIDA research group led by Sandra Neves, and its purpose is to continually re-think new ways of learning and working to help people to live healthier lives.
The group creates opportunities for researchers, companies, public bodies and the general public to collaborate in the devising of innovative solutions that respond to health and care challenges faced by society.
The researchers employ current and emerging research methods to involve their partners and participants, who are invited to share their own experiences.

The mapping of real life practice, the generating of ideas and prototyping is a commonly adopted approach that allows new processes, services and experiences to be tested swiftly. Researchers, partners and participants are supported so that, jointly, they design potential solutions and achieve a desirable future. The resulting ideas thus become candidates for future research and development, allowing them to reach their full potential.

Design research team

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Summary

The SafeTrack project was put forward as an opportunity to support patient safety during their passage through the hospital emergency department (HED), by developing a new patient monitoring system.
The project calls for a multidisciplinary team of researchers from the Polytechnic of Leiria working in the health, IT, electronics and design fields, as well as companies specializing in the development of hardware and software devices (Wiseware), products (DreamPlas), the sale of medical equipment (EPJ Médica), and also calls for the participation of Leiria Hospital (CHL).

This report describes the design research process for developing phases I, II and III of the project. The purpose of Phase I was to provide a better understanding of current HED patient monitoring experience. In order to develop a current scenario that would generally represent the experience of current patient monitoring in the urgent area (yellow). The aim of this first research project stage focused on exploring the ways in which health professionals conduct the patient monitoring practices, as well as patients' experiences of HED monitoring. In addition, it aimed to understand which strategies were employed and which challenges were faced in practice and during the monitoring period, so as to acquire a better understanding of what actually happens in the real world.
Phase II sought to understand what could be done to promote quality patient monitoring in order to deal with safety matters and patient health care in the HED. Here a preferred patient monitoring scenario would be presented, highlighting, in general terms, health professionals' ideas and points of view as to what would be a significant future outcome in HED patient monitoring.
The aim of this second research project stage focused on exploring the opportunities for change, so as to respond to the needs identified in the current patient monitoring scenario.
Phase III calls for the active involvement of a relevant group of participants (engineers, designers, nurses, doctors, among others) in the developing of a prototype of the new patient monitoring system for clinical deterioration detection alerts.
To meet these aims the Design and Arts Research Laboratory's (LIDA) design researchers team led a Participative Design process in conjunction with CHL to observe emergency department practices, as well as to actively involve health professionals and HED patient representatives in the examining of the different experiences: 1) who monitors and 2) who is monitored.

The reason for involving health professionals who work in the HED is based on their being seen as very knowledgeable participants due to their experience of care delivery, treatment and the monitoring of patients' vital signs. A diversified group of patient representatives was also involved in the participative design activities, where they were invited to express their opinions and points of view in regard to their experience of being monitored in the HED. The LIDA researchers team ran design-led activities, and developed a series of visual aids for communicating the information found and for mapping significant information sharing moments.

The analysis of the observations and the conversations led to the identification of:

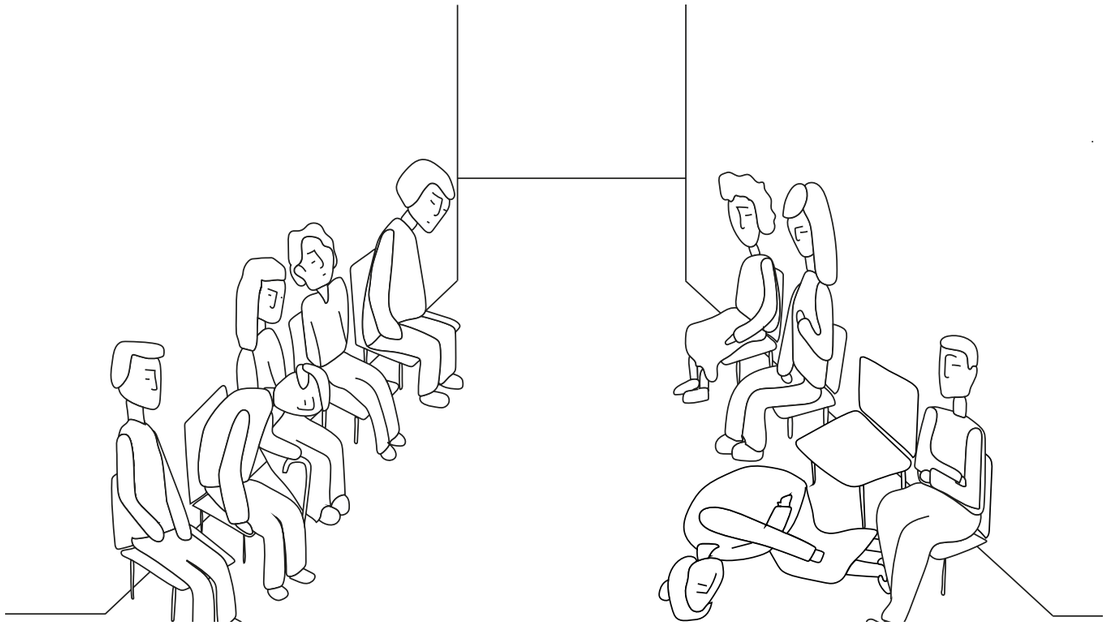
Phase I
1) The patient pathway in the hospital emergency department;
2) Valuable information on the experiences of health professionals and HED patients;

3) An example of the current scenario of patient monitoring experiences in the HED urgent area, which illustrates a series of questions arising about the current situation.

Phase II
1) A general example of a preferred patient monitoring scenario in the HED urgent area and standard area, which illustrates a series of opportunities around what would be a significant future outcome, so as to promote patient safety;
2) Valuable information on the ideas of health professionals in regard to the developing of a future HED patient monitoring system.

This report concludes with the presentation of the first version of the prototype of the new patient monitoring system for clinical deterioration early detection alerts, as evidence for supporting the next stages of development and prototype refinement.

The Context



What is the patient pathway in the emergency department and how does the current monitoring system respond to patient safety during hospitalization?

Portuguese hospital emergency departments face challenges when treating patients swiftly and safely due to the increase in the number of patients admitted to an emergency department [1]. This situation leads to constant crowding of the department which works daily to deal with acute and highly complex health conditions [2], [3].
The crowding and human resource shortfall have the potential to impact on patient safety [1], [4], [5], because of the apparently stable patients admitted to the HED, in other words the non-priority cases, around 31% show signs of deterioration over the next 24 hours [6]. It has been shown that the deterioration in the patient's health in the HED is not always recognised in good time, leading to unplanned internments, the risk of morbidity and unexpected hospital deaths [2], [3], [6], [7].
This situation's prominence highlights concern for quality health care and the implications for clinical efficacy, the promoting of safety and the patient experience. It shows that it is particularly important for HED health professionals to recognise, promptly, any deterioration in patients' state of health [8].
Therefore, SafeTrack seeks to develop a better understanding of real emergency department practice in regard to early detection of clinical deterioration.
The issues arising from this understanding will be the basis and the starting point for future project research and development.

Objectives

The general research objective of the first phase of this project was to find out how patients were monitored in the hospital emergency department (HED), and which strategies were employed and which challenges were faced in monitoring practice and experience, so as to acquire a better understanding of what was happening in the real world. To that end it was necessary to conduct an information survey by way of observations made in the HED along with design workshops. The aim was to hear and record the expectations and experiences of health professionals and patients in regard to monitoring [9].

Some of the major questions that Phase I sought to answer were:
Why do patients come to the emergency department?

What is the health professionals' role in patient care in the emergency department?

What is the patient pathway in the emergency department?

What are the experiences and practices of the current patient monitoring system in the emergency department?

At its core, by means of a Co–participative Design approach, this project initially set out to conduct an information survey about the existing "status quo" context so as to identify the issues that could influence patient safety. Here the hypothesis was that this knowledge (Phase I) would help us devise a strategy for exploring improvement opportunities (Phase II) which would then be reflected in prototypes (Phase III) to be honed and later evaluated and implemented by the community.

Thus, the main aim of the second phase of this project was to discover, along with the health professionals, what would be a significant future outcome in patient monitoring, in order to promote health care safety and quality throughout the patient pathway within the hospital emergency department. Therefore, it was necessary to conduct an information survey by way of a co-design workshop, with a view to hearing and recording health professionals' ideas about how we can improve the response to patient safety issues along their pathway within the HED.

Some of the major questions that Phase II sought to answer were:
What does the ideal monitoring system, beginning as soon as the patients reach triage, look like to health professionals?

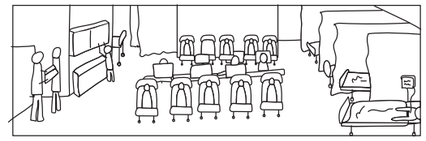
What would help when a patient starts to deteriorate clinically?

What type of information merits an alert?

What type of tool/interaction/ action should health professionals be using or taking?

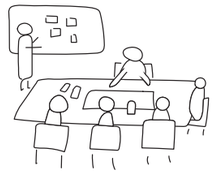
Here the hypothesis was that this knowledge, obtained in Phases I and II, would help us devise the basis for beginning to build, collaboratively, a prototype for the new patient monitoring system for clinical deterioration detection alerts, so as to respond better to patient safety issues throughout their pathway in the hospital emergency department.
The first version of the prototype sought to show the interconnection between 2 stages of the system:
1) Monitoring vital signs via a sensor;
2) Visualizing the information by way of a graphic interface.

Phase I

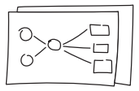


Observations in the HED
Gather a range of information by conducting observations in the HED, so as to acquire a better understanding of what is happening, making it possible to plan the next activity.

Workshop 1
A participative workshop with a group of health professionals to understand their expectations and experiences of patient monitoring in the HED.

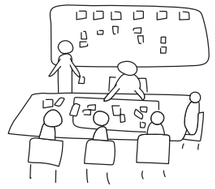


Workshop 2
A participative workshop with a group of patient representatives to acquire a better understanding of patients' experiences relative to monitoring and their views on safety within the HED.

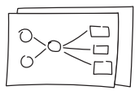


Scenario 1
Gather information and present the findings of this project phase.

Phase II



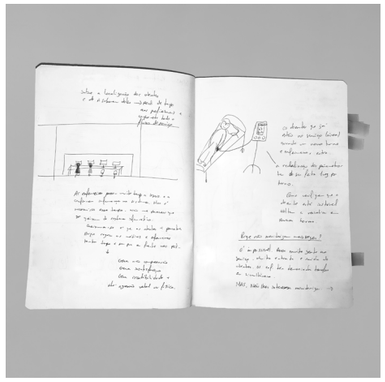
Workshop 3
Co-design workshop with a group of health professionals to explore ideas and aid the conceiving of a new patient monitoring system for the hospital emergency department, in the urgent and standard areas.

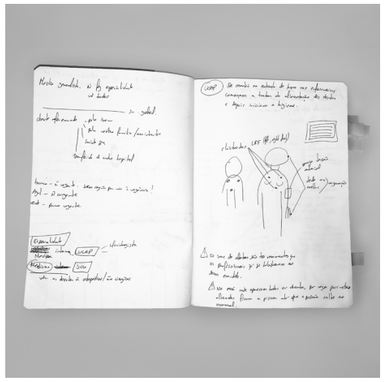


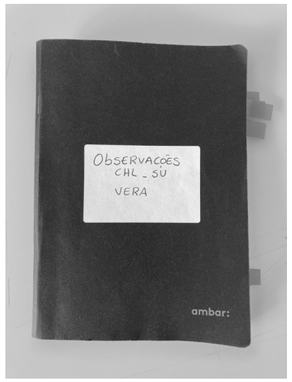
Scenario 2
Gather the basic information and present the findings of this project phase. The findings will be the starting point for the first version of the prototype of the new HED patient monitoring system.

Phase III

Prototyping (version 1)
Development of the prototype sensor for monitoring vital signs, plus the development of the digital prototype for visualizing the monitoring information.







Photographs of the booklet containing the information gathered via observations in the HED.

Mapping by topic of the information collected through the observations.

Observations

What we did

We began by making observations of the hospital emergency department with the aim of identifying key moments in patient monitoring practice and experience, to be analysed in greater detail in workshops 1 and 2.
The observations were made over three days in different areas of the HED (triage, wards with different priority ratings, nursing workstations and the corridors where patients wait to be seen). Focusing on the experiences of health professionals and patients, while also identifying their views on their own practices, words, attitudes and emotions. Records were kept by way of a notebook for noting and illustrating the information gathered at the time, and a digital camera was used to photograph patient monitoring equipment and their graphic interfaces. Thus we were able to obtain genuine information to illustrate what happened before, during and after the patient was admitted to the HED.
During the observation period in the HED, the LIDA Researcher Fellow was a visitor who made their observations in the company of a nurse, who would explain what happened on a daily basis, as well as giving their views as to the problems the department faced.
At the end, a map of the information gathered was drawn up to provide a better understanding of the stages of patient monitoring in the HED. The information generated by the observations was key to the structuring and planning of workshop 1.

Illustration of health professionals' voices in the first activity.

Workshop 1

What we did

Workshop 1, a three-hour session, was undertaken with a group of health professionals (one doctor and three nurses). A total of four activities, overseen by the design team, were conducted with a view to examining the current patient monitoring situation in the HED, on the basis of these health professionals' outlook.
The information generated in Workshop 1 was subsequently used to begin the building of a scenario that showed the current patient monitoring situation in the HED.

The main aim of the first activity was to acquire a better understanding of the roles of the different actors (doctors, nurses, etc.) in the provision of health care to patients.
This activity was supported by a large, printed diagram and a series of figures, which were used by the participants to illustrate, individually, their role and to share their experiences of patient care in the HED.
This group session was led by LIDA's Principal Researcher, who posed questions designed to encourage a discussion, while two facilitators mapped out the shared information.

Tools for preparing the third activity.

Discussion of priorities, experiences and practices.

The facilitators (SafeTrack project design and clinical physiology research fellows) also marked on the diagram what was said by the group during the discussion, which revealed a range of issues, such as poor communication and coordination between the various health professionals.

The aim of the second activity was to explore:

- **How the patient arrives at the hospital emergency department?**
- **How they would represent the patient pathway in the emergency department?**

The idea was to understand the patient pathway in the emergency department, from the time they arrived until the time they left, plus all the stages of the pathway.
To explore these topics a large, printed diagram was used that illustrated the initial understanding of the patient pathway. This tool meant a discussion could be generated, in which the participants were invited to express their point of view about the diagram, as well as to correct and add to the information.

The third activity sought to examine the clinical priority system within the HED.
To that end the participants were invited to express their thoughts, opinions and experiences in regard to each priority area (immediate, very urgent, urgent and standard). Here the participants' comments were recorded directly on post-its by the facilitators. The information gathered in this discussion revealed that the urgent (yellow) and standard (green) priority areas were the greatest concern, since they covered a range of daily problems and challenges. For example, a large number of people come onto the wards in these areas with multiple and diverse clinical conditions. These cause strong emotions and heavy workloads, poor communication and organization.

Ordering vital signs by degree of importance to monitoring.

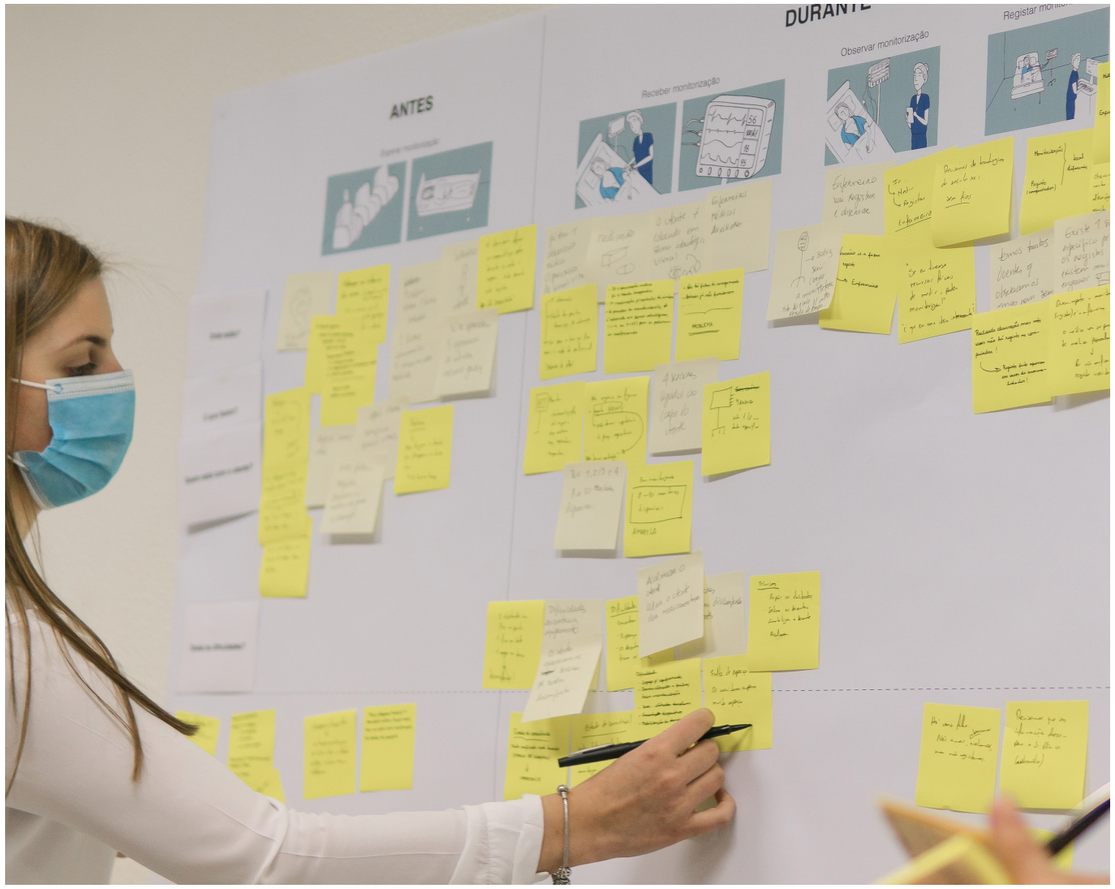
Information gathered from health professionals' voices in the third activity on clinical priority areas.

Gathering of shared information from health professionals' voices mapped on the storyboard in activity 4.

Discussion with a health professional about patient monitoring, using visual tools.

In the fourth activity we focused our attention on the urgent priority area (yellow), where we invited the participants to express their understanding of how patients are monitored in this area.
Contributions were analysed by means of a large, printed storyboard, which provided for the gathering of information in 3 stages: before, during and after monitoring. There were four main topics to discuss: Where are they?
What do they do?
Who is with the patient?
What are the difficulties?
The Principal Researcher asked questions to begin the discussion, while the participants' voices were mapped on the storyboard directly by the facilitators.

This allowed the participants to follow what was being discussed. This tool led to a better understanding of the current context of patient monitoring in the urgent priority area, as well as identifying the major challenges faced in early detection of deterioration in the patients' state of health.
The workshops were recorded on video and through photographs in order to enrich the qualitative data and to support the facilitators' notes on the various activities. The information collected was analysed by topic so as to reveal recurring themes.



Workshop 2

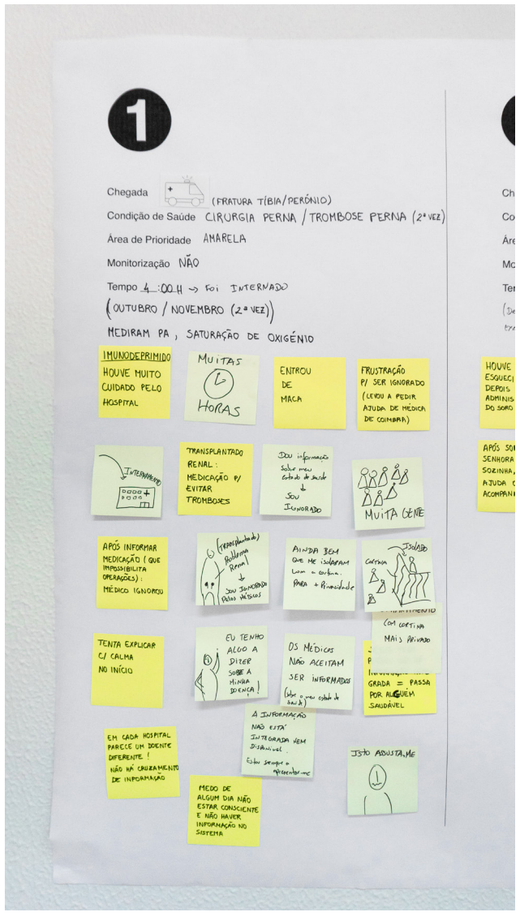
What we did

This project also sets out to create opportunities to listen to patients, so as to learn from their feedback. Therefore, the aim of workshop 2 was to bring together patients' experience of patient monitoring, when they were temporarily receiving health care in the urgent area.

Workshop 2, a three-hour session, was conducted with a group of patient representatives – two females and two males, who had recently been discharged from the HED's urgent area.
Their experiences were deemed valuable to the development of the current patient monitoring scenario. Workshop 2 was founded on a continuous dialogue that explored the patients' experiences, and it included 2 activities.

The first activity began by exploring what led the participants to the HED.
Here we found that the HED receives a variety of people with specific and differing health needs and conditions.
The discussion was built around both the Principal Researcher asking a series of questions that invited the participants to express their experiences and opinions, and the facilitators illustrating the information generated in the discussion on a large, printed diagram, so that the participants could see what was being discussed and have an overview of what they were building together.
The plan was to collect a range of individual information in order to identify individual experiences in the HED.

Illustration of patient representatives' voices in activity 1, in regard to the reason they went to the emergency department and their experience at the time.



In the second activity we focused our attention on the patient monitoring context and we invited the participants to express their actual experiences in the HED's urgent area.
Here we used a new version of the storyboard used in the previous workshop, so that patients' experiences could be collected in 3 phases: before, during and after monitoring. The Principal Researcher posed a series of questions to encourage participation, and also showed a number of cards with pictures of hospital monitoring equipment, so as to generate reflection and discussion, in order to collect further information about the monitoring. This gave rise to a rudimentary visual "experience" map of the positive and negative aspects of current monitoring. Some issues that are key to future potential improvements were identified, while a range of interactions related to patient monitoring were revealed.
At the end the participants were invited to provide any additional information they felt was relevant, but had not arisen during the conversation.

Recording of patient representatives' voices on the storyboard in activity 3, about the phases: before, during and after monitoring.

Visual aids representing the monitoring system to guide discussion.

What we discovered

Analysis of the conversations and the maps generated by the observations and workshops led to:

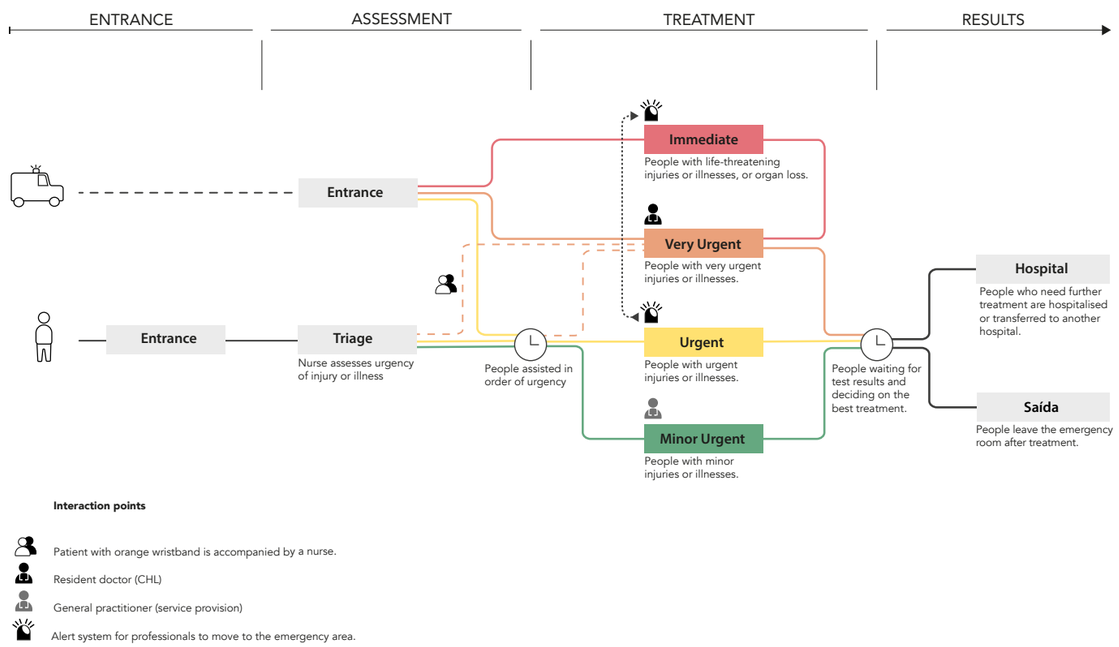
— The identifying of the patient pathway and the major points of interaction in the hospital emergency department;

— Valuable information on the department's four clinical priority areas and the current challenges faced in the urgent and standard areas, in terms of patient monitoring;

— A general example of the current scenario of experiences in the HED's urgent area, which describes the real challenges in the context of patient monitoring and reveals a number of problematic issues.

The information gathered in Phase I will be the basic structure for planning the next phase of the SafeTrack project, intended to develop a monitoring system that promptly detects clinical deterioration in the HED.
All issues that arise will be highlighted and presented alongside the information and the thoughts that revealed them. The current scenario illustrates the opinions of both health professionals and patients.

Patient pathway in the emergency department



We have learnt that patients who arrive at the emergency department by themselves, must go through triage before being admitted for treatment. The initial evaluation is undertaken by a nurse trained in the Manchester triage system, who assesses the patient's complaint regarding an injury or disease and determines the severity. This leads to the issuing of a wrist band in the colour matching the priority of the treatment. Here we find that people with less urgent injuries or diseases have to wait longer to be seen.

Participant workshop 1:
"The green area is the most difficult because patients spend their time questioning. Patients wait for many hours without being seen."

"The green patients are the ones you look at and see less."

"Worrying discharges: patients wait for a decision that never comes."

We also found that people with injuries or diseases whose life is at risk, or who could lose an organ, go straight to the immediate area (red), in which case an audible alert is heard in the urgent area (yellow) in order to move health professionals from that area to the immediate area, to provide support to the delivery of patient care.

Pw1: "A patient at risk of death or the loss of an organ is a concern. The alert sounds calling nurses and ancillary staff from the yellow area to the red. It calls for team and resource management".

The immediate and very urgent areas were understood to be areas requiring permanent medical assistance.

Pw1: "An Orange patient is a serious patient. They need at least two doctors. Sometimes there is only one doctor in the orange area. The doctor is often re-evaluating other patients."

"The patient is accompanied by a nurse. The patient is not monitored while going from triage to the orange area."

We found that the urgent area faces complex challenges.

Pw1: "The yellows are a problem. You get all sorts. It is hard to keep an eye on the patients. The major difficulty is the crowding. Many patients tend to exaggerate the pain, so as to be classed as yellow and wait less time."

"Many yellows are really greens and it is complicated because they can become orange. Patients with a range of conditions … GP patients, internal medicine, psychiatry, orthopaedics, cardiology… while they are all yellows their clinical condition varies considerably."

"The area needs a person dedicated to those patients…a serious problem is how disorganized things are."

Current patient monitoring scenario in the urgent area of the emergency department

From our observations and conversations with health professionals and patients, we found that there is great concern for the urgent cases (yellow) and standard cases (green). Despite being areas with lower clinical priority, they bear a great complexity of issues that can impact patient safety during their time in the HED.

Thus, the following visual narrative provides a general example of the experiences of health professionals and patients in the current monitoring scenario in the HED's urgent area. Individual scenarios can be built on the basis of the information collected from each patient representative. Illustrating the voices of the health professionals and patients allowed us to acquire a better understanding of what really happens currently.

This visual narrative also has some limitations when synthesizing what is an extremely complex situation. Nonetheless, it still aided reflection and the defining of what should be explored next.

The major problems detected are the waiting time and the feeling of "being forgotten" in an environment where it is hard to be indifferent to "other people's pain". The absence of information, communication and recognisable progress are factors that can cause great anxiety. The lack of the appropriate equipment for integrating and identifying information on patient monitoring reveals an "unsafe" system.

In this visual narrative the quality of the patient monitoring system for early detection of clinical deterioration requires considerations about integration and alerts in the future.

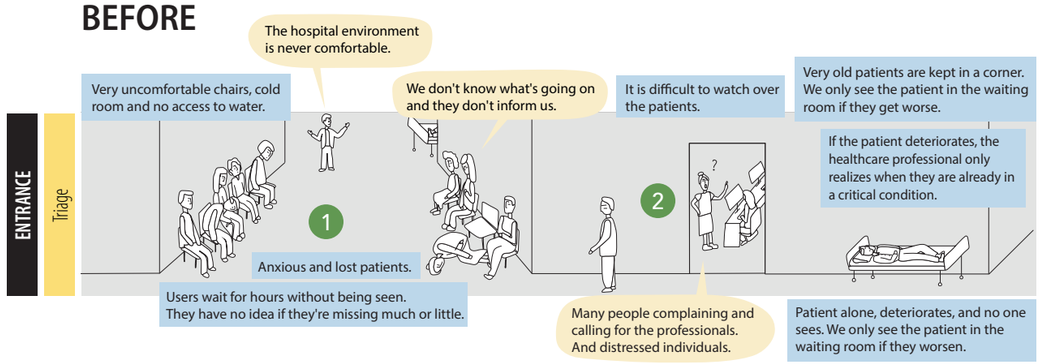
Issues arising

1. Lack of an atmosphere
2. Need to see progress
3. Poor communication
4. Strong emotions
5. Need for an integrated monitoring system
6. Perceived inefficiency

Voices:

- Patients
- Profissionals

BEFORE



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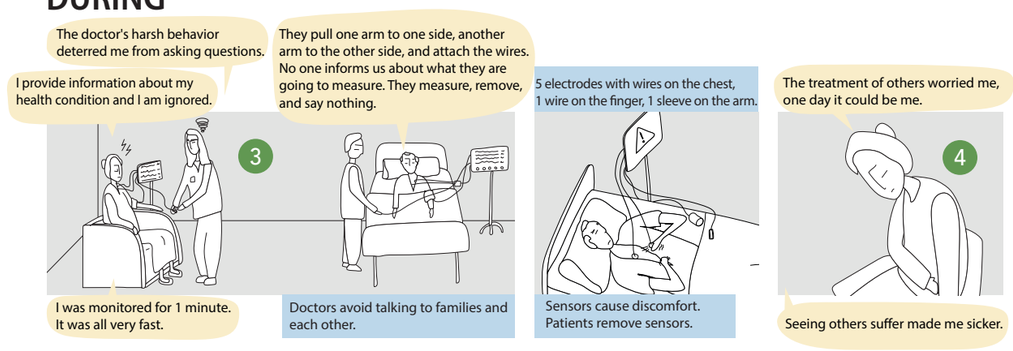
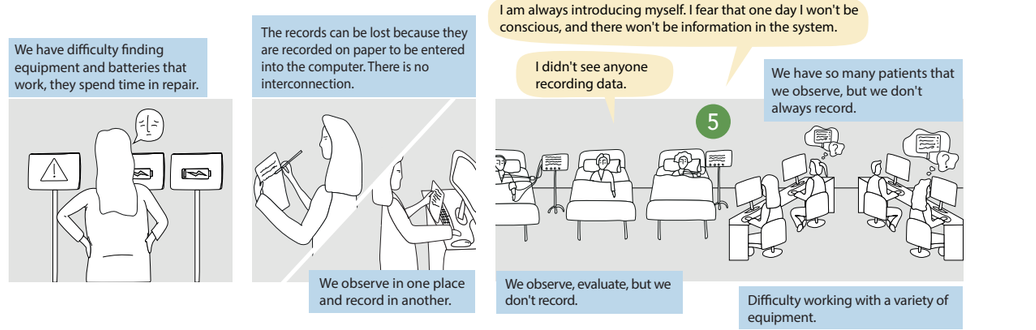
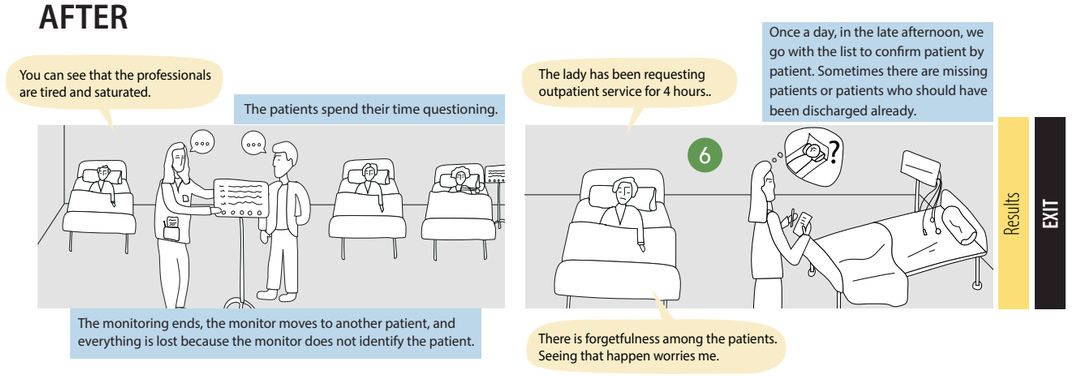




AFTER



Lack of an atmosphere

The atmosphere in the urgent area was described as a place "with a lot of people". It is commonly held that a hospital atmosphere is uncomfortable. We found that the atmosphere in the urgent area can be one of a variety of people with different injuries and diseases, forced together by circumstances, each one dealing with their pain and confronted by their own complex clinical needs.

Participant workshop 1:
"No comfort or decent conditions… cold, uncomfortable, no access to water."

Participant workshop 2:
"Very uncomfortable waiting room chairs. The hospital is never a comfortable place."

Pw2: "People on drips, vomiting, people with heads split open, babies crying: you see it all."

Pw2: "A lot of people were sitting in the waiting room. A lot of people, waiting for hours."

Need to see progress

Waiting for any length of time, especially when a person is in pain, can be a difficult experience. Forced to wait hours without seeing any sign of progress, can bring on feelings of being abandoned or forgotten.

Pw1: "A patient gets worse and nobody notices."

Pw2: "The drip runs out. I had to make them pay attention. Had they forgotten me?"

Pw2: "I was at the hospital for around 12 hours without my medication."

Pw1: "Patients can stay alone for an hour before the first medical observation."

Pw2: "I wasn't allowed to accompany my mother. I don't feel confident when my elderly mother goes to talk about her complaints

Poor communication

in the emergency department by herself."

Pw2: "It is very annoying that a patient cannot be accompanied in the emergency department. Having somebody with me is important to validate the information. Even before Covid-19 came along they would not let me be accompanied, just because I am deemed an adult."

Working in the hospital emergency department was seen as being very demanding on health professionals, many of which "change role from area to area". With a constant flow of patients requiring very different types of health care, health professionals can become physically and emotionally tired, with no energy left to converse and communicate.
The absence of dialogue led to feelings of anxiety, anguish and insecurity in patients.

Pw2: "Nobody tells us what the procedures are. People would understand the waiting times better if they were told what was happening, the reason for the long waiting times."

Pw2: "There is not enough information. Nobody called and only later do you learn you had to ring the bell. You have to ring the bell, but there is nothing that says that.

And there are more people to see in the same situation."

Pw2: "We patients don't know what is happening and we are not told. Providing some information to patient is going to calm them down."

Pw2: "A lot of people complaining and calling for the health professionals and people in pain."

Pw2: "The nurse did not speak to the doctor when the drip ended. I had to leave my place and ask the doctor. There is no dialogue with the doctors."

Pw2: "You can see the health professionals are tired and overwhelmed. I don't hear well, and the doctor's brusque manner put me off, made me hear worse. I refrained from asking questions. They did not accept my complaint. We are often treated like dummies."

Strong emotions

Pw2: "Very rude doctor, shouting and speaking loudly. We are often treated badly. Either we are selfish and we ignore things, or we do something and we hear from the health professionals."

Pw2: "I have had a kidney transplant and I take medication to avoid thromboses. When I said I was on medication, the doctor ignored it. The doctors do not accept being informed about my state of health. I give information about my state of health and I am ignored."

The emergency department is a place where people can experience risk events, develop anxiety, feel stressed or have to deal with other people's pain as well as their own. People "groaning and screaming" was seen as impacting feelings of malaise and great concern for other patients sharing the same space.

Pw2: "Seeing other people suffer made me more ill."

Pw2: "Seeing the suffering of others next to me worried me a lot. I wanted to help a lady who was suffering. We almost forget our pain, and we leave affected psychologically. We become patients just seeing others suffer."

Pw2: "Hearing other people groan, scream and suffering makes us uncomfortable."

Pw2: "There was a person with their head split open. I looked at the cases next to me and I thought that maybe I wasn't so bad."

The need for an integrated monitoring system

We found that "often the patient does not meet the criteria that would show the severity of their situation". While the HED has a triage system to evaluate the patient's complaint and assign a clinical priority for examination and treatment, their condition may change while they are in the emergency department. In other words, a patient's state of health may change and they should be assigned a different clinical priority level to that given when they entered triage. Even if the clinical priority does change, the colour of the wristband remains the same.

We found that in the urgent area, as well as the standard area, promptly detecting deterioration in a patient's state of health can be a challenge. We were told that "if the patient gets worse, the health professional only realizes when the patient is already very bad" and "we only see the patient in the waiting room if they get worse."

We understand that in a hospital, patients can benefit greatly from the technology that is continually monitoring their vital signs, as happens in other hospital departments, so as to ensure patient safety. Nonetheless, patient monitoring in the HED's urgent area turns out to be a non-integrated monitoring system rather than an integrated one.

Pw1: "The monitors take up a lot of space, they are not compatible… and they are worn out. They are always being repaired."

Pw1: "Uncharged bobbies [monitors], moving this and that from one side to the other, wasting time… batteries that no longer work… trouble finding equipment."

Another issue that arose under the current urgent area monitoring is that the monitors do not store or automatically record the patient's data during monitoring.

Pw1: "We need the monitor to identify the data as belonging to a particular patient. It can happen that the monitoring comes to an end, the monitor moves on to the patient next door and since the data are not associated with a particular patient everything is lost. There is a problem when I turn it off and forget to record the data."

Pw1: "The monitor does not identify the patient and a health professional can turn up and take the monitor. Either I have recorded everything or when I change the monitor, I lose everything. We have so many patients to observe, and we don't always keep records. Records can get lost because they are on paper."

Pw2: "I didn't see them recording my vital signs in front of me. I didn't see anyone recording the figures."

Pw2: "In the emergency department they brought along the cart, took the monitoring data and they took the equipment."

Pw1: "There is a specific place to do the records, but a lot of mistakes are made. We observe patients in one place and record stuff in another."

It is generally held that monitoring can cause some discomfort to patients, due to the various sensors that are placed on different parts of the body to monitor the different parameters (for example, heart rate, oxygen saturation, blood pressure, breathing rate and temperature).

Pw1: "Five electrodes with wires on the chest, a wire on the finger and a sleeve on the arm… sensors cause discomfort… patients pull off the sensors because they feel uncomfortable."

Pw2: "They pull one arm to one side, the other arm to the other and they connect wires. Nobody tells us what they are measuring. They measure, take the stuff off and say nothing. It was all over in less than a minute."

The health professionals referred to the importance of and need for monitoring to be an alert system for quickly detecting "if the patient is getting worse". The participants said:

Pw1: "The alerts are important. We need visual alerts. Just sound and in the middle of so many sounds, nobody hears the alerts: they are just more noise. A visual alert… that blinks… to know that it really is necessary to go there."

Pw1: "If there were vital signs monitoring and critical alerts, there would be less errors and problems."

Perceived inefficiency

From the standpoint of the health professionals and patients there is the perception that the emergency department, in particular the urgent area, is disorganized and there is a lack of focus. The patients see themselves and others having to wait for long periods, while the health professionals have trouble performing their duties due to the constant flow of patients in and out, in a clinical environment that possesses no integrated information system that could aid management and coordination in the clinical area.

Pw1: "The yellow area needs a person dedicated to those patients… needs a manager."

Pw1: "A serious problem is how disorganized things are… once a day, at the end of the afternoon, we check the patients on the list one by one and sometimes there are patients missing or patients who should have been discharged already."

Pw2: "The patients are forgotten. Seeing that happen worries me. I was waiting 45 minutes to give a blood sample, 45 minutes from the time the doctor ordered it until the blood analysis was done.
I witnessed a lady who had asked for an ambulance 4 hours earlier.
A lady was waiting 4 hours for an ambulance."

Pw1: "We need 21st century technology. There are N brands and N models of equipment. Monitoring data are written on paper… the data are typed into a computer… there is no interconnection. We need an integrated system. We need the information to go to the *SClínico* system automatically."

Pw2: "Information is neither integrated nor available. I am always introducing myself. There is no information crossover. I get worried because there is no integrated information. Every time I go to the hospital I am mistaken for a healthy person, rather that someone who has had a transplant and has major needs… I fear one day I will not be conscious and there will be no information in the system.
That frightens me."

Summary of major needs

In the first phase, aimed at understanding the current state of patient monitoring in the HED, the health professionals and patients highlighted a series of problematic issues that can be converted into a series of considerations, a basis for rethinking the concept of patient monitoring in the HED in the future.

An understanding of the practices and experiences under the current HED patient monitoring system suggests the need for future monitoring to be **an integrated alert system that automatically records vital signs to aid management, coordination and communication of individual information on each patient during monitoring.**
Participants also called attention to the important contribution monitoring can make to a comfortable patient experience. For example, would it be possible to measure the various vital signs by way of a single sensor?

If so, what is the best way the sensor can adapt to the patient's body in order to provide a comfortable experience?
Although patient monitoring is clearly vital in the HED, we understand that in the urgent and standard priority areas it is fundamental. The participants highlighted the importance of patient monitoring in the waiting room, so that if a person enters into clinical deterioration they can be identified and observed as quickly as possible.

Illustration of health professionals' voices when designing the sensor in activity 3.

Workshop 3

What we did

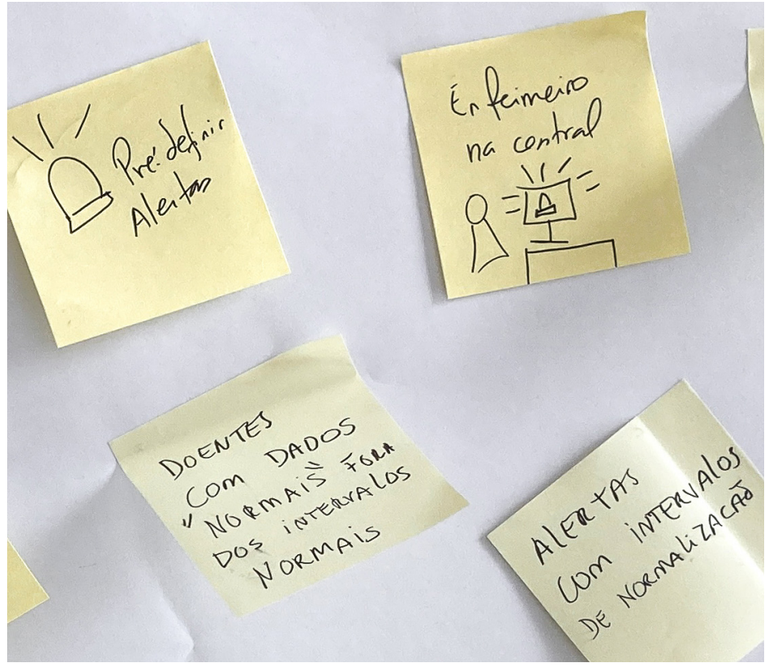
Workshop 3, a three-hour session, was undertaken with a group of health professionals (a doctor and three nurses). Three of them had taken part in workshop 1.
This workshop aimed to bring together a range of ideas to explore a preferred scenario for future patient monitoring in the HED.
It was seen as a way of bringing together the health professionals' ideas on the ideal HED patient monitoring system, with the expectation that guidelines would be drawn up for the best way to deal with the clinical deterioration issues. Thus, 3 activities were undertaken employing the design games approach [10], which placed the health professional group in collective creativity moments to explore what would be a significant future outcome for promoting health care safety and quality throughout the patient pathway in the hospital emergency department.
The information generated in this workshop will be the basis for building a first version of the future patient monitoring system prototype, which will provide early alerts for clinical deterioration in the HED.

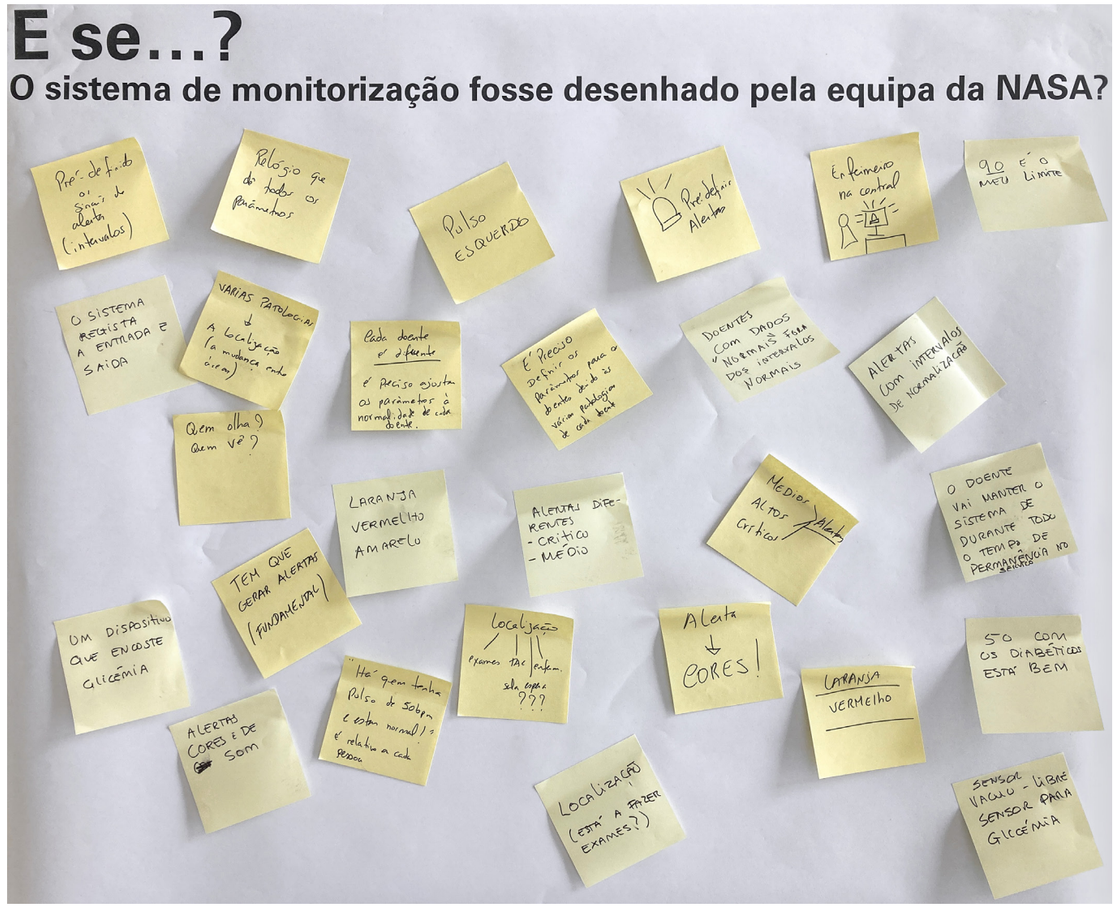
The first activity set out to encourage health professionals to reflect on the design of patient monitoring improvements that would promote health care safety and quality in the HED.

It began with a presentation, to show the current scenario of patient and health professional experiences in the context of the HED in three occasions: after triage, during treatment and when being discharged.

The presentation illustrated a narrative that highlighted the experience of two fictitious characters: a patient – Julia, and a health professional – Maria. The presentation helped to encourage the health professionals to think about patient monitoring in the following way: "And if the monitoring system were designed by a team from NASA?". This was a group session moderated by LIDA's Principal Researcher who asked questions to begin the discussion, while two facilitators mapped the shared information. The facilitators (a design research fellow and a designer) also mapped what was said by the group throughout the discussion on a diagram, revealing a variety of issues, such as: the need to create a monitoring system that sends clinical deterioration alerts to the health professional in real time and which allows the health professional to match the parameters to each patient's pathology.

Illustration of health professionals' voices in the first activity in the game "And if...?".





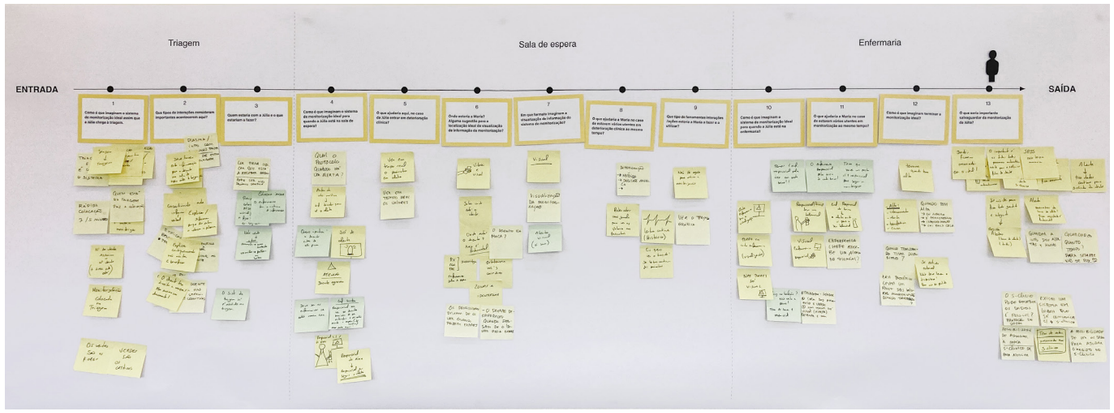


Illustration of health professionals' voices in the second activity.

The second activity aimed to explore:

- **What would be the ideal monitoring system in the hospital emergency department;**
- **What an alert system for early detection of clinical deterioration would look like.**

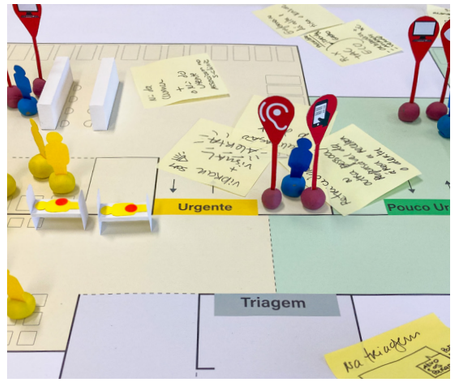
This activity set out to generate ideas about a desirable future patient monitoring system, within the vision of providing alerts, from the time the patient was admitted until they were discharged, of early detection of clinical deterioration in the emergency department.

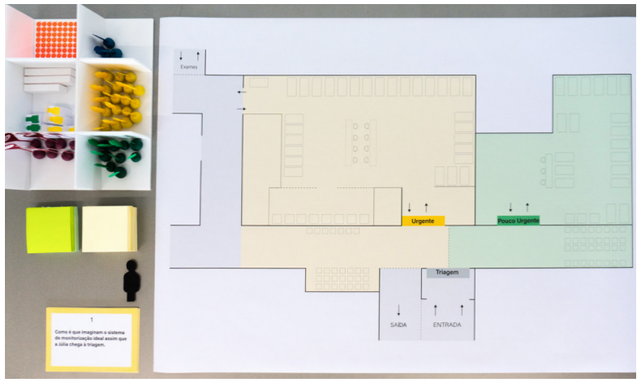
To that end a large, printed diagram was used – as a game board – that mapped the urgent (yellow) and standard (green) areas in Leiria Hospital's emergency department. This tool provided for discussion of where and when the monitoring system should begin and who were the major actors in the interaction, organization and coordination throughout the patient pathway in the hospital emergency department. Here the participants were invited to express their ideas about the diagram, bearing in mind the various stages of the patient pathway: triage, waiting room and ward.

A series of quick-fire questions were asked and included on the wall map to encourage reflection on each stage. For example, what happens when the patient arrives at triage? What should happen when the patient is waiting? What would help if a number of patients enter into clinical deterioration at the same time?

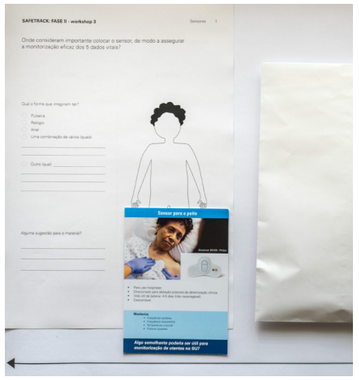
A set of items were available on the table to add to or polish the information in the diagram.

For example, items that illustrate a range of possibilities for visualizing information (e.g., audible, visual), formats (e.g., computer, smartphone, etc.), patients in the yellow and green priority areas and health professionals.





Visual tools and game board used with health professionals in activity 2.



Set of tools to analyse and envision the sensor.

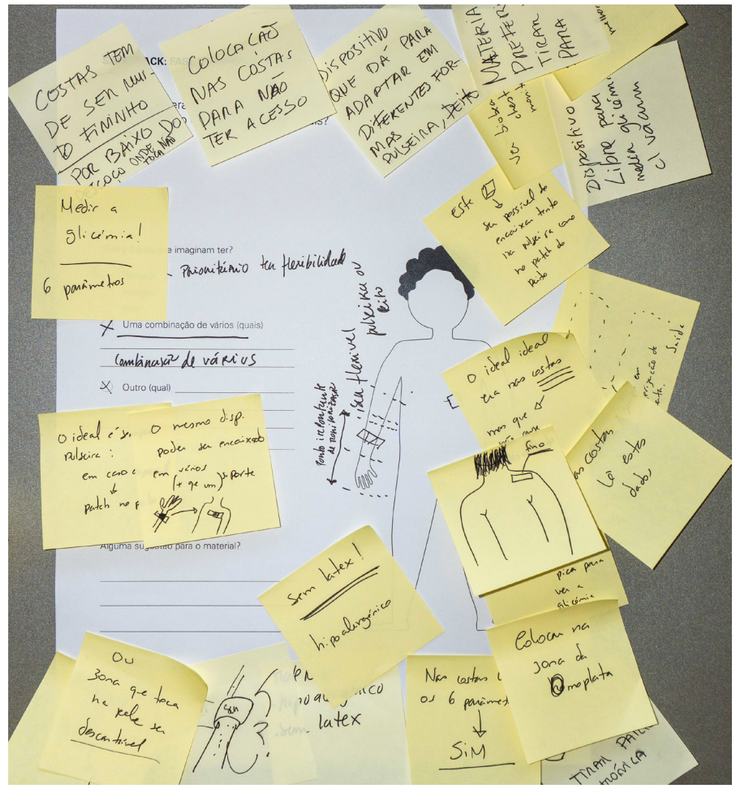
Set of tools to analyse and envision the graphic interface.

The third activity sought to generate ideas in order to envision the two interconnected components of the monitoring system: the sensor that would measure the patient's vital signs and the graphic interface that would convert the information gathered by the sensor into an image.

To that end, the participants were invited to express their thoughts and ideas about the sensor and the graphic interface, using a set of tools. The sharing of ideas about the sensor and graphic interface were explored by way of a booklet, prompt cards and a kit containing diverse materials, which made it possible to generate a range of information. In the case of the sensor, for example, the prompt cards enabled an understanding of the positive and negative aspects of hospital sensors and call attention to the key aspects to be considered when envisioning the new sensor. The booklet sought to explore information relating to the format, material and sensor's location on the patient's body.

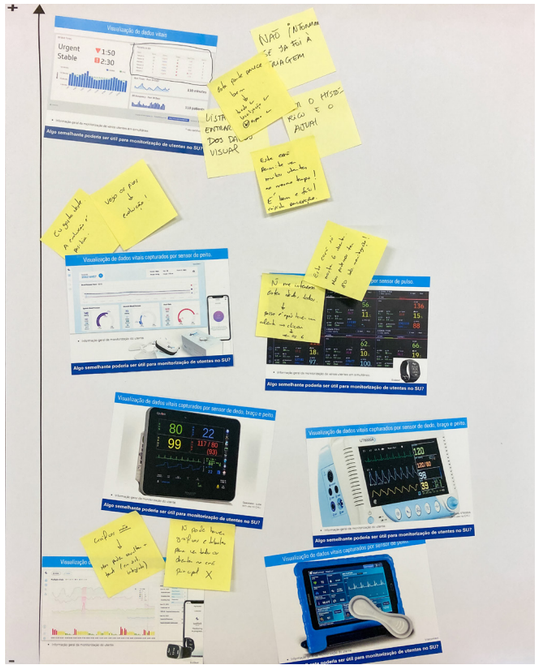
The materials kit set out to encourage the participants to a build a 3-D model of the ideas generated as to what should be visible on the sensor. Here the dialogue with the participants was recorded directly on post-its by the facilitators, at the same time as the Principal Researcher asked questions in order to encourage the participants to build up a picture of the ideas generated.

As for the sensor, the information gathered showed that it should:
1) measure six vital signs – heart rate, oxygen saturation, blood pressure, breathing rate, temperature and blood sugar;
2) have a versatile format that can be placed on the arm, chest or shoulder blade;
3) be flexible material wise, for example, the material that touches on the skin should be disposable; and 4) interact passively with the patient. In other words, when a patient enters into clinical deterioration, the sensor should only send that information to the health professional. That is because if the patient sees the alert indicators, it could set off a chain reaction of greater anxiety and stress, rather than promote tranquillity and calm.



Discussion around hospital sensors presented on the prompt cards in activity 3.

Illustration of health professionals' voices when exploring the features of the future sensor.

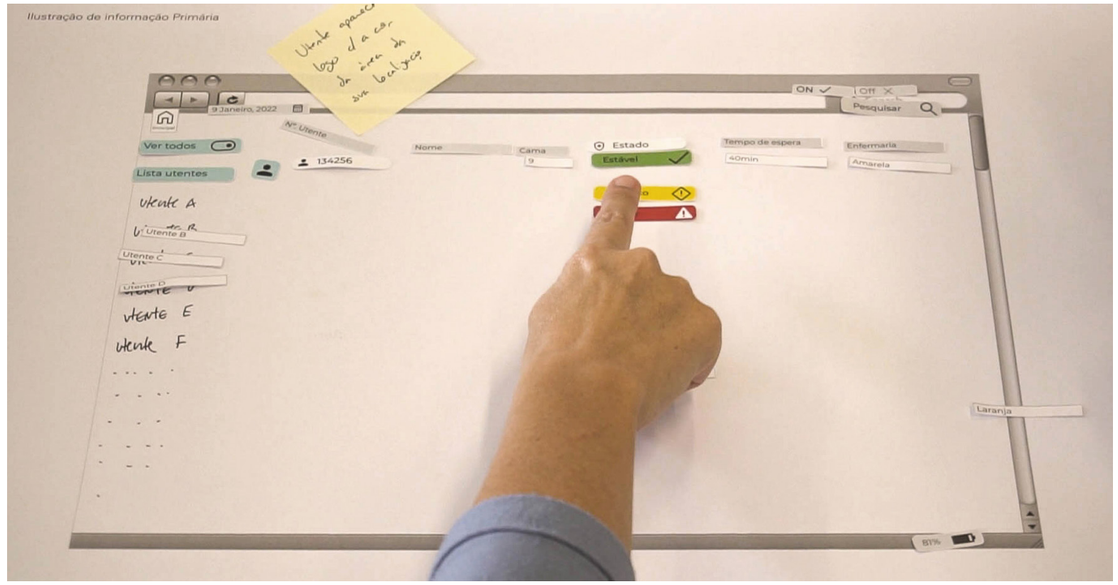


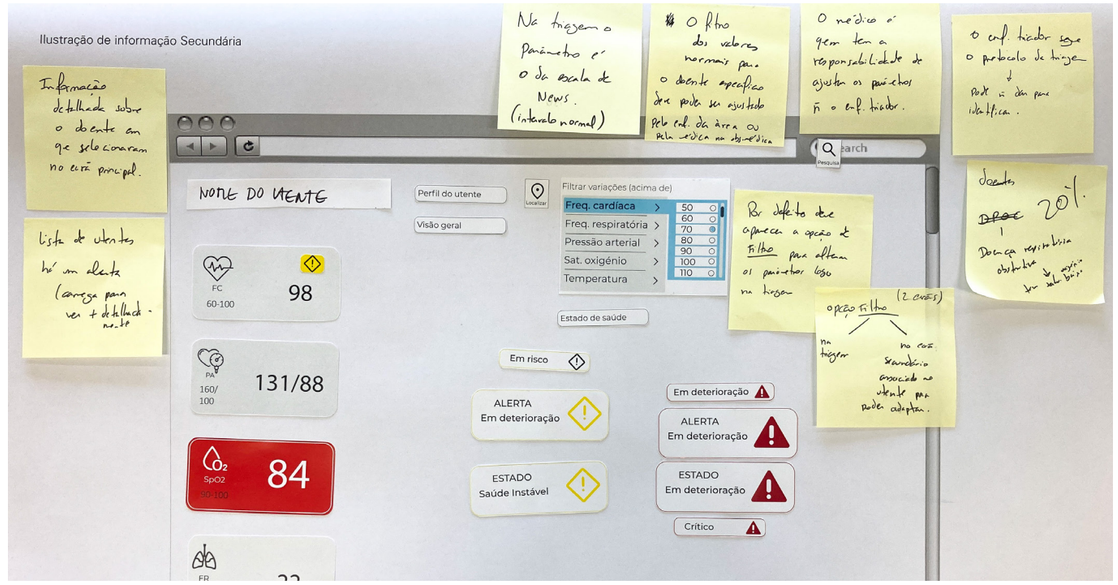
As for the graphic interface, the prompt cards helped to understand the key aspects of information visualization. The booklet sought to explore information about the digital format, the type of language and information levels. The materials kit set out to cause reflection and represent a visual interpretation of the ideas generated about digital interaction and the type of information that should be visualized during the monitoring. Here the participants' comments were also recorded directly on post-its by the facilitators, at the same time as the Principal Researcher asked questions in order to cause reflection and encourage the participants to build up a picture of their ideas for a graphic interface using a set of materials. The information gathered about the graphic interface showed it should provide two levels of information: 1) a view of the general information on the state of health of the various patients admitted to the urgent and standard areas in the HED, and 2) a view of each patient's own information. For example, it was said that it was important to have a "speedy perception" of what is happening in the emergency department, if there are patients who are stable, at risk or critical, and thus act swiftly in light of the priorities.

Discussion of the individual's information revealed the need to know more about the state of health of the patient who is a cause for concern. Here a specific visualization of the various signs and their parameters was deemed important to support clinical decisions. The workshop was recorded on video and through photographs in order to enrich the qualitative data and to support the facilitators' notes on the various activities. The information collected was analysed by topic so as to reveal recurring themes.

Ordering of graphic interface prompt cards, by degree of preference as to each one's individual characteristics.

Building of a visual representation of the graphic interface with the information that must be visualized.





What we discovered

The analysis of the observations, maps and models generated in the workshop led to:

— An example of a preferred scenario for patient monitoring in the urgent and standard areas of the HED, which identifies a series of opportunities for developing the future patient monitoring system that will provide early alerts for clinical deterioration.

— Information on the guidelines to be followed when developing the sensor and the graphic interface to aid information integration, management and coordination.

The information gathered in this Phase II will act as the basic structure for starting Phase III, which consists of an interactive process for developing and refining the prototype of the new HED patient monitoring system. The preferred monitoring scenario illustrates the health professionals' points of view. The ideas and concepts generated will be highlighted alongside the information and thoughts that produced them.

Preferred scenario for patient monitoring in the urgent and standard areas of the emergency department

From our conversations with health professionals, we found that there is a desire for any future patient monitoring system in the emergency department to aid supervision by health professionals and to provide alerts of clinical deterioration in real time.

The following visual narrative illustrates health professionals' voices and reveals a series of opportunities for rethinking the future of patient monitoring in the HED. Nonetheless, the visual narrative also reveals some limitations for synthesizing what is currently an extremely complex situation. In short, its construction aided reflection on important points to be considered when developing the future patient monitoring system, to improve the response to issues of patient safety and health care quality. We have understood that in order to promote greater health care safety and quality in the future HED calls for conceiving of a system that connects, facilitates and displays both collective and individual information.

This visual narrative shows how health professionals' ideas can make a difference, for example, thinking how we can show people the importance of being permanently monitored while in the emergency department? They also point out that it is important for monitoring to be a system that provides real time "alerts" as to the patient's state of health. Another point is that monitoring can facilitate the managing and coordinating of individuals' information. What this narrative shows us is that these voices reveal a type of monitoring intervention based on the "control tower" concept which sends clinical deterioration alerts to health professionals, so that they can, promptly and appropriately, respond better by delivering health care at that time.

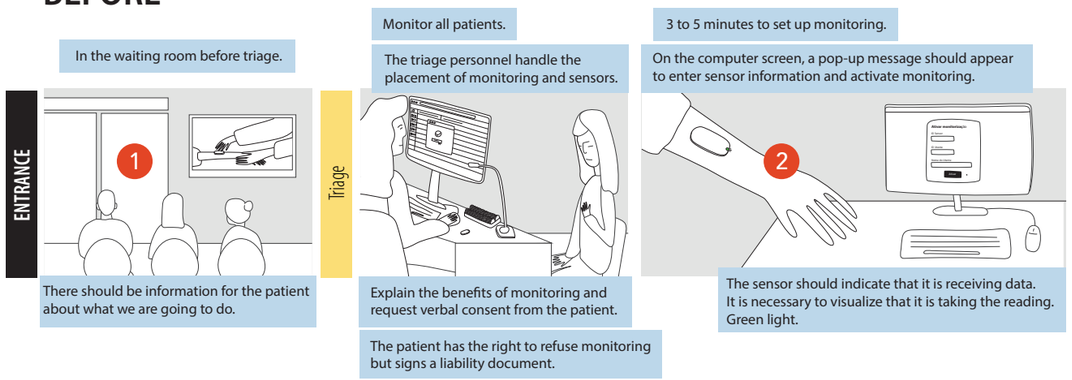
Opportunities

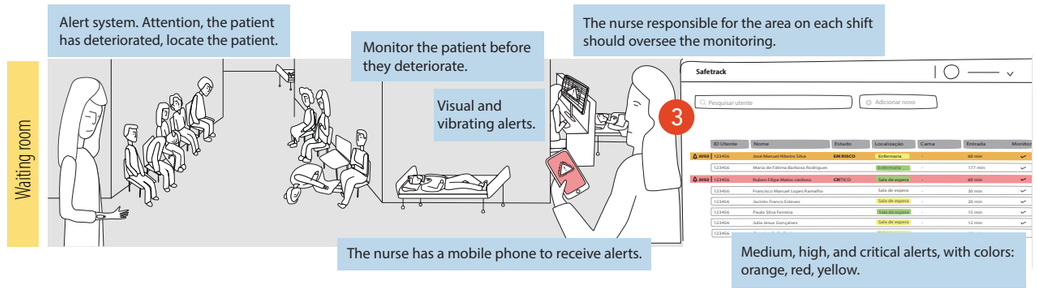
1. Create informing moments
2. Facilitate the applying and activating of the monitoring system
3. Devise alerts
4. Display moments
5. Automatic information records
6. Protection of personal information

Voices:

- Profissionals

BEFORE





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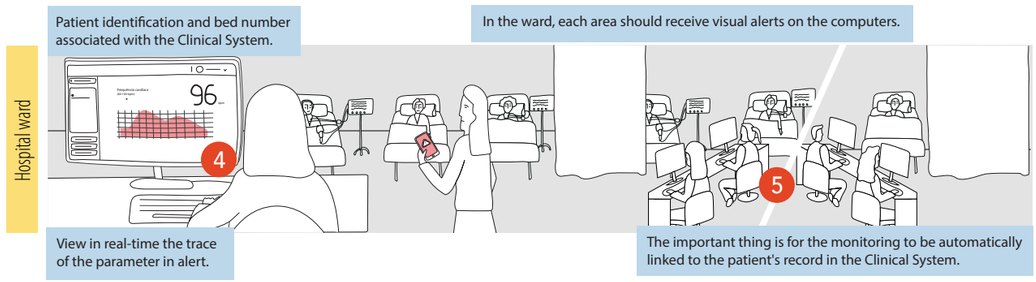

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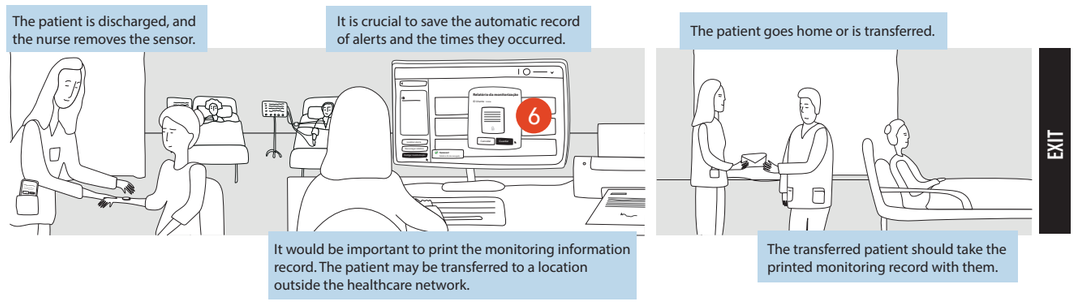


Create informing moments

Triage was described as the place where the nurse only has "3 to 5 minutes to screen the patients". We found that creating informing moments, which describe what the patient is going to experience before triage, was deemed important in order to prepare people for what they should expect after triage. That is to say, they receive information about the benefits of a monitoring system to guarantee patient health care safety and quality during their time in the emergency department.

Pw3: "There should be communication with the patient before triage. A screen with information about what we are going to do that they can read before they enter triage."

Pw3: "Explain the benefits of having the system (…) why I am giving them a wrist band."

Facilitate the applying and activating of the monitoring system

It is commonly held that the new patient monitoring system should begin in triage. It was understood that applying and activating the monitoring system on the patient should assist the triage nurse who has limited time for screening. Therefore, a desirable goal for triage in the future is to include a speedy evaluation of the patient's complaint and facilitate the applying and activating of the new monitoring system.

Pw3: "Monitoring device applied in triage. Who is in triage applies the sensor."

Pw3: "The application must be quick, the nurse has 3 to 5 minutes to screen. All patients should receive the device. One hundred percent of patients being monitored."

Pw3: "Ask for the patient's verbal consent. Explain to the patient the benefits and the consequences of not accepting being monitored. The patient has the right to say no, but then they should sign a waiver, if there is no cognitive impairment."

Pw3: "They apply the sensor: there should be visual feedback to show it is taking readings. For example, a green light, a green ball for active, yellow for poor contact and red for a reading problem."

Pw3: "In the triage area, on the computer screen a pop-up message appears with the monitoring information to confirm the sensor is active, and that the system is receiving the patient's parameters."

Devise alerts

To be able to recognize "in real time" a patient's clinical deterioration in the emergency department is deemed to be a key point in "catching the patient before they get worse".
We found it will be important in the future to develop a monitoring system that provides early alerts about clinical deterioration, and that constantly communicates what is happening in regards to the patient's state of health.

Pw3: "It has to provide alerts. Standard, high and critical alerts, coloured orange, red, yellow."

Pw3: "A system of alerts only. Attention patient got worse. I want to accompany the patient before they get worse. See in real time the parameter causing the alert."

Pw3: "Visual alerts that vibrate."

Pw3: "It is the triage nurse or the nurse responsible for the area who should receive the alerts. The triage nurse is responsible for seeing which patients need to be screened again and if they are waiting for medical observation. It should be the nurses who are in that area."

Display moments

From the constant flow of patients needing a wide range of care, we learn that a monitoring system that provides various formats for displaying information may assist health professionals in the managing and coordinating of health care in the emergency department.

Pw3: "The system records the patient entering and leaving the emergency department. The patient will remain in the system for their entire time in the emergency department. I want to know where the patient is. The area is essential, imaging department (X-ray, ECO, CAT), wards, waiting room, orthopaedic trauma, WC, corridors…"

Pw3: "I want to see the graph of the continuous reading of the parameters, to be able to open a window so see the complete values of the various parameters, the alert time, the history."

Automatic information records

We found that "automatically associate" the patient information generated in the future monitoring system with the current hospital information system *(SClínico)* would facilitate the complex management and coordination of patient health care in the emergency department. For example, applying and activating the future monitoring system on the patient in triage should create opportunities to automatically associate the patient's general information, such as, name and case number that are already in the *SClínico* system, which would be also associated with the monitoring system, so as to facilitate the link between the patient's state of health information generated by the monitoring system and the hospital information system.

Pw3: "It is important for all the data to be sent automatically to the patient's *SClínico* file. Associating the data would be ideal."

Protection of personal information

Pw3: "It has to be associated with the *SClínico* system. Must be possible to see the data to help with the *SClínico* records. There is a system in Lisbon that already communicates with the *SClínico*. Is it possible for the SClínico to receive the data? The *SPMS* does not allow the association. If it is not possible to save and integrate, to be recorded is key. Parameter alerts, alert times in the patient's *SClínico* file."

Pw3: "Record alerts, times, should be associated with the patient's ID file."

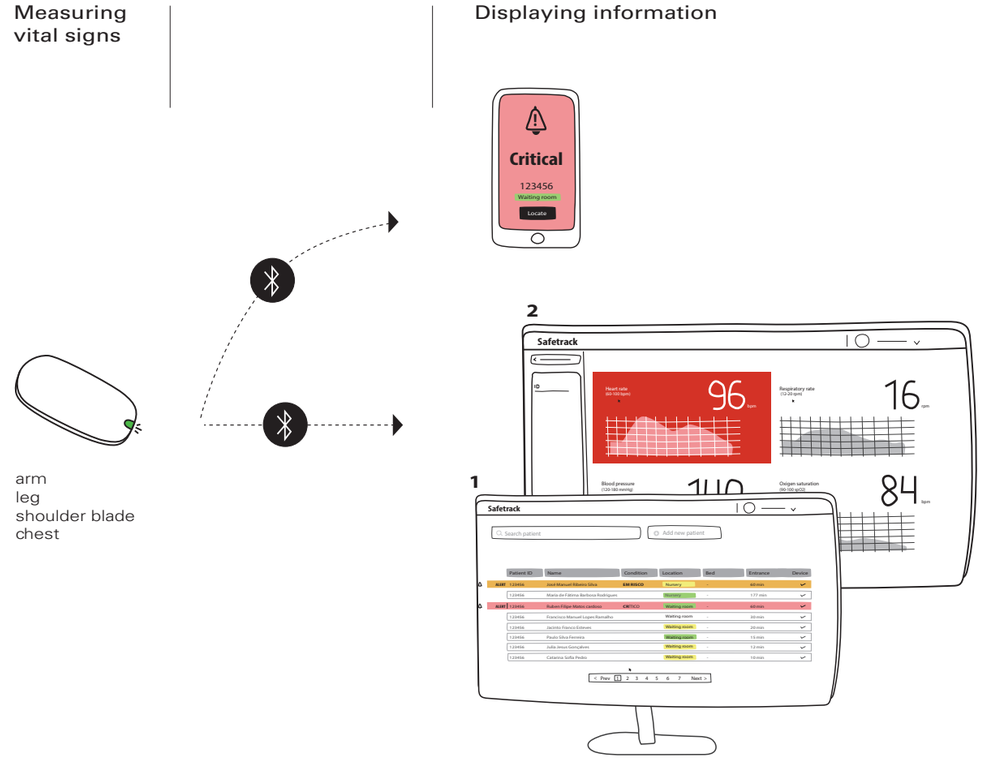
We understand that in a hospital patient information is saved "forever". This situation highlights the importance of the matters of confidentiality, privacy and data protection. Here we highlight the importance of reflecting upon how the future patient monitoring system protects and safeguards personal information generated during hospital monitoring.

Pw3: "The patient either dies or is discharged and the nurse removes the sensor, or they are transferred or they go home."

Pw3: "When they are transferred, if they are stable, they should not take the device with them so that it won't be lost. It will be useful to take a printed model of the monitoring data for when they leave the reference network. Take a letter in an envelope."

Pw3: "Patient data shall be saved: it can't be deleted by law. Patients' data are stored for their entire lives."

Main guidelines for developing the future monitoring system



Here we invited health professionals to reflect on how we could represent the vision of this future HED monitoring system. We found that it was commonly felt that introducing a new system in the HED should make it easy to apply and activate the sensor in triage and the main aim should be patient monitoring that provides alerts for early detection of clinical in real time. From ideas generated by the health professionals we understood that there are two interconnected stages in a monitoring system:

1) Measuring vital signs by means of the sensor (a medical device that will record the patient's vital signs), which should have a modular format so as to adapt to the different parts of the body and the patient's state of health;

2) Displaying information by means of a graphic interface (a digital tool that receives the data from the sensor and turns them into visual information), which should provide two levels of visual information: the first level will display general (collective) information and the second will display detailed (individual) information.

1) Measuring vital signs

In Phase I, we identified the need to monitor, automatically, 5 vital signs: heart rate, oxygen saturation, blood pressure, breathing rate and temperature.

In Phase II we found that "measuring blood sugar" and "locating the patient" should also be considered when designing the new HED monitoring system.

Therefore, the medical device (sensor) of the future patient monitoring system providing alerts for the early detection of clinical deterioration should be able to monitor:

- **Heart rate**
- **Oxygen saturation**
- **Blood pressure**
- **Breathing rate**
- **Temperature**
- **Blood sugar**
- **Patient's location**

Sensor functions

Among the ideas generated was a general opinion that when the sensor was placed on the patient it should emit a light signal, for example: green – it is gathering data; orange – there is a faulty connection; red – it is not gathering data, in order to aid the applying and activating of the monitoring device.

Pw3: "The colour of the sensor to indicate it is receiving data."

Pw3: "I like a green light, shows it is working."

Pw3: "The green light on the sensor must always be visible. A light to show it is collecting data."

We found that there were a range of opinions as to what should be visible on the sensor to the patient and what should not. However, we confirmed the importance of the sensor not making the patient more anxious or stressed.

Pw3: "The patient should not see the data. They should not have that information because it causes anxiety."

Pw3: "The information being visible could be useful. It is important because the patient is going to alert the health professional. It would be easier for the health professionals."

Pw3: "But they may not be literate enough. Thinking of the patient, to see the data is going to cause anxiety. It stresses the patients."

Pw3: "But it also empowers the patient. It should be an option, see or not see the data. Even if the patient sees the data, they will only alert the health professional."

Pw3: "The patient should not see the alarm, ever. Speaking as a nurse, the patient should not see the parameters. If it makes the patient stressed, we are not helping the department. A patient in the emergency department is anxious and vulnerable. The fact the patient knows they are being monitored already helps them relax."

Sensor shape

We understand that the sensor should have a modular format in order to adapt to the various body parts. For example, the arm, shoulder blade and leg. Here we understood that the sensor should be "thin" so as to be comfortable, and have a shape that can be applied to various people with different body shapes and health conditions.

Pw3: "The ideal place would be the back, but without causing discomfort. Backs have to be very thin, below the neck, in the shoulder blade area."

Pw3: "We need options. It can be placed on the ankle. The patient may be an amputee or have burns."

Pw3: "The ideal place would be the wrist, but it has to be able to adapt to different wrists. In special cases it could be a patch on the chest. In a flexure zone or on the hand where you prick to see blood sugar. The same device can be encased in various supports, such as a wristband or a chest patch. Adapt to different parts of the body, wrist and chest."

Pw3: "For example, like the *Biobeat* chest monitor. A device that can be adapted to different shapes, wrist and chest, or like the Libre device for measuring blood sugar with a vacuum."

Pw3: "Be flexible. It is best if it can be flexible."

Sensor material

The emergency department is a place that provides treatment and care for a variety of health conditions. We found that the ideal solution would be to be able to peel off the part of the sensor that touches the patient's skin, in other words, "use and throw away". Textile materials are not recommended because there are issues with disinfecting and contamination by body fluids, such as sweat, blood, among others. The material should allow for cleaning and sterilization. Isopropyl alcohol and alcohol at 70% were considered to be the ones used to disinfect hospital products.

Pw3: "The ideal solution would be to remove and put in the garbage the part that touches the skin, be a peel-off item. As with baby wristbands. Baby wristbands also have a reusable part, which is cleaned and disinfected. The baby is discharged: another nurse removes the band and disinfects it. With isopropyl alcohol."

Pw3: "The stick-on sensor is good because you throw away the part with the adhesive."

Pw3: "I don't know if it will drop off if the patient sweats a lot. Do the self-adhesive items react well to sweat?"

Pw3: "It must be non-allergic, latex-free."

Pw3: "Waterproof."

Disinfecting and charging the sensor

From the ideas generated we understand that a charging system that uses cables interferes with health care practices. The ideal system would combine disinfection and speedy, wireless charging. Home base or induction charging systems were given as examples.

Pw3: "The ideal solution is a charging unit, just place the sensor on it and it charges. Charge the batteries easily. If they have to connect cables it will lead to stress. The baby system uses batteries."

Pw3: "The ideal solution would be to place them in a basket for disinfection and charging."

2) Displaying information

Health professionals find themselves forced to work daily with a range of information systems, in order to manage and coordinate hospital information. It is generally held that it is important to see "what really matters", that is, to give prevalence to whether the patient's health is "at risk" or not. From the ideas generated we understand that the ideal solution would be a new patient monitoring system that displays two levels of information gathered by the sensor.

General information

The first level of information should show a list of patients who are in the emergency department at the time. It is important to highlight the following information:

- **Patient ID;**
- **Patient's name;**
- **Patient's state of health in real time;**
- **The patient's location within the emergency department by area (green or yellow);**
- **The patient's bed number, where applicable;**
- **The time the patient entered the emergency department;**
- **Confirmation that the sensor is gathering data, in other words there is active monitoring;**
- **An indication of the sensor's battery status (for example, 100% charged, 50% charged, no battery).**

Pw3: "The screen allows us to see a number of patients at the same time. It's right and easy to use. Quickly understood."

Pw3: "Ideally you would see the patient list and then select the data of a particular patient. Load the patient to gain access to their data."

Pw3: "There cannot be graphs and tables to see all the patients on the main screen."

Pw3: "A combination of different things. A computer for the general view and the health professional responsible for receiving the patient alert."

Pw3: "The important thing is to understand the patient is at risk. I know that if the patient gets worse, I will receive an alert. I can relax."

Pw3: "The main screen, the patient shows up immediately along with the colour of the area and their location. General information on the patients being monitored. There is an alert, click on the patient to see more detailed information."

Pw3: "Filers, patient ID, case/entry number, patient area colour."

Detailed information

We discovered that the second level of information should allow us to see "detailed information on the patient selected on the main screen", that is, from the interaction with the first level of information. In other words, what was deemed important was a first digital interaction, the system displays general information on the state of health of a number of patients admitted to the emergency department in the urgent and standard areas. Whenever there is a case of clinical deterioration, that information should be highlighted so the health professional can swiftly identify and select the patient in question. So as to monitor their state of health by way of a series of more detailed information, such as their vital parameters by way of "graphs and tables".

Pw3: "In the first place, see the alert data and, secondly, be able to look at the history and the graphs, the ECG line is important, the blood sugar graph."

Alerts

From the conversations about alerts, we found two alert states: conscious and unconscious alerts. We also understood the importance of adapting by way of "filters" the alert parameters in line with the patients' health conditions.

Pw3: "The alert may be due to a change in an individual parameter. See the numbers that triggered the alert."

Pw3: "Follow the Score News for the normative data. The early alert scores are valid, are established. Score News was validated for the Portuguese population. Alerts scores include the alert state, conscious/unconscious."

Pw3: "Every patient is different: we must adjust the parameters to the normal level for each patient. It is necessary to define the parameters for the patients in line with each patient's pathology."

Pw3: "Pre-set alerts. Alerts with normalization intervals. There are those whose pulse is 50bpm and that is normal. 90bpm is my limit. 50bpm with diabetes is fine."

Pw3: "Filters for each parameter. It should be possible for the area nurse of the doctor on observation to adjust the normal value filters for a specific patient."

Pw3: "The doctor is responsible for adjusting the parameters and not the triage nurse. The triage nurse follows the triage protocol, and it may not be possible to identify the normal intervals for that specific patient."

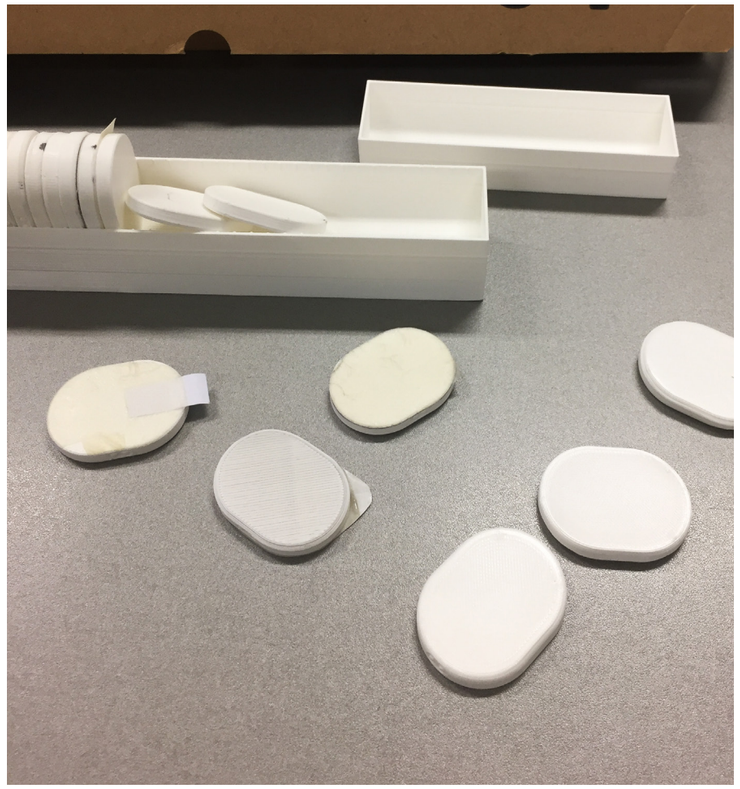
Pw3: "20% of patients have obstructive respiratory disease, low saturated oxygen. The default filter option should be to change the parameters immediately in triage. Two filter options, one in triage and the other on the screen associated with the patient to provide for adaptations.

Summary of ideas generated

The second phase aimed to explore what could be done to promote quality patient monitoring in the hospital emergency department. The health professionals contributed a series of ideas that were turned into concepts and allowed us to visualize path to the developing of an initial prototype of the new patient monitoring system. Reflecting about what would be a significance difference in the future HED patient monitoring system **highlighted the importance of monitoring providing alerts for early detection of clinical deterioration so as to bring about a greater response to matters of health care safety and quality throughout the patient pathway in the hospital emergency department.**

The participants also thought about the role of design in the developing of this new monitoring system and they drew attention to the importance of the design of the monitoring device ensuring speedy application and activation during triage. For example, they felt it would be possible to see, as soon as the monitoring device was put on the patient, whether or not it was gathering data on the patient's vital signs? Here the participants also reflected on the design of the sensor (medical device). The participants' suggestions revealed the importance of the sensor design having a modular format, so that it can be adapted to the patient's different health conditions. For example, they thought it should be possible to place the sensor on different parts of the body. The questions arose here as to whether the sensor design having a modular format would, at the same time, ensure efficient gathering of data on the six vital signs identified as those to measured by the monitoring system? The participants also thought about the design of the graphic interface (digital tool that translates the vital signs data into visual and written information visual). Here the participants' ideas revealed the importance of speedy access to the alerts so as to identify at risk and critical states of health. Their suggestions revealed the design of the general and detailed individual information displays.

The first interaction with the graphic interface should provide a general view of information on monitoring (e.g.: a list of the patients being monitored, their state of health in real time, their location, etc.). The second interaction with the graphic interface should provide detailed information on the parameters of a specific patient. Here the suggestions drew attention to the importance of providing graphs, tables and written information (e.g.: information on the sample recorded during the monitoring period) about the different vital sign parameters. In short, by illustrating the health professionals' ideas we have managed to identify the major points that make future opportunities clear.



Design of the sensor capsule shape and 3-D printed models.

Prototyping: first steps

What we did

The first version of the prototype of the new patient monitoring system is the result of the information generated in Phase II and a series of discussions among the various specialists of the SafeTrack project consortium – design researchers, designers and electronic engineers – who have supported its development. The new patient monitoring system calls for the prototyping of two components: 1) the sensor to measure the vital signs and 2) the graphic interface to display the information.
The first version of the prototype will identify the next steps to be taken in its development within an iterative co-design process, to involve a new relevant group of participants (nurses, doctors and hospital emergency department heads) who have been invited to interact with the prototype (version 1) and to share their thoughts and suggestions for homing and improving it.

Beginning sensor prototyping – version 1

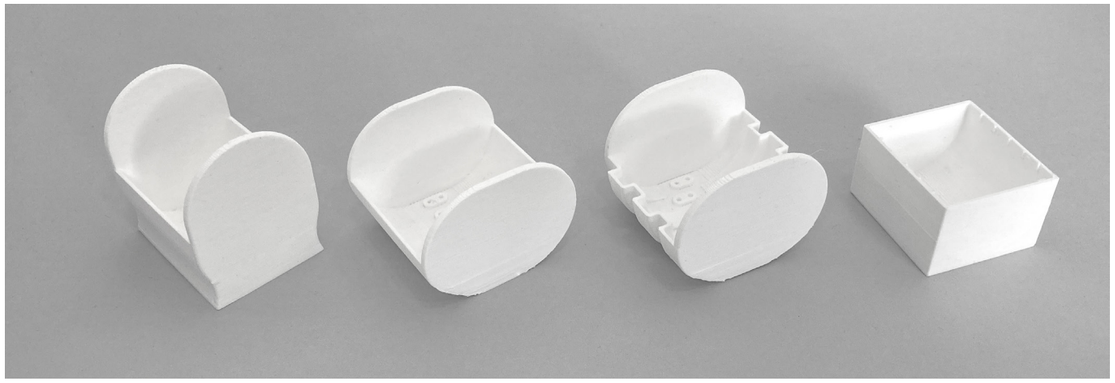
The prototyping of the sensor to record vital signs in the new monitoring system highlights the health professionals' ideas as points to be considered when developing the new sensor. Modelling and building of the sensor calls for reflecting on 3 main aspects:

1) The capsule (part) that encases the sensor (electronic system) to record vital signs;
2) The sensor charging unit;
3) The sensor pre-cleaning/ disinfecting unit.

3-D printed models of various sensor capsule shapes and the peel-off section.

The capsule that encases the sensor

We began by exploring what the health professionals saw as a benchmark when envisioning the sensor capsule as being modular and adaptable to various body parts, being small in size, wireless and attached to the skin by means of a hypoallergenic adhesive strip. Here LIDA's team of researchers and designers, in order to conduct tests promptly, highlighted the importance of the 3-D printed model method.
In this way, following a few tests, the oval shape was deemed to meet the requirements as to shape, satisfying the health professionals' preferences for ensuring patient comfort, while also meeting the electronic system's internal space requirements. Since we understood the monitoring device should be activated straight away in triage, it was even more important to be able to apply and activate the sensor speedily. A number of shapes in different sizes were tested for comfort on the body, as well as a number of ways of sticking the sensor to the skin, by way of a hypoallergenic self-adhesive strip, suitable for hospital use. Here we sought the advice of the health care researchers on the SafeTrack project team. Once an adhesive strip that met the necessary criteria had been chosen, a number of tests were conducted with this double-sided strip, in order to find out the best way de apply the capsule using this "plaster" idea. Here we also saw the importance of creating a disposable strip in order to aid the applying and removal of the capsule's adhesive strip.

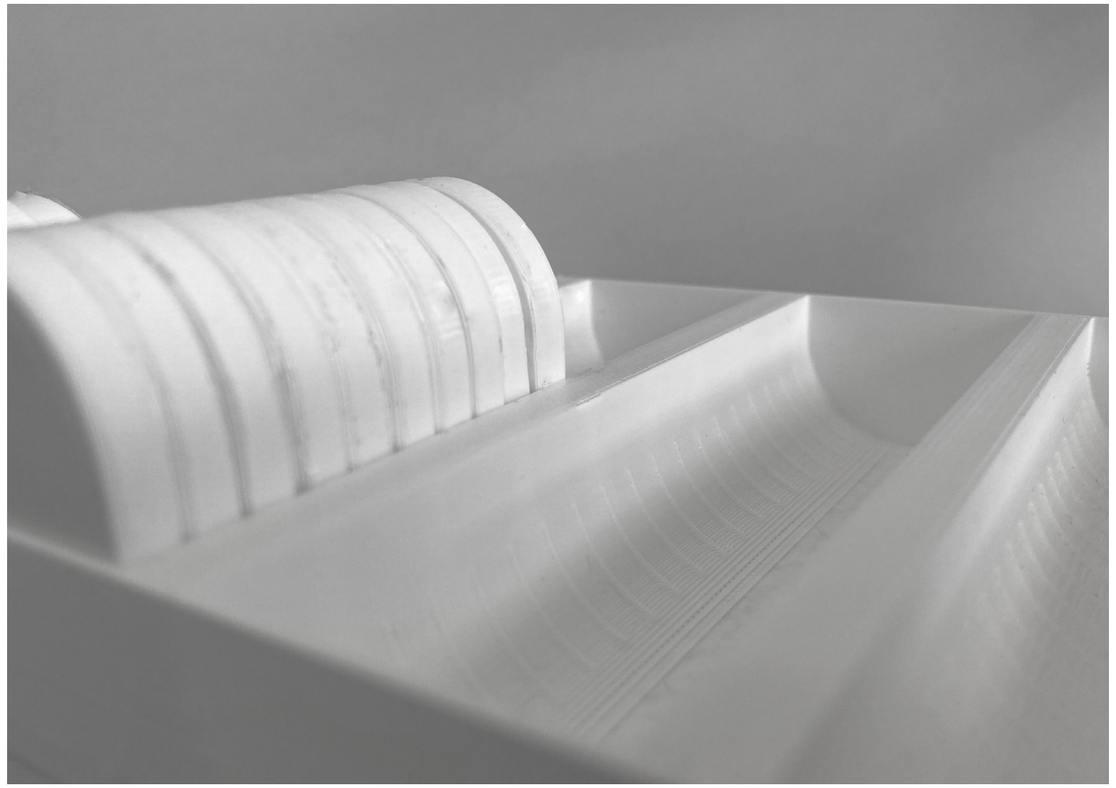


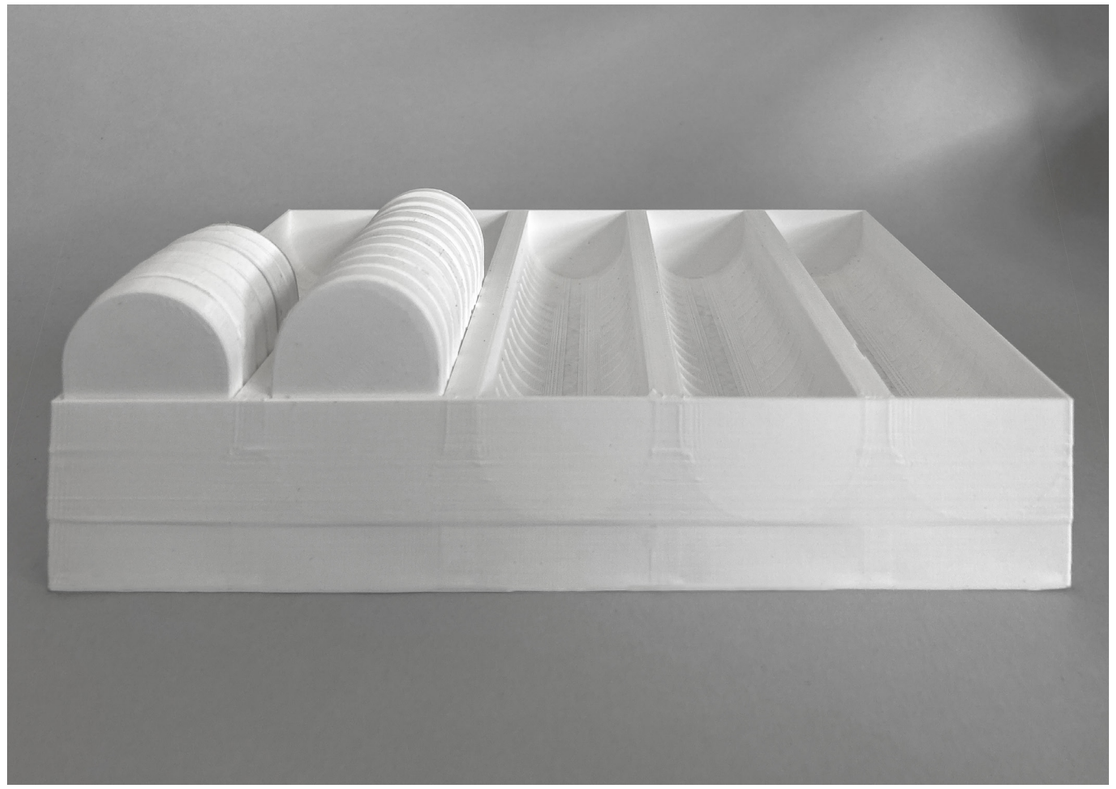
3-D printed models of the initial design of the sensor charging unit.

3-D printed model of the initial design for the 100 sensor capacity charging unit.

The sensor charging unit

The next experiments were aimed at deciding where and how the sensors would be charged. In keeping with the health professionals' guidelines, we set out to envisage a wireless system, since in a hospital context wires can be an encumbrance rather than a benefit. Here we consulted the electronic engineer of the SafeTrack project lead company who suggested we think of a "coin tray" type system, in other words, a system that allows a number of sensors to be charged at the same time. Following this advice, we experimented a number of charging models to understand a series of actions, such as, inserting the sensors, handling when removing/placing them, and checking the charging status. The experiments on the nature of the charging unit gave rise to the need to understand where and who would be responsible for charging disinfecting, so that we could continue them. With the aim of discussing the options in terms of the ideal location for the sensor charging unit, we went to the HED to meet with an emergency department triage nurse (a participant in workshops 1 and 3). We understood that the best place would be in the triage area but it is very small, comprised of a desk with a computer and some clinical equipment for evaluating the patient's complaints. This led us to understand that the charging unit will have to be small enough to fit on the desk, but large enough to charge 100 sensors simultaneously.





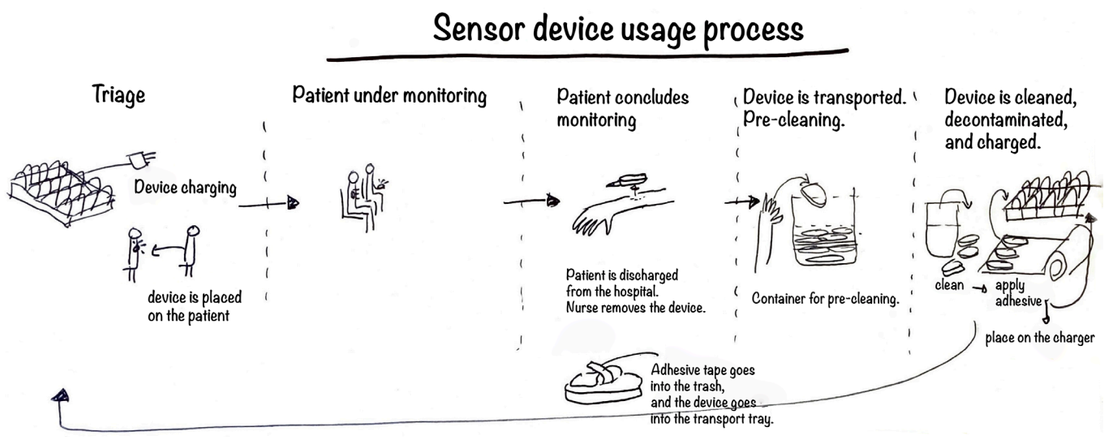


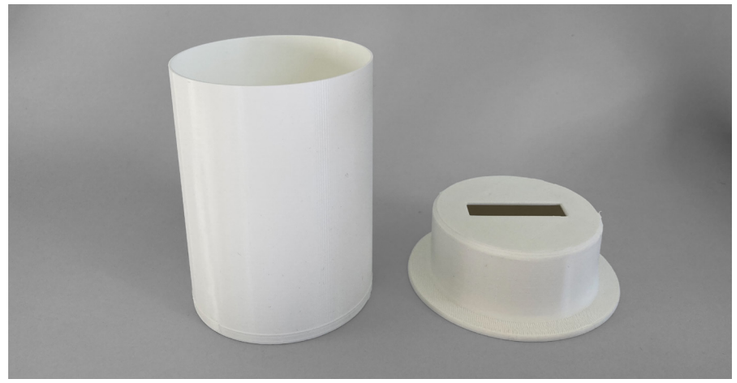
Illustration of the sensor's pathway from the moment it is applied until the cleaning process in the new HED patient monitoring system.

The pre-cleaning/ disinfecting unit

From our observations and conversations with the triage nurse we understood that it was necessary to think about how and who should collect the used sensors and, also, where and how they should be cleaned and disinfected. Here we saw that design also has a key role in the developing of the sensor pathway from the triage area to the cleaning and disinfecting room. Here the nurse highlighted the importance of a container where the health professionals can deposit the sensors once the patient monitoring is over. The containers could be placed in various locations within the HED and at the end of each (8-hour) shift they would be collected for subsequent cleaning and disinfecting. Bearing in mind that the HED is a department where the health professionals undertake multiple tasks simultaneously,

we explored the possibility of creating a pre-cleaning e disinfecting unit along the sensor pathway. The idea was that cleaning and sterilization should involve the smallest number of steps possible. In relation to this subject, we understood the ideal solution would be for the container in which the used sensors are deposited to perform pre-disinfection.

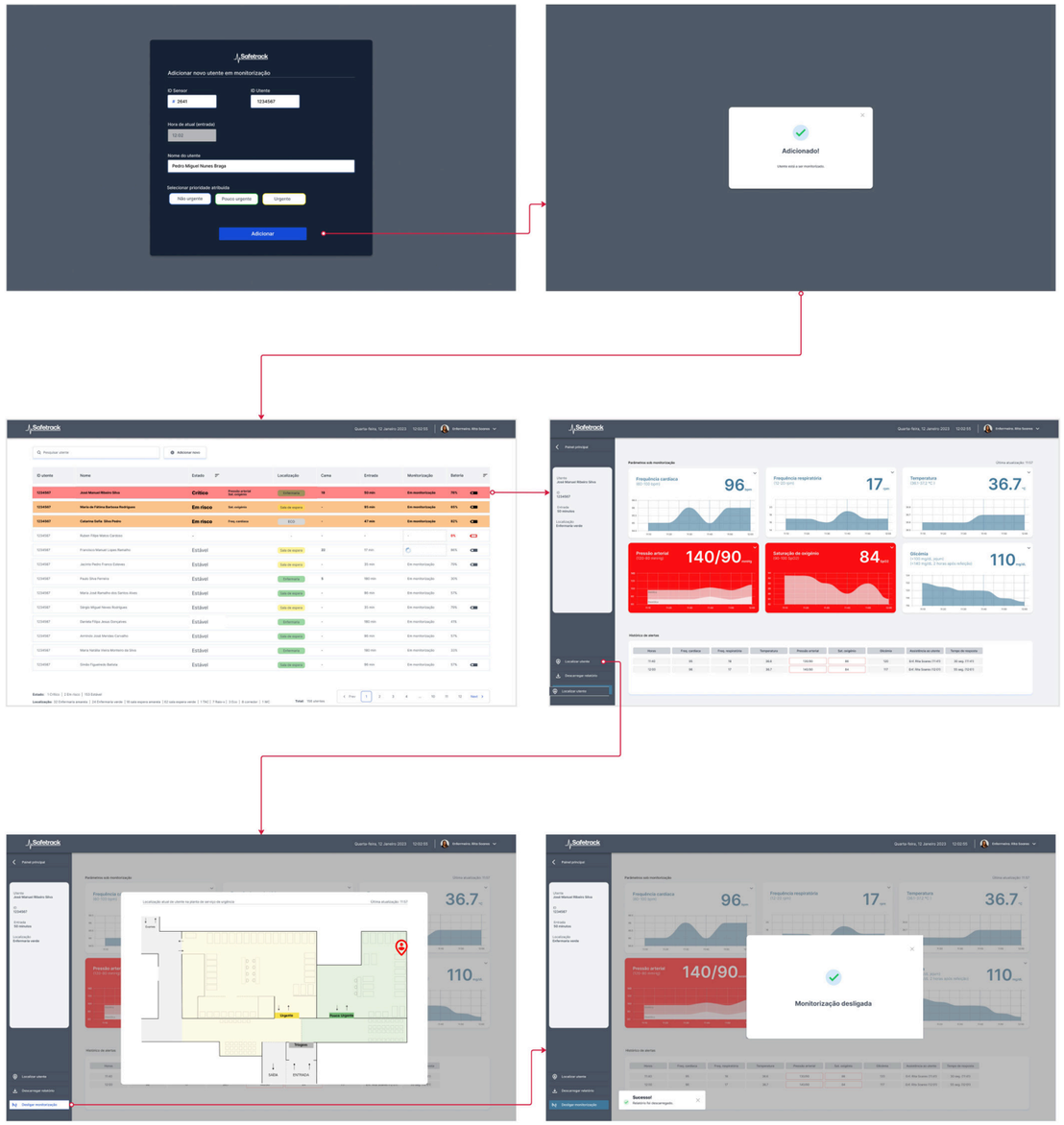
3-D printed model of the initial design of the sensor pre-cleaning and disinfecting unit to be used in the HED.



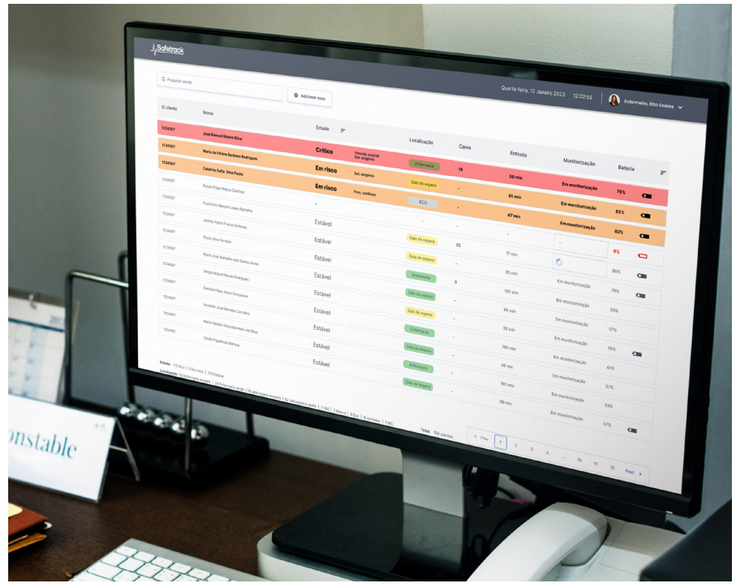
Beginning graphic interface prototyping – version 1

The initial graphic interface (digital tool) prototyping highlights the ideas of the health professionals that they felt were important in terms of visualizing information within the new patient monitoring system that provides clinical deterioration alerts in the hospital emergency department. From our conversations with those professionals, we understood that it was important for the sensor, as soon as it was placed on the patient's skin, to activate a text box on the computer screen (in the graphic interface), indicating when the monitoring of a new user began, and it should also be possible to input additional information to the text box when triggering the monitoring.
We also understood it is important to provide visual information on the graphic interface as to active monitoring, in other words, if the patient is being monitored or not.

Building on these thoughts, we initially began to build a prototype of this digital tool to illustrate a first version of the health professionals' general opinion.
The building of this first version of the graphic interface prototype called for reflection on two levels of information: 1) a general view of the patients who are being monitored within the HED; 2) access to detailed individual information on each specific patient, in case access to more complete information is required.



Prototype of the computer version of the general and detailed view for a patient in the future monitoring system.



Representative mock-up of the prototype graphic interface's general view screen.

These reflections helped us to consider the main interactions. Such as: activating the sensor, navigation (e.g.: pop-up messages allowing information to be introduced simply, when requested) and commands (e.g.: automatic saving of reports, etc.).
On the other hand, these initial reflections on the graphic interface (digital tool) also raised other important questions, such as, what information should be shown and to whom? Which alerts should be given on the mobile app and on the computer? What should happen if the alert is switched off?
How should we distinguish between critical and at risk alerts?
Future steps in the developing of the graphic interface will incorporate an iterative co-design process conducted with the health professionals to hone and develop subsequent versions of the prototype.

As well as the participation of IT engineers, so as to produce more interactive and functional versions that can undergo the first usability tests.

Conclusion

The idea of participating in a study to develop a patient monitoring system, where various vital parameters would be monitored at the same time and continuously, was positively received by health professionals and patients as a way of detecting clinical deterioration early and supporting patient safety along their pathway in the HED.
A Co-participative Design process was deemed relevant to ensure new knowledge was highlighted to support patient safety and health care issues within the hospital emergency department. The points of view and needs of an appropriate group of participants were taken into account when developing a new patient monitoring system in the contact of the hospital emergency department.
The benefits of involving the health professionals and the patients in this discussion are evident in the discoveries made by way of their experiences in and knowledge of this context. The active and continued participation of people who possess knowledge and experience of patient monitoring is vital in order to ensure that any developments in this field meet the needs and aspirations of who is doing the monitoring and who is being monitored.

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