Anesthesia Augmented

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ABSTRACT
In this paper we discuss about the opportunities and constraints encountered during an interaction design project, carried out at Umeå Institute of Design, and based on our collective experience when designing for professional users, in this case, Anaesthesiologists. We tackled the issue by introducing an Augmented Reality system (AR) into our vision of a future Operation room (OR), and explored the usability and consequence of these changes.

The first question we thought about when starting the project was – if human patients are the main focus here, why is the nurse giving their backs to the patient to look at a series of numbers on a machine screen? It seemed obvious, but it was still unanswered by the latest designs of any anesthesia machine on the market. Applying AR in the case of Anaesthesia, means that some parts which might be less thought of in a traditional screens, turn into important issues; for example, when concerning the sorting and placing of information in the real space, which will be presented to the nurse.

AR being a new discipline, means it still requires deeper investigation concerning how the information presented to the user will change compared to a traditional screen User Interface (UI). This is what we have done in our discussion, opening the floor and encouraging further questioning of the challenges and constraints of the technology before it becomes mainstream.

Author Keywords
Augmented Reality; ubiquitous computing; ergonomics; cognitive ergonomics; space design; design methodology for Augmented Reality; medical design; medical device; anesthesia; interaction design; faceless interaction.

INTRODUCTION
How do you improve the life of a medical practitioner in a hospital? Do you improve the teamwork with their colleagues? Improve the patient's journey through the stages they go on a hospital visit? Modernise the machines they use to enable them to work better? There's myriads of ways to do it and all are correct, but we chose to tackle one of the most obvious issues we encountered as soon as we saw the interface of the machine - how to reduce cognitive overload for the nurse and improve the information hierarchy in the system.

We followed user-centred and systems thinking approaches, so as to explore the area of interest, anesthesia, in all its micro and macro levels – from asking the user how they feel about certain aspects of their job/life to trying and create a picture of how the hospital works. All these levels, the micro and macro, come with their own complexities (even the smallest details are hard to tackle, from manufacturing issues, sales, societal and environmental concerns) but at the same time also brings countless possible solutions; still we figured out that one of the first problems we encountered was also the one we thought would impact most in the life of the nurse if solved successfully.

Our brief invited us to discover a way to engage the anesthetist to look at the patient while they are on surgery, instead of constantly looking at the machine, like they do today. The patient, a human being like the nurse, is reduced to a series of numbers and graphs that represent different parts of their body and wellbeing. Even though nurses need these numbers and understand them well, they are still missing the holistic/systemic view of the body - how these numbers are connected with each other to create the entirety of the patients' wellbeing.

The way we tackled the issue was by dividing the information into two different formats, we would handle what we called "complexity" on the machine; which means, the machine would contain all the options and menus that it has today, but shown in a less layered way, so you wouldn't have to go through what seemed infinite amount of menus to change the option you required - everything would be more accessible. Then, we would handle the most used values and graphs in the day to day of the nurse (for most operations), in what we called "simplicity", on an Augmented Reality system.

The advantage of using this system was apparent right away, as we could enable the nurse to look at the patient, while at the same time look at the data they most needed at any given time; if any bigger issues occurred, then the nurse could go to the machine and change values from there in a similar fashion as they do nowadays. Although this would be an intermediate step - as the notion of what might be seen as natural or intuitive interaction has changed when technology has changed (Jacob et al., 2008); the final step would be to completely remove the screen on the machine and just have the AR system, a decision which was welcomed by the nurses we got feedback from.

The other way we could reduce cognitive overload is by reducing the role of "detective" that nurses have to undergo everyday when encountering an alarm or problem with the machine. The machine will let you know there is an issue, but will only specify it in the most generic level, if it's a machine error, a non-critical problem with the patient, or a critical situation with the patient. The nurse has to do all the heavy lifting here, and find where the problem is located, solve it, and keep track of everything else happening in the system in the fastest time they can; their job can put them at any point, and very suddenly, in situations where the patient could be injured because they couldn't find the problem/solution fast enough. As you can imagine, it's a pretty stressful job, and even though it gets a bit easier with experience, "the impossible can happen at any moment", quoting an anesthetist we interviewed during the project.

WHY WOULD THE FUTURE OF ANESTHESIA INVOLVE AR?

We were worried about bringing AR into the project without questioning it, just jumping on the bandwagon of the hype surrounding AR technologies nowadays. We tried to leave the possibilities of how we would show the data, ambiguous, for as long as possible; our design iterations went from projections, to individual devices populating the room and showing feedback through lights, to having "floating" screens hanging from the ceiling; until we finally realised our best option was through AR. We realised that AR could include most of the different solutions we were coming up with, and solve all the details we were creating when thinking about an overall unified system, using a single object; in opposition to to having a solution with many different interconnected physical objects, each with its own screen.

Understated

One of the main benefits AR offers over any other type of technology, is the freedom to create worlds with all its interactions and details, without having the constraints imposed naturally by real physical products. No more worries involving cleanliness, obstructions, limited space; and even more "obscure" issues which aren't entirely visible to the user nowadays, sustainability for example.

This is possibly the most understated advantage of using AR, the fact that things don't have to be made physically, reducing all the waste and at the same time creating a countless number of opportunities, especially when updatability is involved - no rubbish generated. This would be compared to the modern mental model of throwing (mostly storing) technologies that are out of date, which can't be reused and not easy to recycle.

Overstated

The other, possibly most overstated, advantage of AR would be the space gained back in our daily environments, the possibility to interact with technologies in different ways than in the present. If today we mostly interact with technology, and the rest of the world, looking through dark screens of different sizes; this technology brings us back the possibility to detach ourselves from these screens. Through creating new "superimposed" environments or through using the ones we already

have physically, this can bring us the chance to actually use these spaces we live in again, not being bound by a table with a computer.

Technology gets more complex, screens get smaller

Generally speaking, artifact complexity tends to increase in order to deliver more and better functionality, whereas the size of the artifacts stays the same or decreases. The available surface of the artifact has room only for a limited number of controls and displays given the limits of resolution of human perception and dexterity (Lars-Erik Janlert and Erik Stolterman, 2015).

All this ever increasingly complexity is hidden most of the time, and we get shown glimpses of what the machine can do at any certain time. Still, the range of what the machine can do seems boundless. We should reduce this modern anxiety of trying to fit more in less, and again give more space for the data (and us) to breathe; to look, to move around, and to utilise the best of our abilities and the dexterity embedded in our bodies.

Figure 1. The screen nowadays used in OR.

The nurse is overwhelmed with the complexities of a modern anesthesia machine because everything happens through a single viewport on the machine, the screen(s), containing access to all the data and capabilities of the machine (Figure 1); the way to go through these possibilities is through menu levels, a kind of maze involving menu screens. This is the last thing you want if you're trying to carry out your task fast, under stress, and in a difficult situation.

We figured that we had to try to reduce the amount of data shown at once on a screen, this meant that we had to design ways in which to introduce the "right data at the right time". Here the "right data" not only means exact data, but also at the right place, in its actual context. At the right time could mean to make the information "pop" at the moment when they are needed. To illustrate this with an example, one of the nurses told us that it wasn't useful to keep checking the patient's' temperature all the time, or to even have it on continuously on their visual feed; it normally remains constant. On the other hand, if changes on temperature start to happen, then it would be obvious for the nurse/doctor that something is wrong when this temperature data popped out in some way.

Inspiring nurses, inspired designers

During one of our final sessions with the anesthesia nurses of Umea hospital, we asked them to think critically about our solution as feedback for us to continue improving forward during the last week of the project. We thought some might be sceptical of using AR, but we wanted to see if they could come up with possibilities for the solution that we hadn't thought before (Figure 2) .

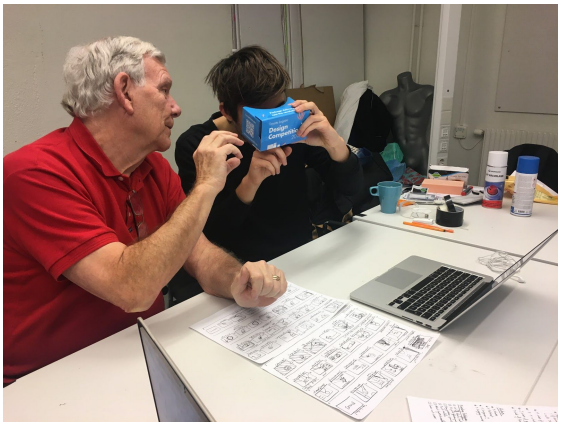

Figure 2. Testing with professional user.

This would mean they saw how easy it would be to reduce physical products and screens, and instead, surround themselves with data so as to avoid errors, and getting lost in the maze during the most critical moments.

Initially we showed how the most important/used data would be seen in the AR environment. This sparkled some eyes, but not much commotion otherwise. As soon as we explained the other ways we could visualise data using AR, away from the looks of common screens and more in the metaphysical realm; the whole paradigm shifted.

Figure 3. Prototype of easing communication between new team members in OR.

We introduced a simple yet powerful addition to the nurse's' environment - showing the names of the other team members on top of their bodies so as to ease communication between teams of people working together for the first time (Figure 3). The nurses then started coming up with different scenarios of how it could be used, and what data could be shown where – for example blood saturation could be shown on the wrists, and h eart rate on top of the chest.

- Bringing contextualisation to the system helps separate the information into the areas where they make most sense.
- Context is the menu - the way to separate the layers of information.

What about the patient?

We can't forget the patient, the most important actor in the play. We found out that "by improving the patient's' journey, you improve the anesthetists' journey". We then started researching on hypnosis; and how relaxing the patient's mind would not only help the patient to recover faster and with less pain, but also help the anesthetist to carry out their job better while using less amount of drugs.

Through the use of augmented technology, future patients could undergo surgery, through a journey unlike anything seen by anybody going to surgery before. We could mould or create relaxing environments, re-upholster whole operation rooms obscuring the actual environment, which can sometimes feel overwhelming for the patient. **We could turn that same environment into a forest in the eyes of the patient (Figure 4), in order to keep the mind away from thoughts and anxieties that can scare and harm us.**

Figure 4. Prototype of forest environment in augmented reality for patient relaxation.

"If every surgery, patient, and nurse is different; why do we have a one-size-fits-all solution?"

Personalisation turned out to be more crucial than we initially predicted; we had designed a system where the user could choose the data they would bring to the AR environment before each surgery, and the feedback of the nurses was super positive. They liked the idea that data was chosen depending on the type of operation being performed, and they also wanted to be able to change what they saw at any point during the operation too. Providing different levels of flexibility depending on the data being used is one of the most important advantages of using this technology.

EVALUATING AR IN THE OR

How does this fit in the OR environment?

Before answering the question, we would like to introduce the challenges of usability encountered through general usage of AR. This part of the paper is focused mainly on the usability and accessibility of AR; not constrained by today's standards regarding the technology, due to the fact that most of the research happening nowadays in AR is hidden behind NDAs and patents.

Let's take a driver as an example, the information needed to flawlessly accomplish the driving task is up to 90% perceived by the visual channel (Cohen & Hirsig, 1990). Currently, additional visual information is acquired through the instrument cluster in front of the driver (Central information display, CID). AR implementation reduces the time eyes need for focal accommodation and improves 'eyes on the road' by reducing the cluttering experienced by the eyes in-vehicle and outside of the vehicle as Burnett explored in his example (Burnett, 2003). Introducing AR in a vehicle can

reduce the risk of occluding relevant objects on traffic as well as phenomena like perception tunneling and cognitive capture.

The ergonomics of displayed information

We explored applying 2D objects throughout the depths of perception of the human eye, creating a mixed reality (a blend of reality and virtuality). This mixed world is already changing the way humans perceive reality, as in this case both of them could be indistinguishable from each other, this is something Plavšić & Bubb explained in their discussion of AR. The evaluation of the ergonomics of depth perception and contrast, especially in time-critical situations, are crucial factors for AR effectivity.

During the design process it was necessary to understand how humans react to data presented in AR, floating in the environment, instead of all being co-located in one space; and which aspects, like peripheral vision, need to be understood fully in order to create the best possible visualization. We can't just use the same rules we applied on traditional UI design, with this the flood gates are finally open for innovation in UI.

Talking about peripheral vision, these findings were the most useful when thinking how to present the data around the user. When design in AR you have to keep in mind are you designing the space all around the viewer, so you have to find the way of attracting the attention not just to what they have in front of them, but also to the sides and maybe even behind. We can distinguish between egocentric and exocentric presentations of data depending on the use case. Egocentric information is fully embedded in the nurse's point of view, following around with their gaze/head movement. In exocentric, information is shown from a "non-users" point of view, in our case, mapped to the environment.

Fighting for space

We also explored the framing of this data being presented, as virtuality has, like in classic HCI UI, the advantage of time multiplexing. So inside these egocentric and exocentric systems, we also include the second layer which brings the possibility of concealed objects. Objects which appear only when called for or that show up when the right context/situation arises, for example the timing for breathing with the pump shows up when the user picks up the pump and goes to manual mode.

When designing with AR, virtual objects can be shown in close proximity to its relevant counterpart (for example 'Drug information UI' next to the Drug agent). We explored this possibility to locate the UI where the necessary information exists in the physical environment, what Plavšić & Bobb call Contact-analog way of presentation, in opposition to unregistered. The angle the data is presented to the eyes of the viewer is also important and can tighten the connection to the physical space, by naturally occupying but not disturbing the space.

The so-called 'Contact-analog' way of presenting information does not require the nurse to perform spatial calculations, reducing the "detective" part of the job described previously; and should, therefore, enhance information perception and reaction times compared to unregistered presentations. There is potential to considerably increase rapid information-recognition, "finding information at a glance" as described by a nurse, and by splitting information around the room we reduce nurses cognitive overload while performing tasks.

Basically, the main advantage is that this kind of presentation requires no mental effort when surrounding the user with virtual and physical information; and that more information can be received/understood at any time as this information comes from different levels on the cognitive spectrum.

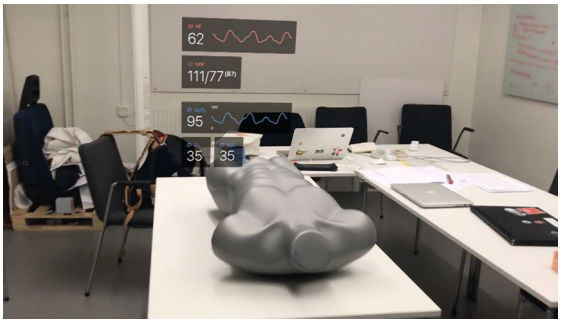

Figure 5. Prototype of mapping data in the space.

In Figure 5, we show how we arrived at this approach unconsciously, it just seemed the most natural way of portraying the data; by mapping it next to its context, we separate data in a logical way.

The consequences of augmenting the OR

As we touched at the beginning of the paper, we seek to create a concept that will lead to better work flow for the anesthetist; but, in the time span given, it was impossible to avoid potential problems when thinking about the consequences of introducing this kind of technology in an Operation room. One of the challenges we clearly solved was "looking at the patient more than at the screen", but we still question - how do you design this dynamic system which can follow you wherever you are, but still invites awareness for patient observation.

Maybe some people won't deem it successful to end up a project with more questions than answers, but we think these kinds of projects help understand the consequences of introducing any type of novel technology into our everyday environments, to really think how this impacts our lives in every way, not just in terms of efficiency and exactitude, but also emotionally and subconsciously. Below we outline some of the final questions we left in the stack.

CONCLUSION

The AR challenges of the future

Clearly, this kind of technology is not just useful for Anaesthesia machine but also for many other machines encountered in an OR environment, how to communicate with third-party products, and different stakeholders is still left unresolved by this project, and open for questioning and further discussion.

We see as a challenge to design a framework that will enable presenting rich data, but leave space for the already rich environment encountered in reality. As currently the most pressing problem with the Internet of things is the problem of how to create a cohesive ecosystem.

At the beginning, we saw potential in bringing AR into the OR, but this turns out to be a challenge of designing a whole new system, far outside the scope of our project. So in the given weeks we focused on our hotspot discovered during research; but at the same time, leaving space for an open discussion on how AR can disturb current environments and workflows. We see huge potential bringing immateriality, the tangibility of digital space/data and new ways of controlling data into this professional area.

AR is still a young field in the design discipline, not yet explored in too much depth, therefore we think that this paper can be helpful to other students/researchers to evaluate the value of AR in professional environments and invite further discussion regarding possibilities and consequences (positive and negative) of using this technology in the future.

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