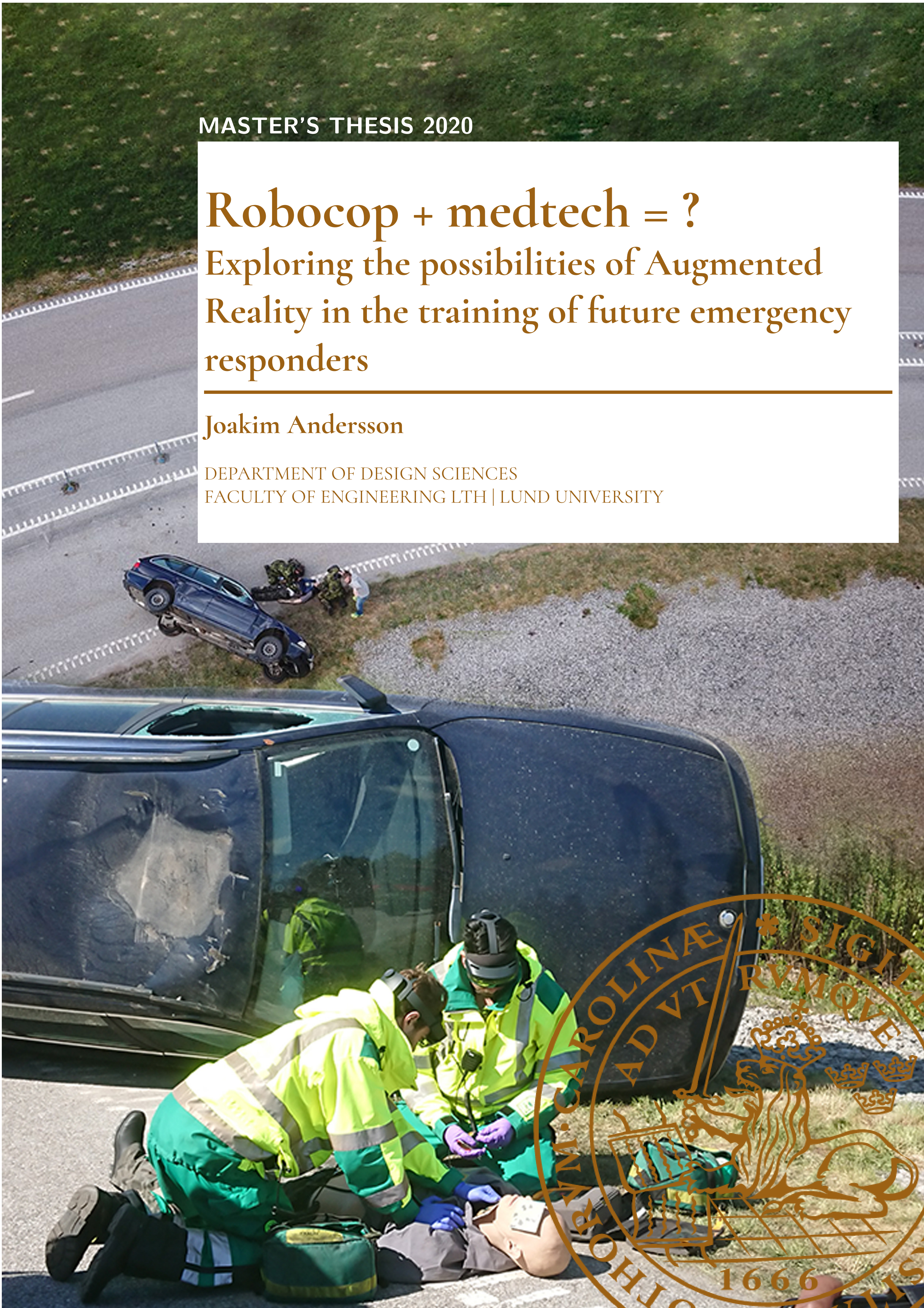

MASTER'S THESIS 2020

Robocop + medtech = ?

Exploring the possibilities of Augmented Reality in the training of future emergency responders

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Master's thesis work carried out at
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Abstract

This master thesis is aimed to evaluate how this current generation augmented reality glasses can enhance the experience for emergency response personnel during practice scenarios. How to design a suitable interface for people in the industry. Planning and developing a functioning system for the Microsoft Hololens G1 (Generation one) to feature such an application.

This project was split into two parts, where part one was a pre study, resulting in a proof of concept AR prototype tested on industry members during year 2019. Part two of this project is the continuation, with the knowledge gathered it was redesigned into a specific learning task within medical training of triage.

This project resulted in a functioning triage practice application designed for the Microsoft Hololens G1 which allowed for patient simulation, inspection, treatment and triage sorting. The application was developed and tested with input from MSB (Myndighet för säkerhet och beredskap), FM (Försvarsmakten) and Räddningstjänsten syd.

The AR application was usertested against an existing training system used today, to determine if AR allows for a better learning experience and quality. A total of eight participants, all with background in emergency response or medical areas, contributed to the test.

The scientific results gathered from the study case proved that an AR device would greatly enhance the experience with sound and visuals, it would allow the users to act more natural while inspecting a patient for injuries, respiratory rates and pulse. Six of eighth participants felt increased stress and workload while using the system, which indicates immersion and a sense of realism in the simulation.

However the results show no difference in learnt information through knowledge tests compared to the traditional systems used today. The test also proved that majority of the user errors and frustration came from the Hololens G1 interaction and low field of view.

Keywords: Prototyping, Augmented Reality, Hololens Generation 1, User experience, Medtech, Simulation

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Of course I would like to thank Daniel Kindstrand, founder of HeroSight. HeroSight has greatly contributed to this project with information, industry insights, contacts and meetings with relevant people who are active or connected to the industry. Without the help of HeroSight and Daniel the outcome of this project would not have been developed so closely to the real industry as it was.

The last group of people I want to thank are my family members and closely related friends who have supported me and pushed me to finnish this thesis project as well as contributed with testing and provided feedback. Many thanks to them.

Contents

Chapter 1
Introduction

Today in the world not all training is done by the means of traditional school desk learning, we have access to a range of more advanced equipment and techniques used to prepare the student fully. After all it was only three generations away when there were no such things as digital devices, and preparation for students had been done with solutions from that era.

The great war led to many inspirational training methods, especially within aviation. How do you learn flying an airplane without ever setting a foot in a real one? The solution was to build a fully mechanical on ground device, that emulated pitch, roll and yaw with replicated flight controls. The first ever flight simulator. Suddenly new pilots could be taught to fly without actually flying. These techniques lived on to the second world war, the cold war and some are still taught the same way today. However today, we can combine this training with digital simulators and create virtual experiences where you can almost feel the real thing.

Technology and training has evolved greatly but with more modern and realistic training comes cost. Cost of instructors, cost of materials, cost of equipment, cost of actors, everything can become expensive quite fast the more real a simulation is. If you want to lower the cost you have to become more abstract and mimic more. For instance, instead of having a field exercise you could simulate it in virtual reality (VR) with a computer. However, not all can be simulated to the satisfaction of the user. Flight and driving controls can be simulated well enough with abstract methods, but for some, especially within fields that require physical contact, this does not suffice. The medical field, specifically emergency aid, is an area where training is more often done with practical field exercises rather than abstract simulation.

Practical training also comes with a hefty cost which leads to the practice being held less often. So why can't we do basic medical training in the way it has been done with aviation training to lower some costs? After all by creating a fully rendered scene in VR and putting the user in any scenario would save a lot of cost of actors, makeup, props and enable more senses to be used in the practise. Why haven't major training centers adapted this method for emergency response (ER)? An potential answer is that this skill is learned best with hands on methods, which fits the personality of the people doing work like this. Hence a cost saving VR solution might not be the most efficient way to handle it, you cannot at this current time immerse a non VR user fully for this kind of physical work. Augmented reality on the other hand could allow the user to normally interact with the ambient while projecting other features. Features like replacing actors, injury makeup, props and above that introduce sounds. These sounds could enhance the learning experience by getting used to sirens, crying family members, angry bystanders, cars or active shootings. By creating such an AR solution for a medical field where training is held less frequent we could potentially help improve for the people who arrive first to accidents or disasters. By lowering the costs, time and preparation for an exercise they could be held more often.

This thesis project will feature such an AR solution for a specific learning within emergency response. Which is the practice of primary triage. Triage practice for firefighters, military recruits, police and ambulance personnel is not held often. Depending on the branch, ongoing mass casualty training is held approximately two times a year for working staff, and sometimes as low as once for a student. The reason for that is the time preparation needed, gathering of actors and applying makeup for them and of course the cost of such a field exercise.

1.1 Personal motivation

Hololens augmented reality (AR) for learning experiences is not something new, however it is only used to such a small extent. VR is a popular platform amongst many simulation training companies and is used throughout different industries. The platform is also shunned by many for its downsides, heat generation, field of view, nausea and at times lack of immersion. AR on the other hand allows the user to stay in the real world layered with visual enhancements. This AR platform would therefore be perfect for an industry where the users want to feel objects and tools that they use daily. Fitting to this description is the medical industry. It just so happens that with today's increased security in western countries and obligatory terror training for fire, medical, police and military, the medical practice of triage could be a perfect candidate for this research project.

Another motivation behind this project is to explore how to solve the current limitations in the medical training industry. Many fire departments, law enforcement students and military recruits don't get many opportunities to practice mass casualty scenarios, due to the cost and time needed to prepare such an event.

1.2 HeroSight AB

In collaboration with this thesis is HeroSight AB which at the time of publishing this thesis work, a startup company founded in early 2019 with the goal to deliver innovative first responder training solutions as a replacement or addition to currently more expensive solutions. The products that the company creates are available for private as well as government and regional agencies. Companies whose employees require basic medical training and are subject to experience mass casualty events or emergencies.

HeroSight currently has its headquarters in Malmö Sweden and has a combined workforce of 6 people including advisors.

1.3 Product goals

Since the product created and covered by this thesis is a triage practice application, simulating primary triage at the scene of the incident, some goals are set for the product.

The goals setup by the company where:
- Triage following NATO standard sieve
- Selection for Multiple Scenarios
- Ability to quickly add and customize patients
- Audio simulation

Since the target group are users whose technical skill differs, the application must have a designed UI that can be handled and used efficiently by any user who knows the basic device interaction.

Hence some usability goals where set:
- Design a UI compatible with professionals in the field
- Create a UX compatible with users of different skill level
- Seamless interaction with components and real physical tools
- Aim to create the usage, natural

1.4 Research questions

This thesis's main goals are to explore and figure out how professionals within the medical field view AR as a tool. Determine if AR can push the practise sessions to another level or if it is more cumbersome than traditional triage practise.

Therefore the research questions set for this thesis are:
- To measure the learning quality of wearable AR in training scenarios
- To determine if wearable AR at the current stage, can be considered a real learning tool

1.5 Target group

Hence the goal and aim of the project the target group is mainly people who work with or are prone to being a first responder at any accident scene. The age of the user is not important, what is important is their line of work. This application needs to work with people in that category and be designed with them in mind. This includes limited knowledge of new technologies since many branches do not include advanced digital components or when they do, they are often designed to be handled under stress.

The optimal target group are:

- Ambulance crew / students
- Military recruits
- Law enforcers / students
- Firefighters / students

Firefighters are included since they are also trained in ongoing deadly violence (PDV, Pågående Dödligt Våld) and each swedish fire truck is equipped with a bag dedicated for such events.

1.6 Limitations

Every project has some limiting factors and this thesis project is limited to a couple, some which are more clear after reading chapter two.

The simulation is limited to one medical practice, which is primary triage. The application will not simulate secondary triage or any other medical practise. Since the project is limited to primary triage, there will only be one round of examining the patients. During this round the patient's condition will not simulate deterioration in any way.

The application will feature simulation of dangerous situations, however this paper won't feature this during the testing sessions.

Medical treatment is limited to only what is necessary during primary triage. Thus ignoring other practices associated with first aid.

The project is created for the Microsoft Hololens Generation 1, and all UX and UI elements are designed with its hardware in mind.

Chapter 2
Background: Theoretical & Technical

Some of the theoretical information used in this thesis will be described in this chapter. The methods and theory presented here are used as foundation for the project.

2.1 Current emergency medical responder learning techniques

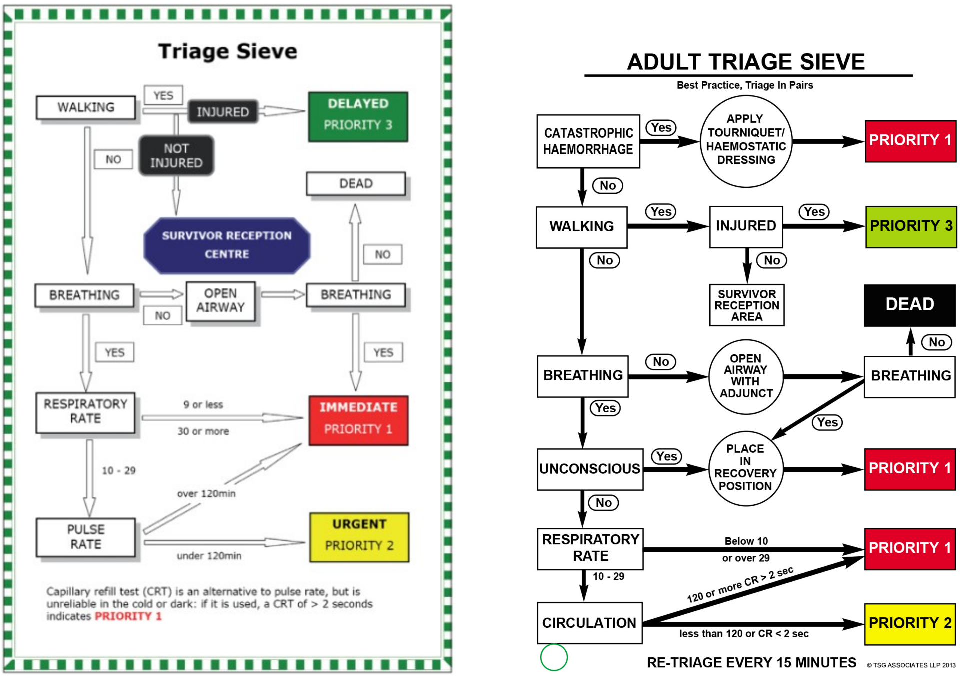
In many organisations that practice mass casualty scenarios, triage is a part of the routine. Triage has its roots far back in history, rating back to the napoleonic era in which it was developed the most. With of course a tragic backstory. By grading a patient into three grades which would decide if the patient would be left to die or treated for its injuries. Ultimately however, this reduced overall battlefield casualties [9].

Today unfortunately triage is not only practised by military but also civilians with the increased terror threat, therefore swedish firefighters and ambulance are trained in on going deadly violence, a course which is called PDV (Pågående dödligt våld). This course prepares for potential terror or violence that may occur. Triage can be applied in different ways, for different branches. In the military, a process flow short may be very short, designed to work fast. Whilst for firefighters it takes more to declare a person dead, and for pre hospital work and hospitals it can contain more steps.

Generally triage on the field is split into two parts, primary triage and secondary triage.

Primary triage

Primary triage is used at the scene of an incident. Its goal is to be rapid and consume as little resources as possible. The triage sorting is done with a sieve, which is designed differently depending who it is meant for. The sieve is a flow chart with different sorting paths, depending on the patient's condition a path is chosen which leads to a final priority for the patient. A sample of triage sieves are shown in figure 2.1.



(a) (b)

Figure 2.1: Examples of triage sieves

Secondary triage

Once victims are evacuated to safer locations or more resources are available, secondary triage can be applied. The goal here is to further decide the triage sorting with preferably medical professionals, as a final step in the pre hospital treatment and observation. An example of a sorting chart is figure 2.2.

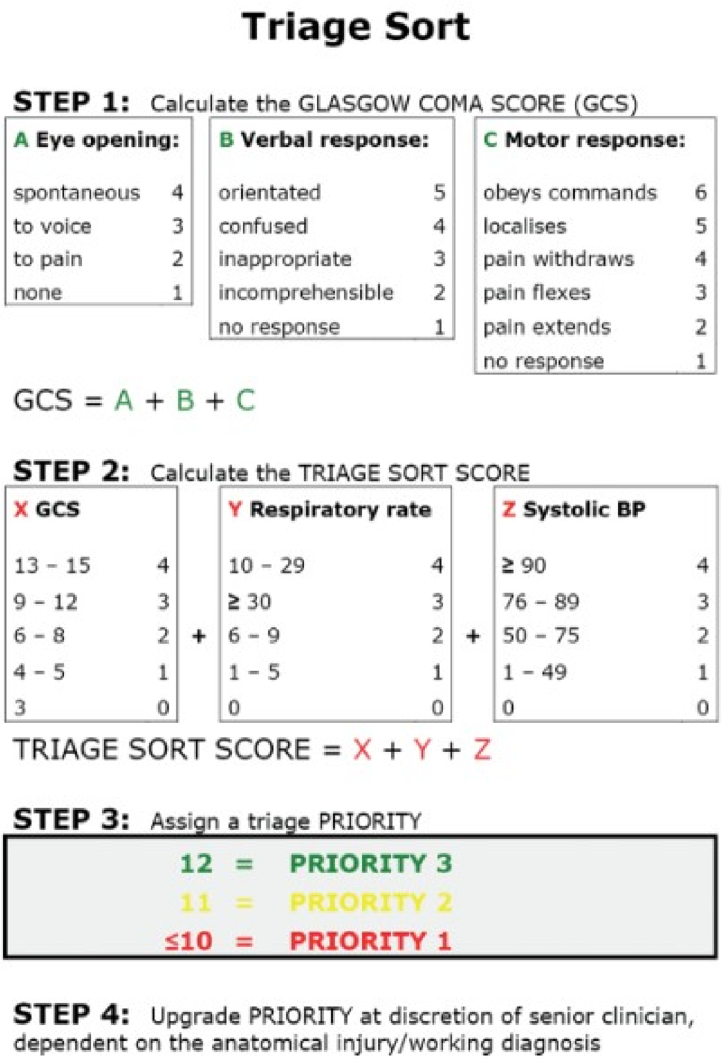


Figure 2.2: Example of a secondary triage sieve

The Glasgow Coma Score (GCS) which is featured in secondary triage is a chart developed to measure the responsiveness of a patient, often during real emergency events replaced by the AVPU (Alert, Verbal, Pain, Unresponsiveness) scale. Which is easier to categorize and approximately corresponds to GCS according to this chart.

- Alert = 15 GCS
- Voice Responsive = 12 GCS
- Pain Responsive = 8 GCS
- Unconscious / Dead On Arrival = 3 GCS

Practicing triage

In Sweden mass casualty training works differently depending on what doctrine / industry it is applied to. Generally, practices are held in larger groups where you divide students into pairs. The instructor follows the student pair and observers their actions during the treatment of the patients.

The patients in the scenario are either dolls or actors. These actors are often other students or people from the public who want to contribute, who normally are eldery and pensioners. When there is a larger budget, real actors are hired to play the role of a patient.

These actors are also normally given makeup to represent their "role" as a patient. The makeup can represent penetrating wounds, slashes, blood and so on. This is a time consuming process which takes 1 hour for approximately 4 patients. The images in figure 2.3 are examples of injury makeup applied at Sahlgrenska University Hospital in Gothenburg and the tools to do them.

(a) **(b)**

Figure 2.3: Makeup equipment (a) 3D scan of an injury makeup applied to a student (b)

To create a scenario each actor is assigned a personality and injury profile. Such information is given to the actor and makeup artist. Emergo Train System is a training system used in Sweden by organisations. The system features many realistic injury profiles printed on a card worn around a person's neck. Such a patient card is shown in figure 2.4.

(a) (b)

Figure 2.4: Patient profile card

Figure 2.4 is an example patient and features no injuries and is only psychologically affected. Each actor would wear this printout around their neck allowing a student to inspect them. The ABCDE categories featured on the card refers to treating and identifying life threatening conditions in the correct order [12].

Type	Description
A	Open airways, check for free airways and or clear them
B	Breathing, measure respiratory rate and check for distress
C	Circulation, heart rate measurement and capillary refill time
D	Disability, consciousness and responsiveness
E	Exposure, visible external injuries

Table 2.1: ABCDE procedure table

A practice session can be more or less active by actually treating the patient with real tools or just telling the instructor what procedure you would do verbally. During decision training, the latter is often prefered for speed and mass practising. The session can be held in a classroom or a decorated environment fitting the scenario set.

Example of organizations practicing triage in Sweden are the Swedish Armed Forces, and its reserves, firedepartent during PDV, emergency responders such as ambulance crew.

2.2 Augmented Reality

Systems that use Augmented Reality (AR) can be with the most widespread accepted definition by R.Azuma be defined as, a system that has the three following characteristics [6]:

1. Combines real and virtual
2. Interactive in real time
3. Registered in 3D

This definition was set in 1997 while exploring the possible usage of that current age optical see through displays. The three characteristics are important in distinguishing AR from other tech and definitions, by not limiting or specifying exactly the device's physical design and behavior, but rather the capabilities. To further develop its means, each category is explained below.

Combines real and virtual
The virtual world, which consists solely of 3D objects often representing real world objects. These 3D objects can be of any shape that can be described with vertices, thus taking the shape of terrain geometry, vehicle shapes, water bottles or other objects.

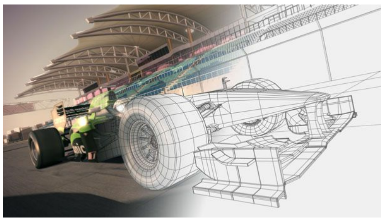


Figure 2.5: Example of 3D geometry

Traditionally completely 3D generated objects are displayed as 2D, that is in 2 dimensions e.g a monitor or display. But what defines AR is the ability to display 3D objects, not necessary on a computer monitor, but on top of the real physical world. However to display 3D models, on top of a video recording, which is displayed on a monitor is also fine. This specific category includes movies that combine the real physical world with 3D objects. This on its own, does not make a film or system "AR", which will be explained with the two remaining categories.

The combination of real and virtual can be done with either a Head Mounted Display (HMD) or a generic video display. This includes HMDs with see through optics, HMDs with a videostream combined with 3D overlay, monitors with a videostream combined with 3D overlays.

Interactive in real time
By being interactive in real time, a user can control or input data that will directly translate to the 3D world, in real time. This means that any films featuring a recording of the real physical world combined with pre-rendered 3D objects, does not count as AR. Since everything is pre

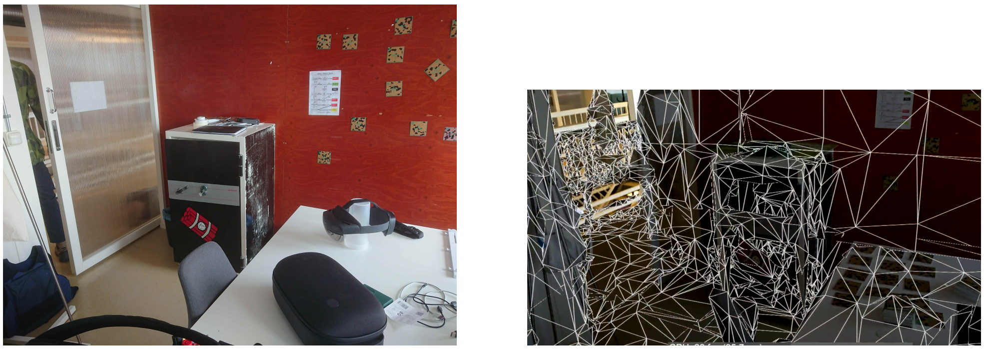
recorded and edited. Real time interaction counts for both worlds, the real physical and the 3D generated, both needs to respond in real time. Thus any pre made recordings of any kind within both worlds, are not accounted as being AR. If we were to look at the movie example.

- A pre-recorded movie featuring controllable 3D overlays, does not count as "Interactive in real time"
- A live video feed featuring pre-rendered 3D overlays, does not count as "Interactive in real time"
- A live video feed featuring live controllable 3D overlays does count as "Interactive in real time"

By fulfilling the real time interactivity criteria, the system could be considered AR, if the rest of the categories are fulfilled as well.

Registered in 3D

By being registered in three dimensions, for a system to be considered AR it must "know" the real physical world. By knowing the physical world, the 3D generated world can copy elements from it and use the positional data for the 3D models. For instance, if the live feed camera moves, the 3D world can follow its movements completely. The images in figure 2.6 show just what registered in 3D could mean visually.



(a) **(b)**

Figure 2.6: Hololens 2 spatial mapping visualized

Modern solutions are to use the live video feed from the source camera and compute the pixel movements, to create a "map" of the surroundings. This can be achieved with different methods, methods that originate from the Simultaneous Location And Mapping (SLAM) technique. SLAM is a technique which means creating and updating an map of an uncharted area while tracking the position of the "camera". SLAM is often used in larger manned or robotic operations, and is not entirely optimized for smaller spaces, such as an office, apartment in which consumer AR might be more present. Presented by G.Klein and D.Murray in a 2007 ISMAR paper, Parallel Tracking And Mapping (PTAM) was proposed as a more efficient way to handle SLAM for smaller spaces [10].

PTAM splits the computation methods into two parts, one part calculates the SLAM mapping and the other keeps track of orientation via sensor fusion of inertial sensors and

SLAM. The process of tracking goes as follows, an initial 2D course map of the environment is created, with new frames added to the software the pixel points moves and the movement and perspective can be calculated, The system then guesses a dominant plane from these coordinates such as the plane from a table, wall or floor. With the help of sensor fusion, gyros and inertia modules can aid with the accuracy and robustness of the tracking.

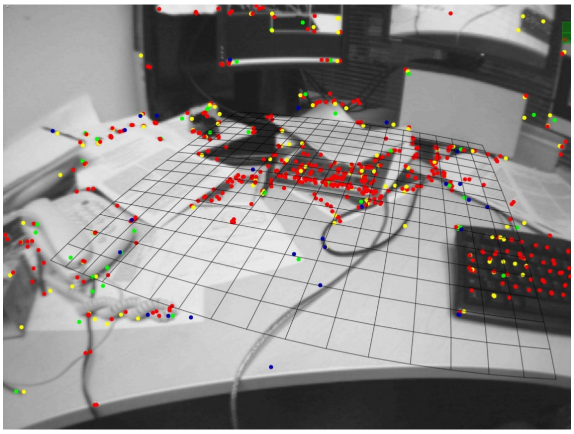


Figure 2.7: PTAM visualized

By fulfilling these three characteristics the system is according to Azuma, considered as AR.

AR systems also have further subsystems which determine its immersiveness. Below are some examples of devices in each category.

Stationary AR

Stationary AR devices are equipment or units that feature a monitor or optical see through display, built into its place of operations. Such devices that fulfills Azuma's AR definition but are not wearable or handheld. Therefore a system that is fixed in place during usage. These AR systems can usually be found in military vehicles, noticeably targeting systems and aircrafts. These devices utilize other sensors to fetch the data from the physical world. Other AR systems more civilian and commercially used are modern reverse cameras for vehicles. New more premium car models that are sold today are often equipped with an advanced reverse camera. These reverse cameras are combining the real and virtual world by the means of guiding blocks positioned and overlaying the real physical world. The system is real time and responds to user controls, such as turning the wheel or accelerating, and it registers the real world in 3D, usually by the means of ultrasonic sensors.

(a) (b)

Figure 2.8: BMW rear camera (a), F22 aircraft HUD (b)

Handheld AR
AR devices that are meant to view handheld, categories as handheld AR. Those are devices which fulfills Azuma's AR definition and were created with the intent to be held in the hand during usage. Meaning that the system source view is controlled and displayed from the hand of a user. Handheld AR is the most accessible type of AR for regular civilian use. The reason for that is the smartphone, which the majority of the population owns is capable of AR. By using the rear camera as a source video feed and the display as the viewing medium. Most phones created after 2013, equipped with a camera would allow this.

Figure 2.9: PTAM visualized

Wearable AR
AR systems with the intent of being worn on the head and using it as a source, are considered as wearable AR. Such devices commonly feature an optical see through display, however are not limited to it. These devices feature an onboard computer which handles tracking, input systems and the display of the devices.

Microsoft Hololens 1	
Microsoft Hololens 2	
MagicLeap ONE	
Lenovo ThinkReality A6	

Table 2.2: Wearable AR devices

2.2.1 Virtual Reality and AR

This thesis defines Virtual reality (VR) systems as: When a computer generates a virtual / artificial environment which engulfs a user within its world completely, by means of perceptual stimuli (visual, audio and locomotion).

VR has its roots further back in history then many believe, with traces of the technique still used today dating back to the "stereoscope" around the 1800's. The stereoscope works by having each eye see an image each through an ocular. The image is created to mimic how the human eye views its surroundings, therefore creating a depth when the two images are aligned. Figure 2.10 shows the process.

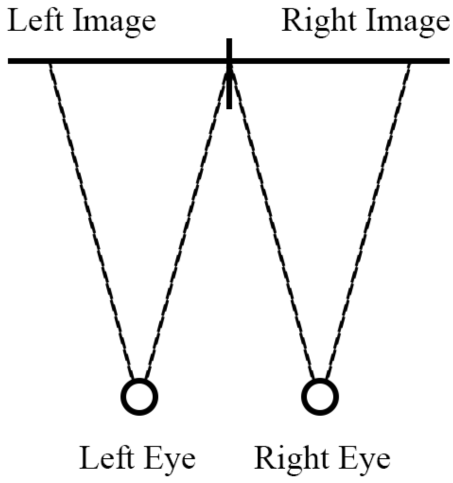


Figure 2.10: Stereoscopy

This technique is still used to this day, either by having the device fit with two displays, one for each eye, or a single display which is visually split into two with software.

Historically the term VR is claimed to be popularized by Jaron Lanier and his company VPL Research, which developed equipment (hardware and software) within the field of VR, and the first to sell it commercially during the 1980's.

Currently two systems are used for tracking of the headsets physical location. The systems are called, inside out tracking and outside in tracking.

Outside in tracking refers to systems which have external stationary sensors mounted around the movement area for the VR experience. These sensors track the headsets movement, along with the controllers. This means that for tracking to work properly, a minimum of one tracking station needs to "see" the headset to be able to track it.

While inside out tracking relies on cameras mounted on the headset itself which through SLAM methods tracks the outside world. The system also tracks the controllers, visually and combined with sensors in the controllers. A potential problem with this is if the controllers are not in view, then tracking would not be possible. This problem is dampened down with algorithms predicting the location of non visible controllers.

Listed below are some commercially available VR systems.

Oculus Rift S	
Valve Index	
HP WMR	

Table 2.3: Commercially available VR devices

2.2.2 Mixed Reality

One of the most accepted definitions of AR to this day is Azuma's definition, since then AR has undergone many new advances and changes and other terms have reemerged. The term "mixed reality" is a result of the blend between the digital and physical world. A definition R.Azuma also acknowledges [7].

The term mixed reality (MR) comes from an even older paper written by P.Milgram and F.Kishino in late 1994. The aim of the paper is to prove that there is a need for a classification framework for the different types of techniques to view a "mixed reality". The paper presents their proposed framework which classes a technology depending on these three characteristics [11].

1. Extent of World Knowledge ("how much do we know about the world being displayed?")
2. Reproduction Fidelity ("how 'realistically' are we able to display it?")
3. Extent of Presence Metaphor ("what is the extent of the illusion that the observer is present within that world?")

These characteristics are used to place a MR technique in their "virtuality continuum" diagram. This diagram shows the linear transition between reality and virtuality. Where virtuality describes a pure graphical environment viewed from the outside. Augmented Virtuality which today is called VR, which is a graphical environment viewed from the inside.

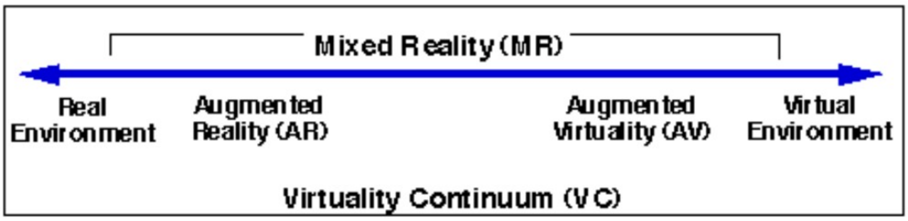


Figure 2.11: Virtuality continuum scale

In contradiction to Milgram, Kishino, some use the term XR (X-Reality or Cross Reality), this is an even broader term than mixed reality which includes x-number of realities that overlap. These realities can be, VR, AR, cybernetics and so on.

The term mixed reality has also been capitalized and is broadly used by Microsoft, with their line of products categorised as Windows Mixed Reality (WMR). All WMR devices are devices that fit somewhere in the Virtuality Continuum, both AR and VR are in their lineup a WMR device.

2.3 Microsoft Hololens Generation 1

On the 30th of march during the E3 event of 2015, Microsoft first announced their new AR glasses in their WMR lineup, the hololens. The device features a security graded visor, sleek design compared to other devices with less technology inside and packed with features. The device supports full environment spatial mapping, thus allowing for room scaled tracking.

Hololens apps can be developed with different frameworks which are supported by Microsoft. The apps are of two kinds. They are either an 2D application, eg. applications that we normally use on computers or Mixed Reality applications, which are immersive and use the 3D space.

2.3.1 Hololens Generation 2

Keeping the information on the new update rather quiet, the newer generation was first announced during the Mobile World Congress in Februari 2019. Compared to the first generation device, the second generation aimed to improve the flaws of the first version. At the time of this thesis there is sparse information about the Hololens 2 except its press releases and Microsoft Docs pages. Nor has production begun fully since the current pandemic is disturbing the process. Even though the device is officially launched, none can buy it. However the company this thesis works in collaboration with still managed to get a hold of two devices from Microsoft headquarters in England.

The Hololens 2 features more gesture interactions with fully active hand tracking. Since the user's hand is now registered fully in 3D it allows the user to "physically" interact with the 3D enviroment or as called in WMR "holograms", the image in Figure X shows the hand tracking.

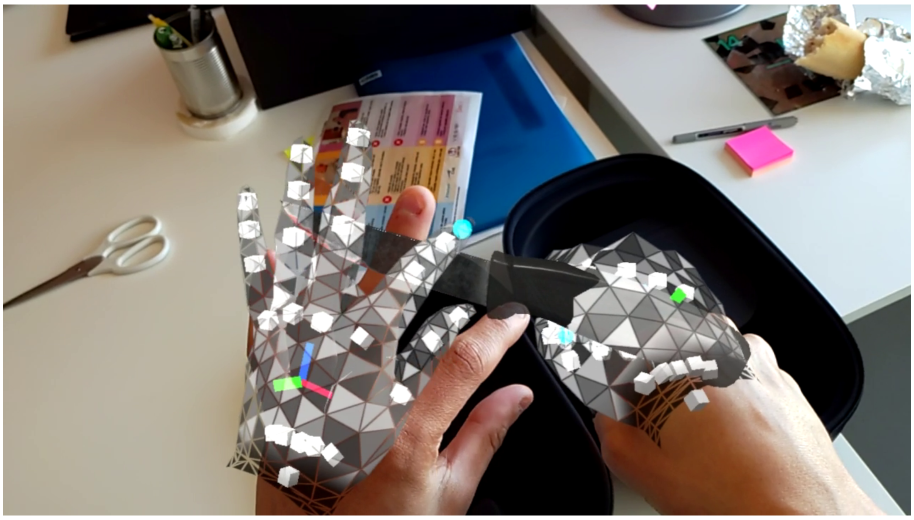


Figure 2.12: Microsoft Hololens 2 hand tracking

The device is also fitted with another display solution allowing for a much larger FOV then the first generation. It works by having two focal planes, the wider most peripheral objects are more blurred and out of focus whilst the most center plane has a crisp image.

Eye tracking is also available by default on the system.

2.4 Agile Development

Since the word agile means to be "able to move fast and easily", it has a special place in software development methodics during planning and development. The goal is to quickly generate assets and iterate on them until a finished product is assembled. There are many different agile methods, some more focused on software rather than business. Described in this chapter are some methods used in this thesis during its development cycles.

Brainstorming
Amongst the most popular idea generation methods is brainstorming. The goal of a brainstorming session is to generate as many ideas as possible during a short span of time. Ideas can be conveyed via drawings, notes or discussed openly with the attendees at the session. The ideas don't need to have any quality behind it, rather it's better with quantity [8].

Bodystorming
Whilst regular brainstorming is limited to open discussion, drawing and texts, bodystorming is a physical version of that. By acting out situations, scenarios physically you can generate further ideas more related to design strategies and interactions [8].

Prototyping
With a prototype a product can undergo user testing on a mocked up version before actually having a fully implemented and thought out product. Generally speaking, there are two stages of a prototype. A Low Fidelity (LoFi) and High Fidelity (HiFi) prototype.

A LoFi prototype can be represented as a paper mockup, a sketch, or a proof of concept model. Furthermore a LoFi serves as a fast and easy medium for testing out an idea, and to have something presentable. The prototype of this fidelity also works towards abstractity, rather than realism of the experience.

The HiFi prototype is a more worked on prototype, which purpose is to mimic as much as possible the real product whilst still being fast to produce and easy to modify. Software products often have a HiFi created with software that mimics the looks and interaction of a "real" developed product. These are normally used during later stages of design choices for more specific parts of the product [8].

Figure 2.13 shows an example of a LoFi and HiFi prototype.

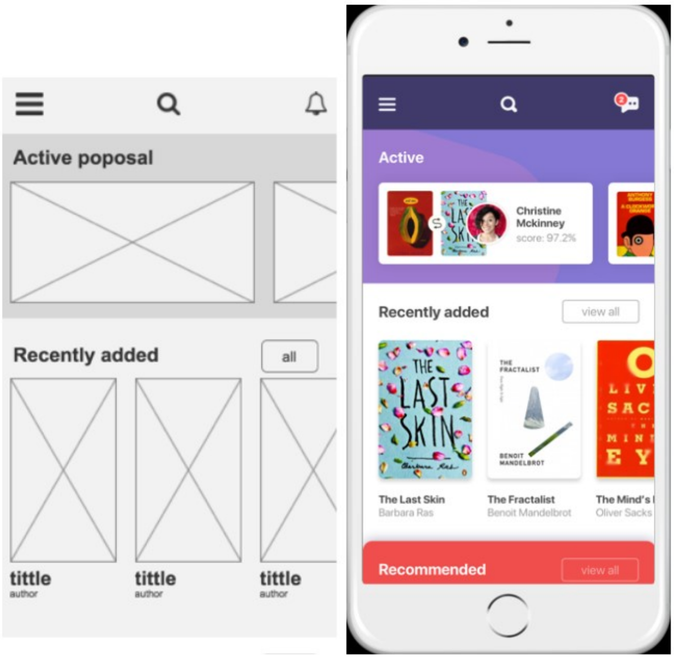


Figure 2.13: Example of a Lofi (left) and Hifi (right) of an smartphone application

AR prototyping

The examples in figure "X" features software with a focus on display oriented products, and with wearable AR on the rise the need for prototyping software is also wanted. As for now LoFi prototyping works well with wearable AR by creating drawings and panels on a paper and having an assistant holding them in the air whilst a user tests it. There have also been successful academic attempts with prototyping in AR. The system WozARd mimics an AR experience on a wearable headset, with an operator controlling what shall be displayed. The operator pushed content to the AR device with a smartphone. This software proved that traditional testing methods work just as well for wearable devices [5].

Product Breakdown Structure

Product Breakdown Structure (PBS) is a method for visualising a system from the perspective of a user. The PBS diagram features elements, interactions, sensors involved, which in turn resembles a tree. Figure 2.14 shows an example of such a tree.

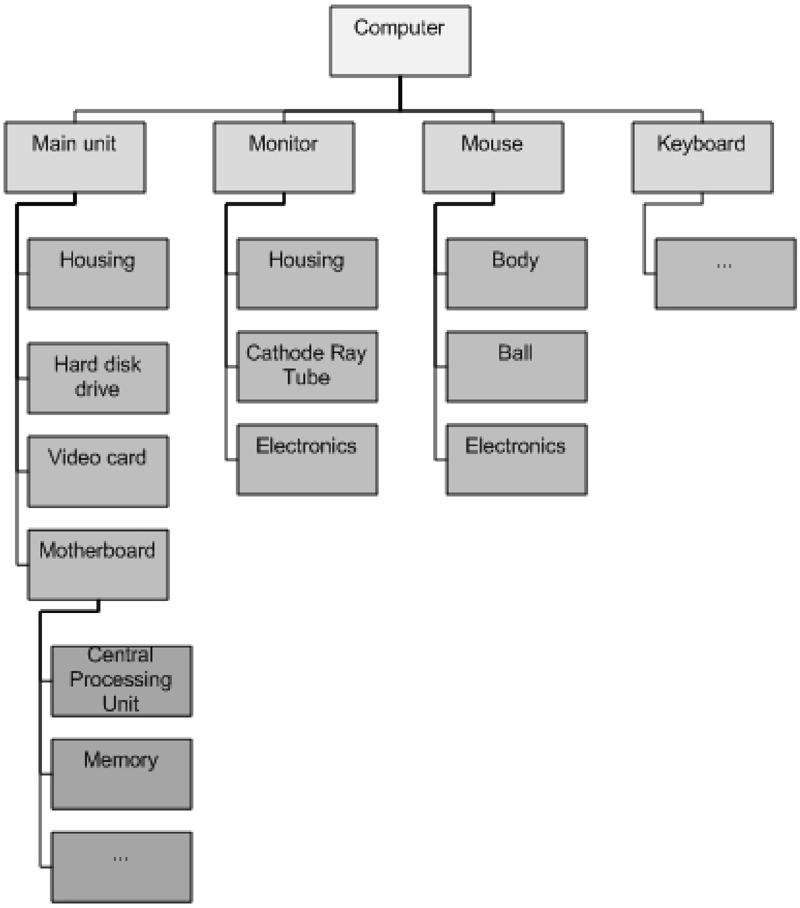


Figure 2.14: Example PBS tree of a desktop computer

The PBS diagram can aid greatly in the architectural design of a software product, by discovering weaknesses, shortcuts and features for the software.

SCRUM

The SCRUM methodology is amongst the most popular agile development methods used in software projects. Not only is it used in software related products, but works as well as for any other branch. The method strongly works towards iteration towards an end product, where the whole product phase is split into sprints. Each sprint contains an end goal or features that shall have been accomplished. When a sprint is complete, the team evaluates the progress and discusses the outcome. The results then affect the next sprint, and optimize the process with solutions to problems with the last sprint.

An example of an iteration circle is shown in figure 2.15.

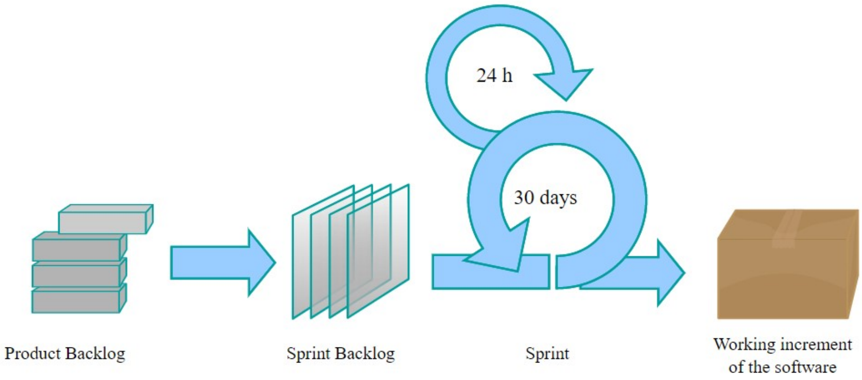


Figure 2.15: Example PBS tree of a desktop computer

2.5 Related work

Once the project started, there was some research into if others had tried triage simulation, and what technologies they used. At the time of this thesis there has been some similar work with triage. The company AugmentedTrainingSystems from Texas, USA creates products for many platforms including AR and VR [1]. They have a VR triage simulation similar to this thesis project. Another american company MedCognition have a treatment simulation in AR with fully rendered patients and a system for controlling the patient from a tablet [3]. The Swedish Defence Research Agency (FOI) have also done substantial amount of work researching the possibilities of AR for the military. Such as testing the possibilities of AR in mobile intensive care platforms. Their experiment was done with non consumer devices, however it proved that AR was good enough for training medics in intensive care [13]. They have also done work on testing AR for general maintenance such as repair guides and or training [14].

Chapter 3

Prestudy: Testing platform & Industry relevance

Linking to the thesis project, the author did a consultancy job for HeroSight which resulted in a proof of concept AR application some time before the official project started. This section contains information and results from the proof of concept and what the scope of it was, followed by a summarization of the discoveries made.

3.1 The HeroSight Prototype

Ongoing during May of 2019 HeroSight had a simple android based AR application with two functions in development

- Visual representation of the medical ABCDE procedure. The user could read and learn about each letter and its meaning in the medical world.
- Interactive patient simulation. The patient could be configured with certain disabilities and the user could at runtime treat the patient with certain actions

The company requested that this prototype were to be ported or re-made for the wearable AR glasses. However due to changing product scopes the ABCDE idea was discarded and it was decided that the Hololens prototype should act as proof of concept for demoing. With it should be developed a framework in which it would be easy to handle different injuries and damage models for a patient.

This resulted in an Hololens application with three functions:

- Positional and rotation tracked injuries
- Injury severity judging. The user could configure a patient with different disabilities and depending on them judge the severity of each injury as well as grading them. The grading was done by selecting each visible injury with the lowest priority selected first.
- Prop spawning, placement and inspection. The user could form an array of objects spawn in life size props such as gas canisters or undetonated ammoniton.

(a) (b)

Figure 3.1: Images from the pre-study application

To display the injuries onto real world objects, Vuforia ImageTargets were used. The ImageTargets allowed for decent tracking while being fast and reliable to set up. Mixed Reality Toolkit (MRTK) was also used for base functionality.

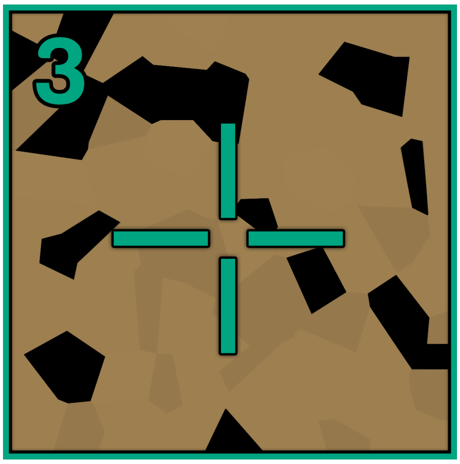


Figure 3.2: Vuforia ImageTarget

3.2 Industry Events

Note that the HeroSight AR prototype did not undergo standard usability testing, on the other hand the idea and functionality of it was used as a demo for a number of industry leading agencies and departments. Listed below are short summaries of each event.

3.2.1 Itec 2019 - Stockholm, SE

Generally each year the International Training Exhibition Conference (ITEC) is held in Europe, known as ITEC. The event hosts companies from all over the world and military representatives from many countries are present as well as arms companies and manufactures. The event does not focus on weapons or vehicles of war, instead it focuses on smart training solutions that can be offered to militaries. This ranges from tank, airplane, truck simulators to fully standalone weapon handling VR courses and physical equipment, like KSP58 machine gun simulation or Carl Gustav Anti Tank launcher training. HeroSight managed to attend this exhibition since the focus of triage closely relates to military exercises [2].

The event lasted two days, where HeroSight and the author were present in the booth. Around 100 people tried the prototype, mostly representatives from militaries or representatives from training facilities.

3.2.2 MSB - Revingehed, SE

Currently in Sweden the MSB (Myndighet för säkerhet och beredskap) is a government unit dedicated to preparation and protection of the swedish civil population. MSB has training grounds at different parts of Sweden where mostly firefighters, police, military and ambulance can undergo training of different types. The proving grounds at Revingehed are aimed for training of accidents and emergency preparation [4].

Our visit here was conducted with eight instructors from MSB Revingehed where they tested the prototype and during a group session, discussed the advantages, disadvantages and what the people who teach thought about it.

3.2.3 Other events, exhibitions or contacts

Soon after the major events the prototype was also demoed at a number of conventions and exhibitions.

It was present at Health Tech Nordic 2019 which was held in Copenhagen Denmark. Present there were doctors, innovators and people in charge of hospitals and training equipment.

TechBBQ is a convention with a focus on startups and technology. The people attending the event were mostly investors, journalists, and people interested in new tech.

Venture CUP is a startup competition where companies submit their business strategy and product ideas and compete against each other. During this event held in Gothenburg Sweden, the prototype was tested by a number of people attending the event.

The project idea was also pitched to an organisation within the Swedish Armed Forces named försvarsmedicinsktcentrum (FörmedC). The organization's main goals are to supply the army with trained medical personnel, train soldiers in medicine, equipment and skills necessary for peace time as well as war time operations.

3.3 Prestudy Conclusions & Discussions

No formal tests were conducted with the prototype due to time and the fact that the end product would not resemble the prototype in any way. All data was gathered by observation and through discussions with users.

The overall responses from the events were positive, with many showing a liking for the usage with augmented reality.

They liked:
- Simplicity of the device
- Ease of use with the markers
- Combination with the real world

What was less enjoyed where:
- The narrow FOV
- Frustration with the complexity of the default Hololens interaction
- Inability to know how to wear the Hololens
- Trailing menus

Learned was therefore, that users would get easily frustrated when they can't achieve something they want because of the complexity with the Hololens interaction for beginners. A large problem is the narrow fov. This limits what the users can perceive and therefore limits the usage alot for medical training. Users tend to wear the Hololens wrongly, this results in the screen not lining up with the users vision and they can't see what they are supposed to. Static objects worked very well with the Hololens. Solutions to these problems can be fixed with a mandatory introduction / tutorial for new users. This would make sure that they know how to wear the device and its basic interactions. Something like this would in theory reduce a lot of the frustration and possibly enhance the experience. Further the trailing menus in the prototype tended to become a problem for many, the menus "follows" the users positional movement and rotation and align itself to always be in front of the user. The menu does this when the user looks too far away from it, and at times users would see the menu slightly off and just stand and wait for it to move into position. Since they don't know that it only moves when it's too far outside the user's eye sight.

Chapter 4
Methods: The Human Centered Process

Regarding the research goals as well as the product goals, the end user needs to be in the center of the design process to successfully achieve them. Thus this project would employ the human centered design process. This methodology revolves around understanding the user and including them in the development process. The process used in this project is shown in the figure "X".

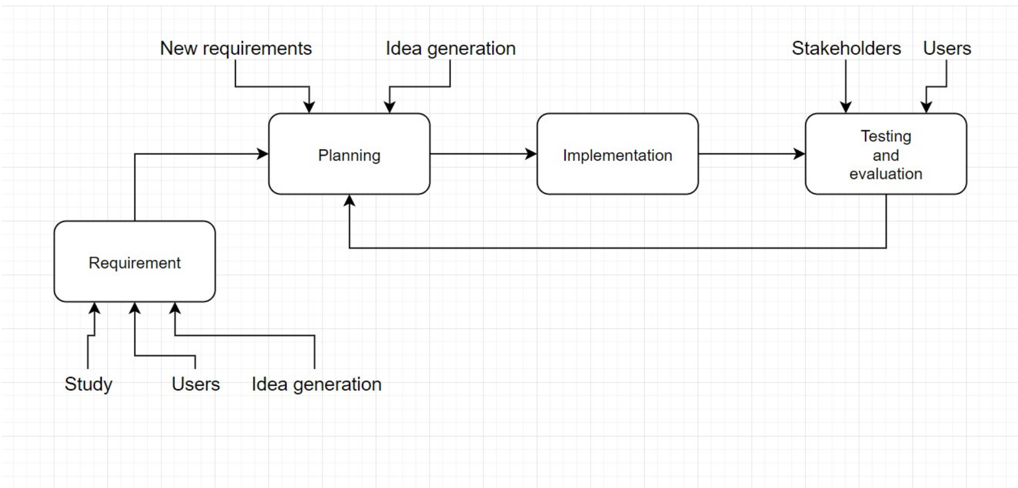


Figure 4.1: Process

This chapter will describe the methods used to achieve the set goals and find an answer to our research questions.

4.1 Literature survey

Each part our application needed a firm ground to relay for it to be useful for customers and users.

The main goal with the research was to find the following:

- How is triage practiced today?
- What is the weak link in today's practice?
- Has something similar to this been done before?

The research was conducted by reaching out to different organisations and asking them for potential material. Material was also found via scientific research search engines.

Parallel to the literal literature papers, we planned to do onsite observations at learning facilities and take expert advice from people in the industri explaining how it's done today.

4.2 Idea Generation

Considering the idea generation it was done together with HeroSight and the thesis author with the aid of different tools. At this point in time the company and author had decided that triage was the medical practice that was going to be implemented. This decision can be read about later in the thesis.

First a traditional brainstorming session was held at the company office. The aim was to derive core functionality and necessities with theses points in mind:

- The hardware
- The problem
- The pre study learnings

The problem is the medical practice of triage and how we could potentially solve some of its current problems. Before holding the brainstorming session we drew a simple scenario in which triage where to be held. By doing so, we could always have a baseline so we don't alter too much from reality and what's needed. When the core functionality was found we could proceed to further explore how interactions would be made. To do this we used the technique bodystorming. By acting as users we could then create a list with different interactions to further decide on.

4.3 Prototyping

After generating the idea, it must be visualized and discussed whether it would hold up as a valid design before committing to it. This was achieved through a LoFi prototype.

In this project a mockup design created by compiling the ideas from the idea generation. The mockup was to be drawn as a storyboard. This storyboard would then be sent out to different customers for reviews and notes. To keep the LoFi phase short it was decided the three iterations of the storyboard was to be made where the last iteration where the final design.

The storyboard was to be sent or shown to the following for review:

- MSB Revingehed, (Swedish Civil Contingencies Agency / Myndighet för säkerhet och beredskap)
- MSB Sandö, (Swedish Civil Contingencies Agency / Myndighet för säkerhet och beredskap)
- Försvarsmedicinsk centrum, (Swedish Armed Forces / Försvarsmakten), Göteborg
- Securitas
- Trängregementet, T2, (Swedish Armed Forces / Försvarsmakten), Skövde
- Ex-military personnel
- Nurses

4.4 Project Planning Phase

Leaving the prototyping phase a plan had to be created for managing the resources and keeping a decent pace. It was already expected that the scale of the project might be larger than anticipated, thus a good plan would make it manageable.

4.4.1 Architecture

Listed functionalities from the prototyping was quite a lot, a good architecture was deemed needed for the project's success. It was decided to keep the number of major changes as low as possible, therefore the initial architecture wouldn't be disturbed too much. However during a project the scope may change, and the application needed this room for improvement. Which puts the architecture and smart implementation at large.

By identifying functionality from the LoFi and listing them, a set of architecture goals where to be set. These goals were then used as a baseline for the applications architecture.

By creating a PBS construction tree, one could now visualize approximately what components would be included in the application and the different modalities used. This application tree was then used to create another construction node tree, with the technical implementation in mind. Once the implementation tree is completed and fits the LoFi design, an propper UML chart of the system could be created.

4.4.2 Team-management

Entire project team will consist of four people. The owner of HeroSight, a 3D graphic modeller, a sound technician and the tech-lead and developer which is the thesis author.

With the nature of the project, and how it is set up, the author decided that Microsoft's project management solution Dev-Ops would fit the project. Within dev ops teams could be created, tasks could be assigned and a code repository could be established. The main feature of dev ops is the integrated Kanban board, which is used to create, track and complete tasks according to SCRUM.

4.5 Project Implementation Phase

During the development a scrum styled mythology was adapted working with sprints for continuous development. The scrum process is however simplified and the retrospective sprint analysis would be skipped.

Our scrum method would look as follows:

- Feature planning
- Task planning
- Sprint
- Review

Since the project evolves and at times new suggestions from customers or features would come at random, each sprint is finished or its major features, before handling a new request. The request would then either alter the sprint if deemed valuable, be implemented in the next sprint or discarded.

4.6 Project Testing Phase

Measuring and data gathering is the last phase of the project. With the project goals in mind, both product and research, the final product needed to be tested against its current day counterpart. Standard application interaction tests are also needed to determine if the user experience is faulty or could be improved.

Data gathering would be done with:

- User tests
  - Observation
  - Time
  - Open discussion
- Knowledge test
- Objective data gathering
  - NASA TLX
  - SUS
- Interviews

With the data gathered, an analysis of the results will be made to answer the initial research questions.

Chapter 5
The Product Process: Results & Discussions

You can read about literature research findings in the theory section of this thesis. However to answer the question "what is the weak link" in the current system today, we visited both Falck Ambulance training center in lockarp and Sahlgrenska Universitetssjukhuset in Gothenburg. HeroSight also conducted numerous meetings with other potential customers.

Through interviews and discussions we found out that actors and injury makeup was one of the major problems with preparation. For each field practice a number of actors had to be acquired, either through voluntary or paid actors. Voluntary actors are commonly other course students or elderly, During our visit to Sahlgrenska the actors were other course students, and MSB explained that some of the time elderly partaken in exercises as actors. Their problem was that actors cannot simulate certain conditions, like death, the effects of trauma or change their pulse. Rapid or slow breathing is also difficult to maintain for longer periods. Naturally dolls are also used for practice, although not all organizations get access to those more advanced smart dolls which can simulate puls, breathing and bleeding. Most organizations only have access to sand filled dolls, and these dolls cannot simulate anything at all beside death, such a doll can be seen in figure "X". Other than actors, injury makeup was the major resource thief. Each actor needs an injury makeup to fit the conditions given to them, and the makeup session takes approximately 90 minutes for around five actors.

Figure 5.1: Sand filled practice doll, image taken from later in the project during test with a member of Piketen

5.1 Ideas

Setting a medical learning goal before generating the idea needed to be decided on. This medical practice would then affect all the decisions in the project regarding literature and ideas. From the pre-study prototype, the company came into contact with a number of people representing companies and organizations, all with different ideas to how they could use AR in their training. Suggestions like, mine disposal training, stationary weapon control training, fire truck controls (ladder, water connections) and of course basic medical training. HeroSight at that time then decided that the practice of triage would fit for AR training, since triage training is expensive and time consuming to plan and execute. It was therefore decided that primary triage was the scope of the project. The pre-study prototype was built with MS Hololens, therefore we knew what to expect from it. Hence this project will also be developed with the Hololens.

Before starting the brainstorming session the author and HeroSight wrote down how triage is done in practice today, this would then act as the baseline so that we didn't deviate too much from our target group and how it is actually done. The specific acts in the drawing originated mostly from literature gathered and from interviews with people in the branch. Our baseline can be seen in figure 5.2.

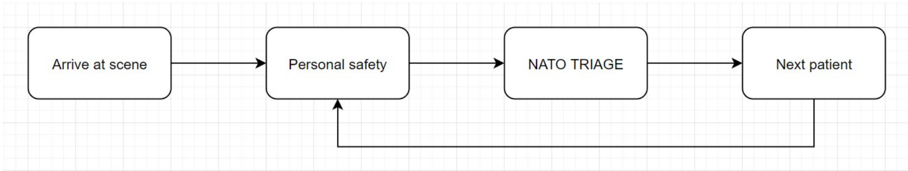


Figure 5.2: Triage workflow baseline

We could now hold an open brainstorming session where we wrote down ideas on a piece of paper. Ideas on what functionality and interaction ideas that could potentially be used and what problems they have today. The ideas here were open and not limited to actual triage, we only kept the baseline as an inspiration. To further develop or remove ideas listed we took the list and held a body storming session. The idea with the body storm is to approximately feel how to do triage with an AR headset. Here we used the baseline we drew earlier so we at all time could relate to it. The bodystorming resulted in that we came up with some new interesting interaction possibilities worth exploring.

A list with the new expanded ideas are listed:

- Projected injuries
  - None fully generated actor, instead projected injuries
- Bleeding effects
  - Depending on state and pressure
- Menus attached to arms
  - Easy access to menus
- Dangerous props attached to the world
- Medic pack menu
  - Menu available for treatment via a physical medic pack
- Third party controller
  - Instructor controls environment via a tablet
- Live view
- Sound depending on interaction
  - Verbal responses from patient
  - Reaction on treatment
- Ambient environment

During the bodystorming session, technical aspects were also considered, how would any of our features actually be implemented? The hardware aspect had to be in mind since the product needed to be portable, easy to use and easy to set up as well as not exceed out of the budget boundaries. The project was also under a time limit.

Listed are some potential technology solutions, as figured out while bodystorming:

- Tracking of location
  - Static placeable world anchors
  - Vuforia markers
  - OpenCV / Tensorflow
- Placement of objects
  - Spatial mapping and auto placement
  - Manual grab mechanic

5.2 Prototypes

The ideas were written down and a simple lofi storyboard style prototype was drawn. The storyboard's content was mostly related to how the user would use the application from start to finnish on one use case. The case was, start the application, handle three patients and exit the simulation. Displayed in figure 5.3 is the first version that was created.

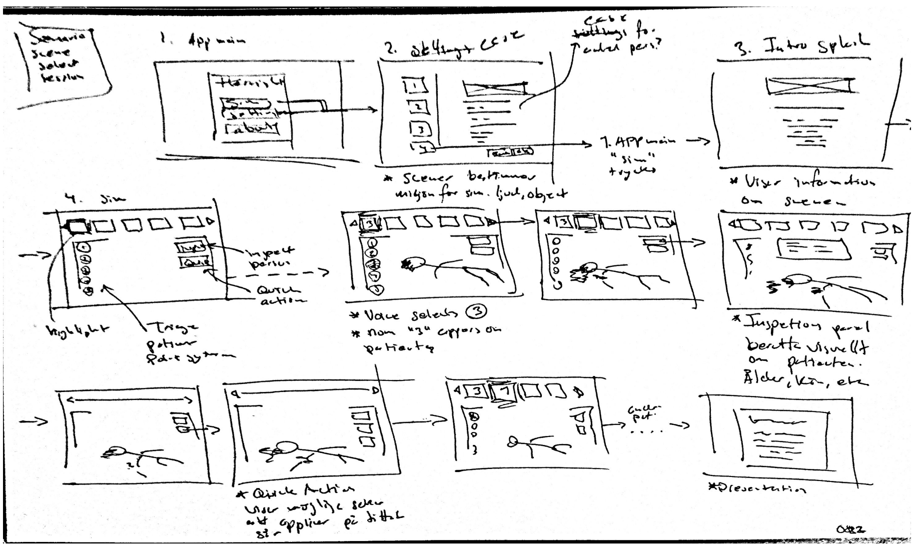
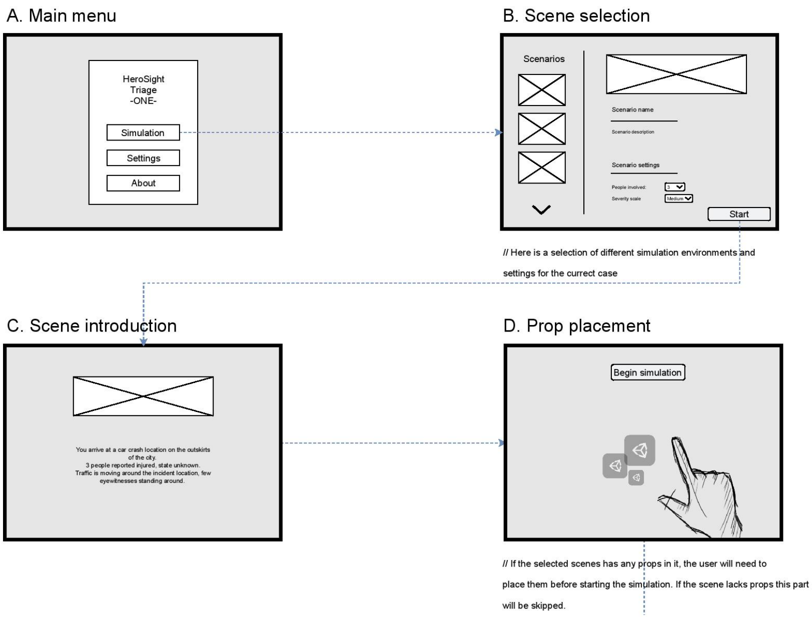


Figure 5.3: First application storyboard, each panel viewed from a users perspective

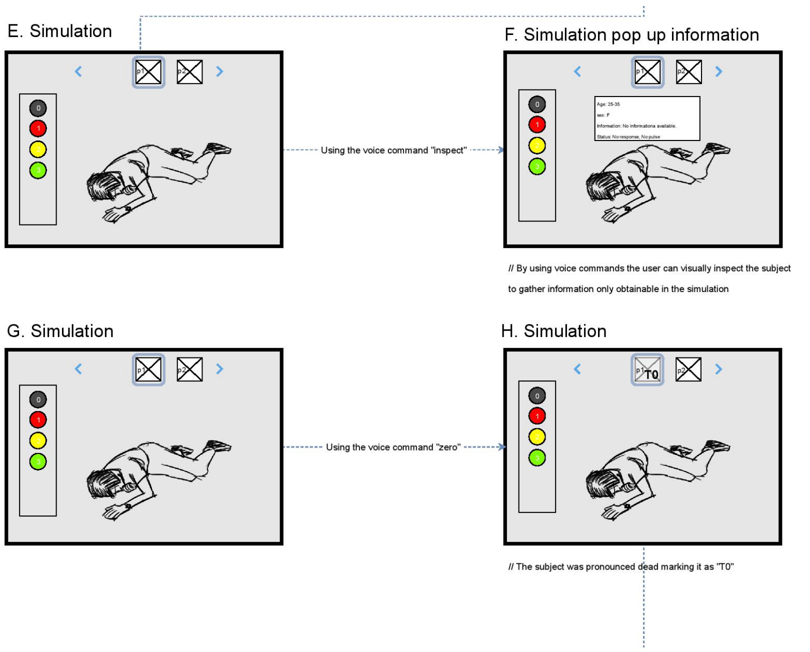
A lot of thinking went into how the UI design of the application should be, after all our target group could potentially consist of many people who are not familiar with fast learning of new technologies. What that means is that new users cannot with ease, figure out the basic methods of interactions or relate to another system they know of. This knowledge originated from the pre study prototype, described in that chapter. However at this stage of the project, a more abstract approach was decided for, with the reasoning of exploration. What worked rather well from the pre study prototype, was the voice control, therefore all elements of the application needed to have the ability of being controlled with voice. The HUD design is heavily inspired by video game design, and would in theory fit for the small fov of the Hololens.

In this prototype the idea is that the patient is one physical doll. This doll would then have different markers attached to limbs and body parts. The software would then project many patients onto this doll, depending of course on which one should be displayed. This would allow us to have an injury site with anything from 1 to many patients displayed on the same doll.

Following responses from advisors and internal reviews, the LoFi was redesigned with more detail and a clear learning goal. The newer refined version is seen in figure 5.4 and 5.5.

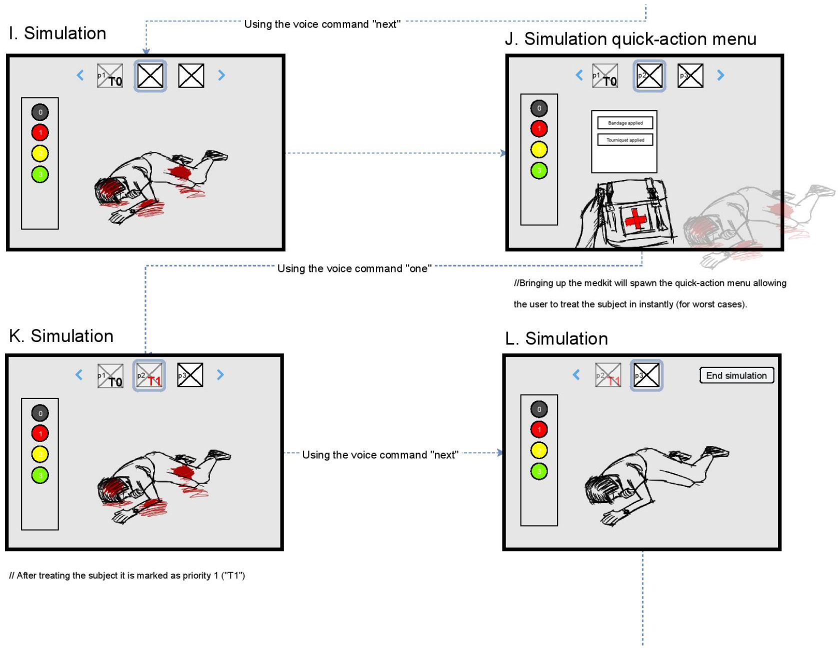


(a)

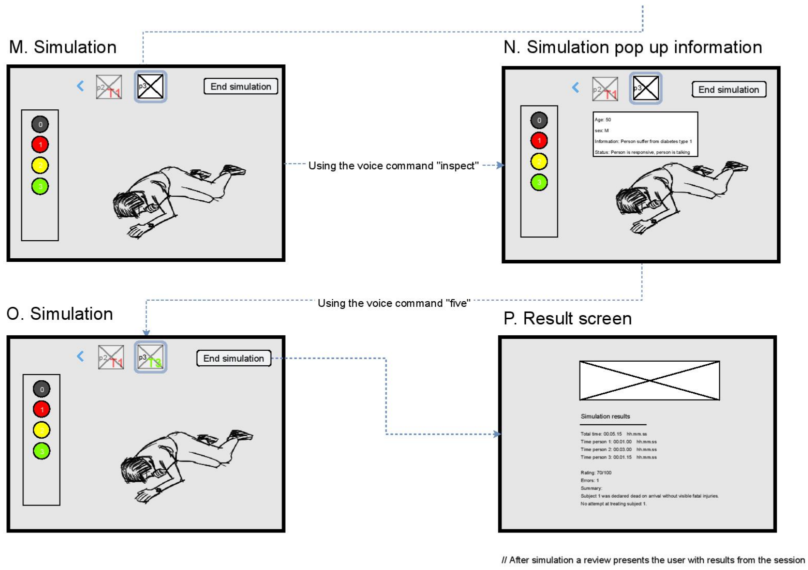


(b)

Figure 5.4: Application storyboard



(a)



(b)

Figure 5.5: Application storyboard

This version was now sent though different channels out to potential customers of the idea. The prototype was sent with either email or post to:

- MSB Sandö
- Försvarsmedicinsk centrum
- Securitas
- Trängregemented T2
- Nurses

This was the first iteration of the storyboard, not all organizations responded to the sent out model, some wanted a different learning goal all together. This thesis wont state each exact response, since it is not necessary for the thesis. However from the responses gathered, the majority who liked the idea wanted to slim down the steps in the design. The reasoning was to lower the amount of clicks in the application.

The changes between iteration one and two are:

- The medic bag idea was discarded
- After prioritising an patient as priority 1, the quick action menu will automatically spawn

The prototype was also discussed in meetings with:

- MSB Revingehed
- Ex-military
- Nurses

After the third iteration of the story board, a final sketch was made and accepted, therefore the next phase could begin. The final storyboard does not differ a lot from the original, therefore it is located in the appendix of this thesis.

5.3 Planning Phase

Using the final storyboard and list of functionality as a requirements specification, the planning for the application could commence. The base architecture design for the software needed to be created, a more specific scenario list and patient lists for the simulation was also needed. The team management services setup and ready for tasks and tracking.

Firstly we set up a preliminary timespan for the project, including different phases during the development, this line-chart is identical to the thesis time-chart and is seen in figure 5.6.

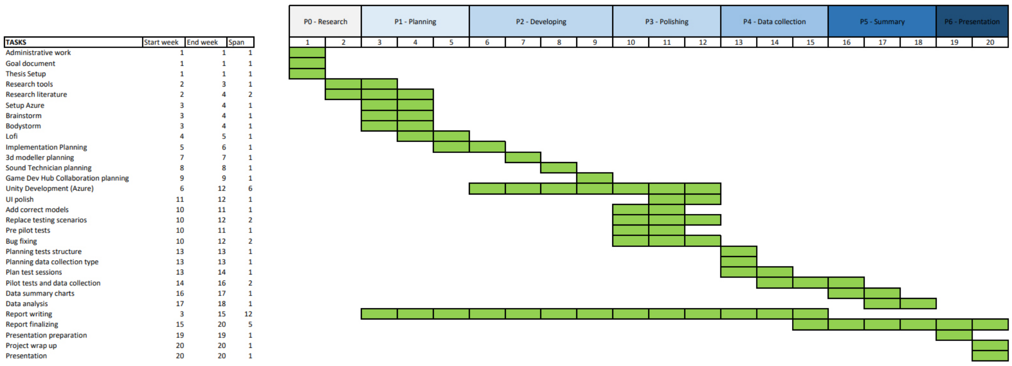


Figure 5.6: Initial project plan

Before working on detailed implementation planning for the project, an product breakdown structure (PBS) chart can be a great tool for quickly get an potential overview of the systems UI elements, functions, and underlying hardware. With this overview, architectural mistakes that could have occurred further in the project can be avoided. It also enabled this project to allow for further design changes without locking in the code to a certain system and make it unmaintainable.

At this point it was also decided what external third party libraries and tools were going to be used. From the initial discussions, MRTK was a necessity for AR development. Vuforia with ImageTargets was going to be used since it allows for positional coordinates and rotation of the markers.

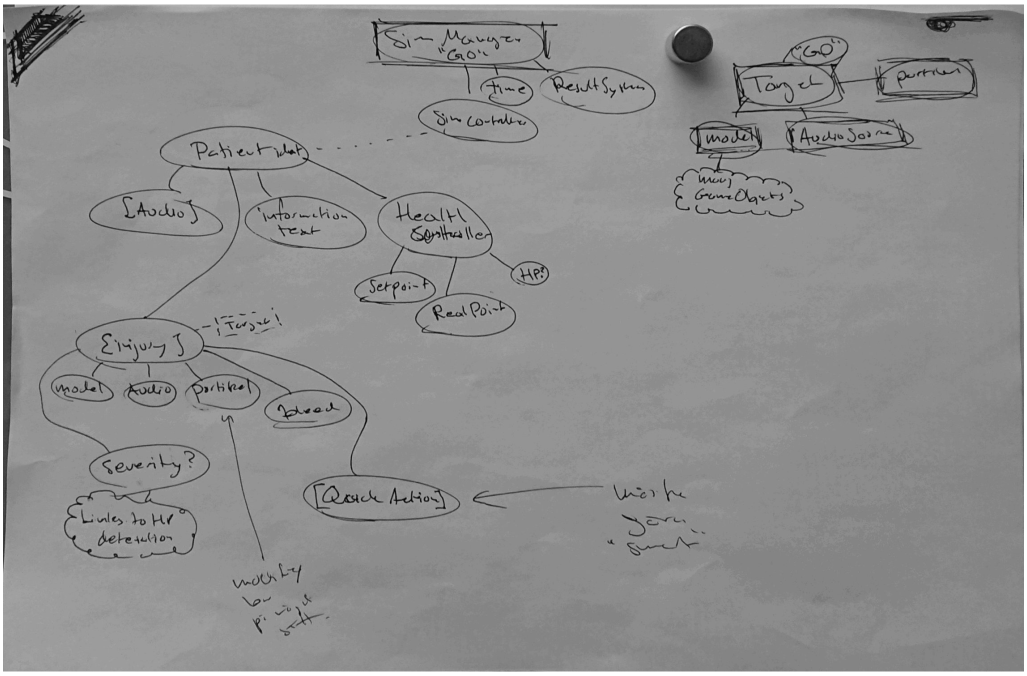


Figure 5.7: Project PBS diagram

Following the PBS chart shown in figure 5.7 was the actual more detailed architecture design. The purpose of the UML diagram is to guide the developer and work as a template for faster development, since with a proper UML chart less thinking about the system is needed while developing. This thesis will not feature the complete system UML chart since it is deemed as not necessary for the reader, instead a snippet from a part of the UML is included in figure 5.8.

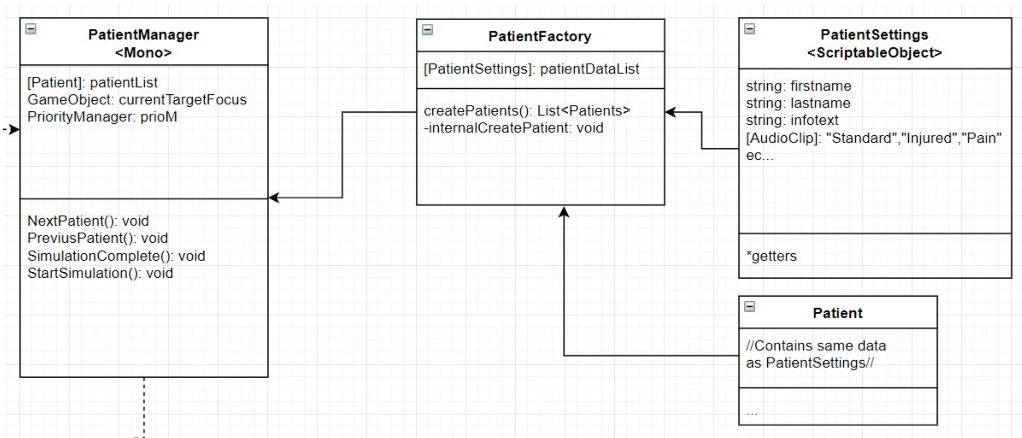


Figure 5.8: UML snippet

The system needed to be capable of:

- Multiple scenarios
- Multiple patients
- Injury treatment
- Easy patient creation
- Easy scenario creation
- Ambient sound creation
- Simulation grading and statistics
- AR injury detection
- AR prop placement

For the first version of the prototype we needed scripts of the scenario the users are put in. During the start of the project a major potential customer for the project was the Swedish Armed Forces. Hence the first build was more war inspired and would feature such an environment.

The first version would then feature:

- One war scenario
  - Six Patients with war related injuries
  - Props found in such an environment
  - Military ambience

Project management was set up in Microsoft agile development solution Dev-ops. Dev-ops allowed for project contributors to be assigned tasks on a Kanban style board. These contributors can be assigned into teams and have their own boards as well as integrate their board tasks into the main project board. The structure was as below:

- Strategy
  - Author
  - HeroSight
- Development
  - Author
  - Sound Technician
  - 3D graphic artist
  - Frogsong (consultants missions)

On the task board, the first sprint was set up as well as other issues and epics that would help guide the projects towards the end goals. The repository was hosted on Dev-ops using GIT. At this point not much thought went into which code management was going to be used however SVN or GIT with LFS plugin would have been better from the start since Unity projects, from experience, tend to be quite large in size.

5.4 Development Phase

Development began shortly after the plan was finished. This chapter will describe each development sprint executed in this project which consisted of four sprints in total. For each sprint the discoveries, problems and solutions will be brought up. The chapter ends with a summary which describes the finished product along with images from the application.

Sprint 1

The first tasks were to rebuild the pre study prototype and use as much learned from it in the new product. Even if the application would be much different from the prototype, the base of it was copied, and with it the already set up Vuforia system. The first sprint was then initialised, and the base functionality and scripts were created. The ImageTarget system which purpose was to swap out the injury model on an ImageTarget was created and works as shown in figure 5.9.

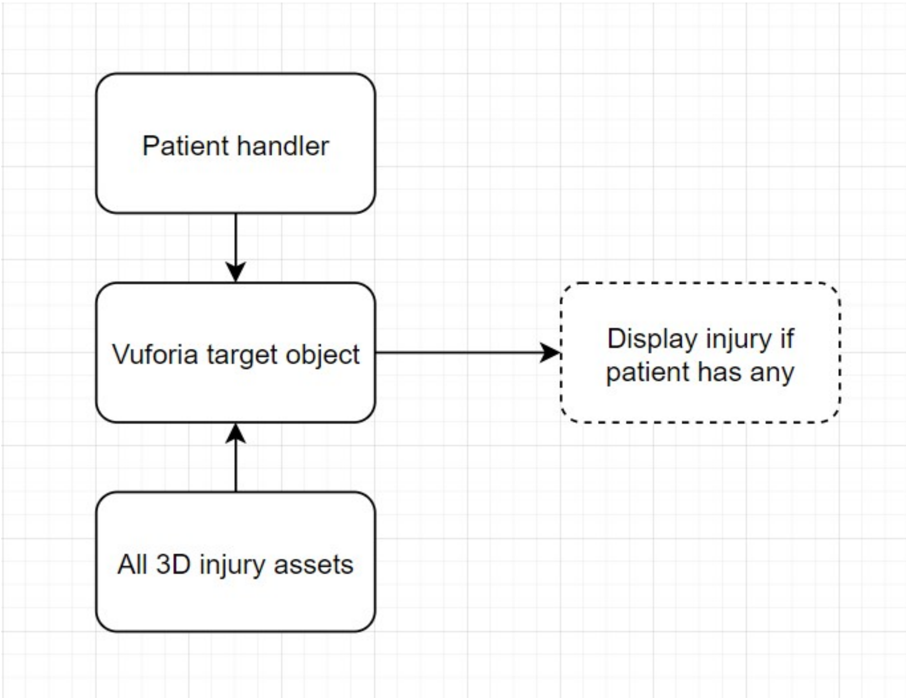


Figure 5.9: Process for handling which model to display on a Image-Target

Following the UML design, a patient was then defined for the system. The patient class has a couple of key features. A patient contains of:

- First name
- Last name
- Description
- An list containing injuries

An injury refers to the class and handles what it's name is, an injury. The injury has:

- An ImageTarget marker
- A 3D model
- A particle system

To easily generate a patient fast, Unity has a feature called scriptableobject. An scriptableobject is a data container created from a class, in this case the patient class variables are represented in the scriptableobject and can be edited with the Unity Editor window or any text editor for that matter. Scriptableobjects are stored as a YAML (YAML Ain't Markup Language), the YAML format allows for human reading of a serialized file. Something to note is that the ScriptableObjects, even though very useful for storing data, is more meant to be a configuration and tampering or writing to the file is not recommended. Therefore during initializing the simulation the created, all the scriptableObjects representing a patient needs to be parsed into a patient class. The creation steps are visualized in figure 5.10.

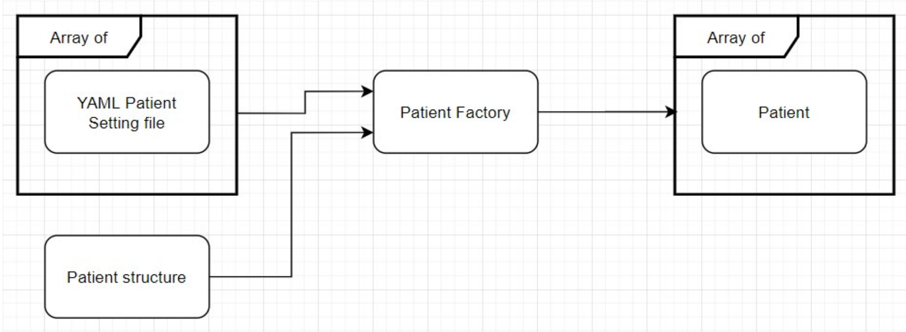


Figure 5.10: Process of creating a patient

This technique is used in the same way for a scenario. A scenario contains:

- Name
- Description
- Banner
- Icon
- Lists of props
- List of patients

The structure is partly visualized in the PBS chart discussed earlier.

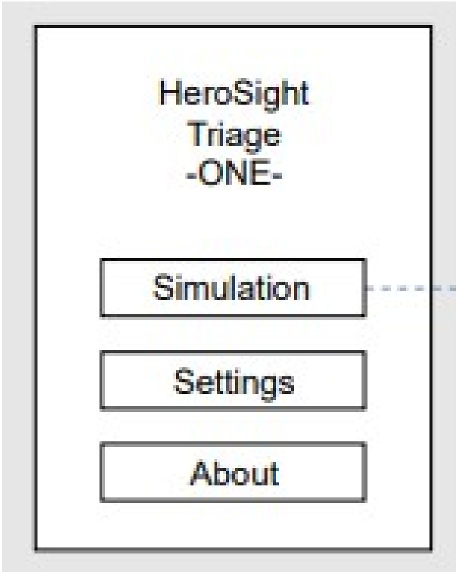
With the core functionality settled. work on setting up the GUI started. During this sprint, the UI designed from the storyboard was implemented by using Unity built in canvas system. Figure 5.11 shows an example of one element.

With the first sprint complete, the application now consisted of a working AR environment for the Hololens. Vuforia detecting and projecting temporary placeholder models onto the markers. Backend system set up, but not connected to the simulation, and a basic UI for menus and runtime simulation.

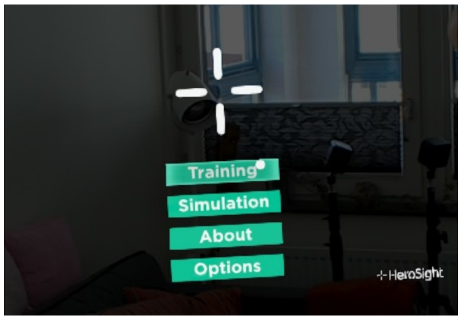
As described in the method section, the whole project process is iterative and by the time the first sprint was complete a number of flaws was discovered during initial testing.

The flaws are listed below:

- Marker recognition distance
- HUD system caused wobble problems
- Only controlled by voice was not stable enough for all dialects



(a)



(b)

Figure 5.11: Patient profile card

Sprint 2
With the first working version complete and test ready, the second sprint could commence. This sprints main focus is to implement and add 3D visual elements, particle systems (blood), improve the HUD, and start work on the quick action system. As noted in the method section this process is iterative, and by testing the HUD solution, we found that it wasn't working as expected. Therefore the whole UI in while in simulation was reworked. This issue was added into this sprint.

The problem with the HUD idea was as listed below.

- Head movement
- Obstructing view
- Not actively interactable with

The first issue was head movement, the human head is not perfectly still even if we tried and micro stutters transferred into the hololens. These stutters are very noticeable when you can see the effects of the stutters in front if you. These stutters were solved by filtering the sensor values for position tracking and rotation tracking of the Hololens, thus smoothing the HUD movement. This however caused other artifacts such as during fast movement it would cause trailing effects.

Further this version was tested with two people in the industry by the means of an open discussion, confirming our suspicion that the view is obscured slightly by the HUD. They also wanted to interact with the HUD elements which at this time only could be controlled by voice, which in fact did not at all time work as intended.

This led us to a new design, this time inspired by the training material some use today. The design conclusions come from framing different aspects of the training card from emergo train systems and triage sieve. The idea is that a user who might be familiar with the training methods would easier recognise the layout. Hence the placement of the buttons. The design is seen 5.12.

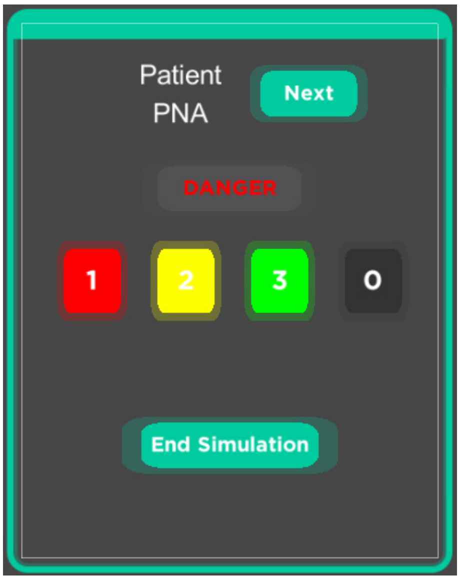


Figure 5.12: UML snippet

Likewise before all the menu items are voice controlled with the addition of being able to click elements if the user would like to do so instead. This menu is not trailing the user, since the pre-study prototype proved that this wasn't optimal for many, this menu is stationary wherever the user decides to put the menu. The menu can be moved by clicking the top bar, essentially grabbing it and clicking again to drop it.

During this sprint the 3D graphic artist and sound technician, who are contractors, was set their tasks. For our military styled scenario we required injuries that would fit in such an environment. The graphic artist was set the following tasks:

- Blast injuries
- Bullet injuries (Entry, Exit)
- Burn injuries
- Open fractures
- Blood
- Non dangerous props
  - Flasks, debris, rubble
- Dangerous props
  - Improvised explosives (IEDs)
  - Firearms
  - Knifes

The sound technician was set these:

- Wind
- Explosions
- Firefights
- Sirens
- Generic ambiance
  - City
  - Desert
  - Industrial

Injuries are handled as described before, by attaching the models to a patient, and displaying it on a physical marker. Props are handled much the same except they are not bound by a marker, they are placed into the scene at the beginning by the user. During sprint 1 the backbone systems were created for a patient, and its generation. Now the rest of the design was to be created.

That includes:

- PatientManager
  - The patient manager handles all that revolves around the patients during runtime simulation. That includes, which patient to display, which sound it makes, treatment and status.
- ScenarioManager
  - Much like the patient manager, this class handles all that is the ambience, a scenario. It handles props and the sound system.
- RuntimeManager
  - Since user inputs might vary, this class works as a medium between the user and the simulation. All interactions the user makes are passed through this class.

With the new UI design, the core system implemented and the contractors at work, sprint 2 was completed, resulting in an application that can:

- Select a scenario
- Start the simulation
- visualize placeholder patients, and injuries
- play ambient placeholder sounds

Internal testing and evaluation of this sprint proved to be more user friendly, therefore the concept stayed. At the time no industry relevant from our target group could test it.

Sprint 3
From the contractors the project received the assets described previously, some of the models had to be optimized and adjusted for Unity. Figure 5.13 showcases some of the assets delivered during this sprint.

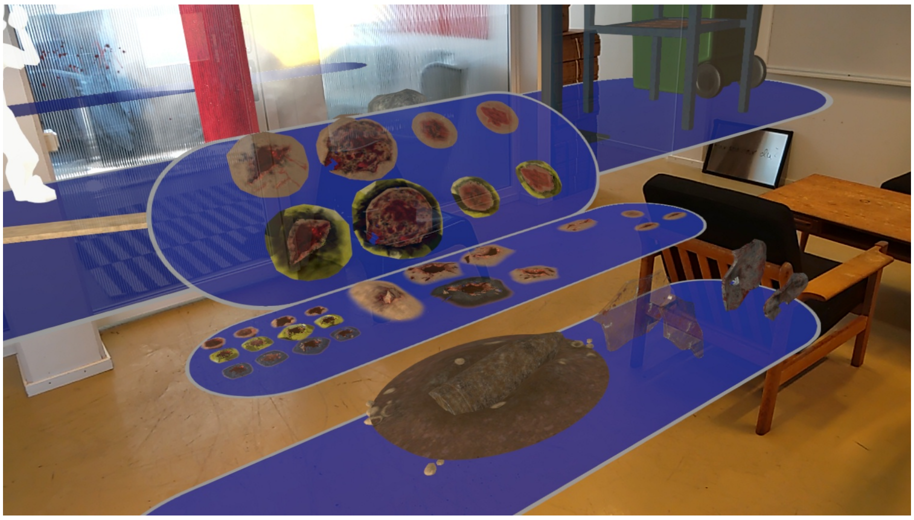
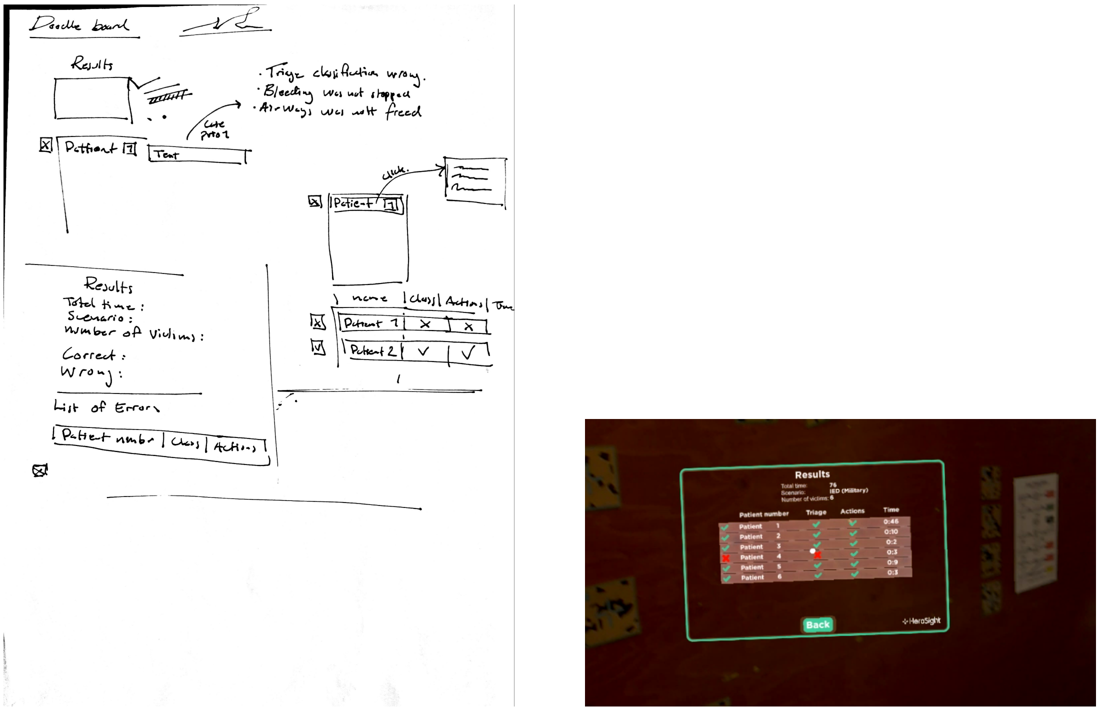


Figure 5.13: Parts of the assets included in the application

These assets were added to the systems and replaced previous placeholders. New UI elements were also received and contained custom, shapes and forms used to replace the current panel shapes. At this point the last core functionality was added, along with the results and feedback system. Since it is unclear exactly how the target group would want the feedback system, it is implemented to be non essential. Meaning that the RuntimeManager who reports user actions will also report the actions to the feedback system, essentially giving that system a picture of how the scene is without getting access or tampering with the other systems. The feedback UI was also finalized according to sketches made, these are shown in figure 5.14.



(a) **(b)**

Figure 5.14: Sketches (a), AR interface (b)

The third sprint is summarized with the new features:

- Added actual injury models
- Added sounds to system
- Feedback system
- Updated UI designs

Sprint 4
During this sprint HeroSight had altered its customer base a bit, and focused more on firefighters, hospital and prehospital field workers. This meant that to demo the product, we needed a more realistic civilian scenario, with the theme of ongoing deadly violence. A new scenario was set up and would feature:

- Explosion near a city square
- Six patients

Since many of the 3D models fit this scenario not much had to be added, however to put more detail on the wounds, the graphic artist created some penetrating objects (metal debris, glass shards) to fit the blast wounds. Alot of the sounds could also be reused.

However for the research experiment, the older military style scenario was kept, since the majority of sounds created was for such a scenario. The research scenario features:

- Six patients
- Ongoing combat
  - Distant explosions sound effects
  - Car alarms
  - Sirens
- Injuries related to the scenario

To measure the pulse of a patient they needed to be able to feel it. During this sprint a simple design specification was created and a freelancer created one version whilst the author created another designed specifically for the research experiment. Both devices generate a vibration simulating a pulse, the research version has all six patients preloaded and with a button can switch between the patients. The freelance version features a low and a high mode as well as a WiFi chip integrated, however this is not currently used. Figure 5.15 shows the devices used in the testing later in the project.

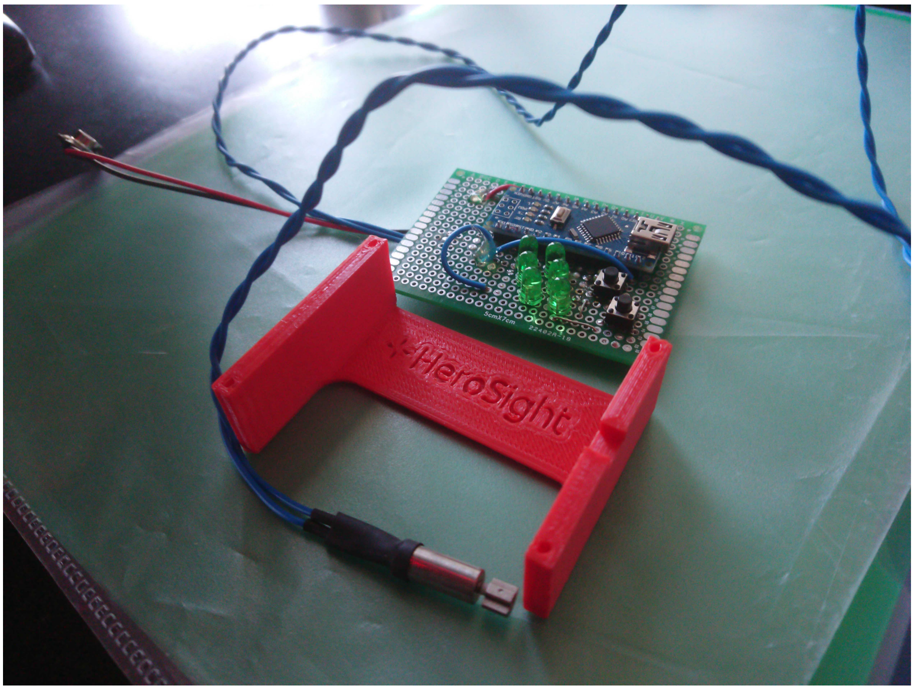


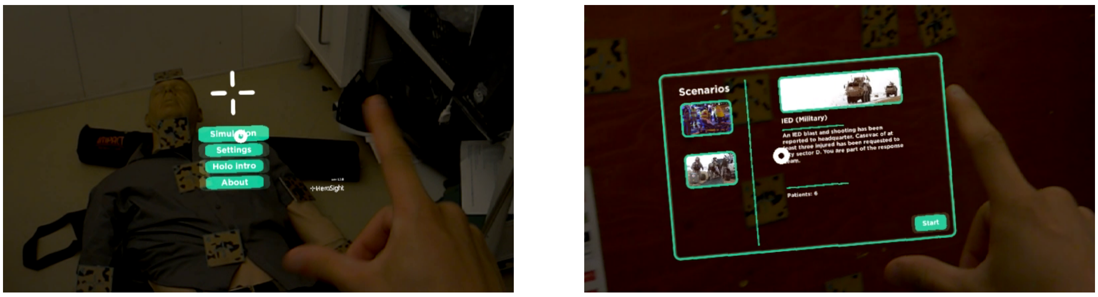
Figure 5.15: Parts of the assets included in the application

One of the original ideas of making the usage seem natural was to use one of the physical tools used in triage, which is the tourniquet or bandage. The technical solution at the time was to add a vuforia marker on top of the tool itself, thus when applied to the doll in vicinity of an injury it would trigger the same action as when the user selects it from the menu. This is another interaction option the user has when dealing with quick actions available for the patient. The solution is seen in figure 5.16.

Figure 5.16: Tourniquet tool with a connected vuforia marker.

Sprint summary

After four sprints the application was ready to be internally tested along with the pilots. The application now consists of a complete triage training flow, scenario selection with two scenarios. A military conflict scenario and an civilian terror attack scenario. It has prop placement in the environment, injury inspection, sorting and treatment for each patient loaded for each scenario. In addition to the Hololens application a physical pulse generator device was created, the device is seen in figure 5.15 and its purpose is to give a pulse to the dolls used for training with the application.



(a) **(b)**

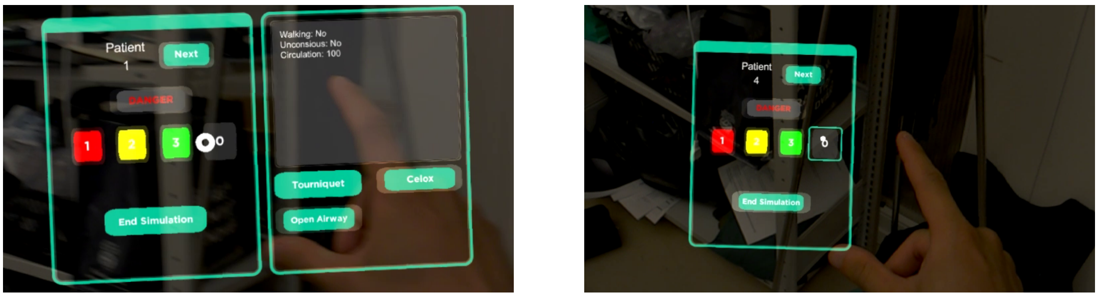
Figure 5.17: Triage main menu (a), scenario selection (b)

(a) (b)

Figure 5.18: Scenario setup (a), prop placement (b)

(a) (b)

Figure 5.19: Injury inspection (a), catastrophic bleeding system (b)



(a) (b)

Figure 5.20: Treatment menu, on wound selection (a), sorting menu (b)

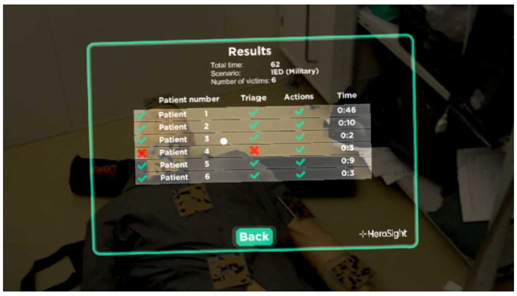


Figure 5.21: Result screen

5.5 Testing Phase

Exiting the development phase, naturally the application was tested internally to find different bugs or problems that could occur if the user miss behaves or interacts with it in non intended ways. Following the bug finding the proper test was needed to be specified, to make sure the research goals are tested and tested in such a way that the results are usable.

To get data sufficient enough to answer both the product goals and research goals it was decided that the AR application was to be tested against a traditional counterpart. The reasoning for this is to see if there are any benefits of AR simulation learning wise. The traditional counterpart will be an Emergo Train Systems inspired version, containing approximately the same data as the AR counterpart. This traditional paper system will feature the same patients as the AR simulation, along with their conditions. The resulting system is shown in figure 5.22.

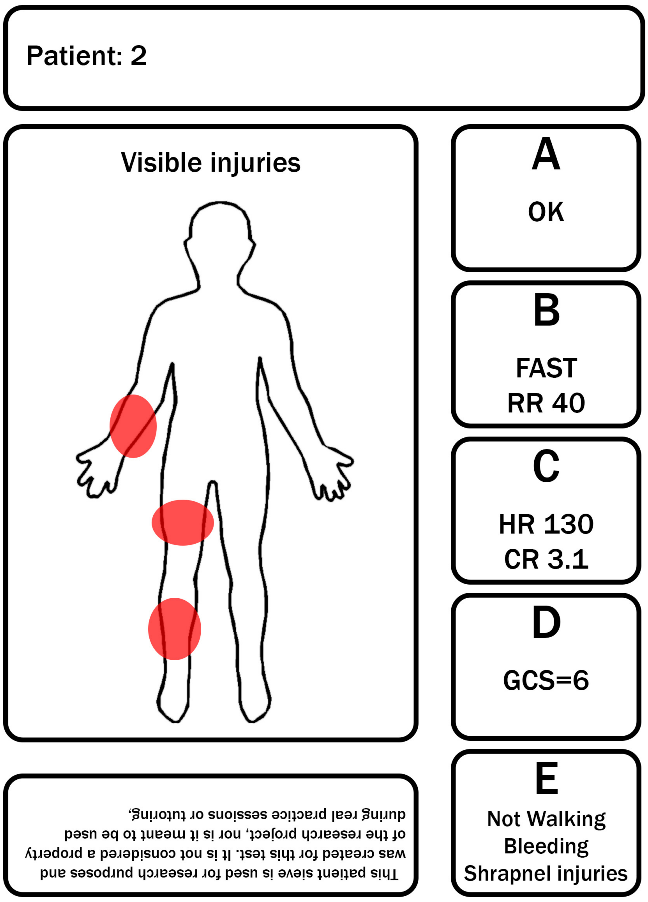


Figure 5.22: Traditional paper system used in tests representing patient two

This test would only feature "surface knowledge" gained by the simulation, a more accurate knowledge test would require far more time than the project has available. Therefore half of the Test Participants (TP) would begin the test session with either the AR version or the paper version. After the test they would perform a knowledge test to see what they learned from the system they tested. This knowledge test is then used to determine the learning factor of our AR protype counter a paper version.

To gain objective data about the experience, the TP will answer both NASA TLX and SUS.

To make sure each test is completed in the same manor, a test plan was written with detailed instructions of the structure. This structure was then put to the test by the means of pilot test, until the instructions were complete. The test plan can be read about in the next chapter.

Chapter 6
Research tests: Design & Results

Now at the end of development the formal testing of the application was designed and committed to. This section will cover the scientific research test, its design, data collection and results outcome. Some information in this section can be found in documents located in the appendix.

6.1 Test plan

This section features different parts of the test plan relevant for the thesis, the full document of the test plan is located in the appendix.

6.1.1 Question to answer

Since the goals are already defined during the start of the project, listed below are therefore the questions that needed to be answered with the use of the tests. Categorised in major questions and minor.

Major questions

- Learning quality of wearable AR in training scenarios
- Determine if wearable AR at the current stage, can be considered a real learning tool in this area

Minor questions

- Can the user maneuver the interface efficient
- Can the user apply treatment to patients
- Can the user prioritize patients

6.1.2 Question Evaluations List

Understanding which data to collect is important for evaluating the question and setting up the tests. The list in figure 6.1 contains how each question shall be evaluated with the corresponding methods for data gathering.

Table 6.1: Gathering methods

Question	Gathering type
Can the user maneuver the interface efficient	Goal reached, grade, observation
Can the user apply treatment to patients	Goal reached, grade, observation
Can the user prioritize patients	Goal reached, grade, observation
Learning quality of wearable AR in training scenarios	Questionnaires
Determine if wearable AR at the current stage, can be considered a real learning tool in this area	Questionnaires, analysis

6.1.3 Test Assignments List

Before the testing, a list containing all the assignments that the user shall do was created and is seen in table 6.2 and table 6.3. The Assignment list is split into two parts, AR and Traditional. The "AR" part will contain tasks that the user completes with the use of AR goggles. The "Traditional" part contains tasks that the user completes without the goggles. Note that the tasks vary a bit, and the reasoning to that is because the usage process between the AR solution and the current manual practices are different. What also varies are the times that the instructor has to interact with the user.

Table 6.3: Traditional test

Traditional test			
Task	Description	Completed when	Instructor task
			Prepare P1
1	Treat P1	User sets prio. Clicks next	Triage seive. Set prio 2
			Clear. Prepare P2
2	Treat P2	Applies Real CAT. User sets prio. Clicks next	Check if user applied CAT. Set prio 1
			Clear. Prepare P3
3	Treat P3	User sets prio. Clicks next	Triage seive. Set prio 1
			Clear. Prepare P4
4	Treat P4	User clear airways. User sets prio. Clicks next	Check clear airways. Set prio 0
			Clear. Prepare P5
5	Treat P5	User clear airways. User sets prio. Clicks next	Check clear airways. Set prio 0
			Clear. Prepare P6
6	Treat P6	Applies real CAT. User sets prio. Clicks next	Check if user applied Real CAT. Set prio 1.
			Clear. Remove CAT
7	Receive score		Tell score

Table 6.2: AR assisted test

AR assisted test			
Task	Description	Completed when	Instructor task
1	Start Simulation selection	User clicks / says Simulation	
2	Initialize Military Scenario	User Selects the Military Scenario and click start	
3	Reads and starts the scenario	Reads the information and clicks start when ready	
4	Treat P1	User sets prio. Clicks next	Triage seive. Set prio 2
5	Treat P2	Applies CAT. User sets prio. Clicks next	Check if user applied CAT. Set prio 1
6	Treat P3	User sets prio. Clicks next	Triage seive. Set prio 1
7	Treat P4	User clear airways. User sets prio. Clicks next	Check clear airways. Set prio 0
8	Treat P5	User clear airways. User sets prio. Clicks next	Check clear airways. Set prio 0
9	Treat P6	Applies real CAT. User sets prio. Clicks next	Check if user applied Real CAT. Set prio 1.
			Remove CAT
10	End simulation	Clicks end simulation	
11	Explain the results	User explains what the results mean	
12	Click Finish	Click finish button and return to main menu	

6.1.4 Resources and equipment for testing

Setting up each test will require some equipment, table 6.4 contains the equipment needed for a test session with one participant. This equipment list is designed for one test, and the amount listed should be available during the test. All vital paper forms are duplicated as a safety measure.

Table 6.4: Equipment list

Type	Amount
Informed Consent	2
SUS form	2
NASA tlx form	2
(No connectivity) Participant memory test	2
Triage Sieve	2
Triage App intro paper	2
Hololens 1	1
Camera Tripod	1
GoPro Hero 7	1
Manikin	1
HeroSight App Kit (Markers, equipment)	1
Tradition Kit (Fake blood, equipment)	1
Instructor Laptop	1
Blank A4 Paper for instructor	2
Stopwatch	1
Audio recorder	1

6.1.5 Test session workflow

In case the test is performed by a different test leader, a script for each test is necessary so that each participant has the same experience. The test session is visualised using the chart below.

Greet participant(1)
Explain the tests and the reasoning for the tests(2)
Have participant fill out Agreements(4)
Have a simple intervjue about the participant and their knowledge of Tech, AR, Medicine(5)
Inform that they are free to leave at any time. And warn them about gore…(1)
(If needed) Perform the Basics of Triage Introduction(5)
(IF AR) Perform the Traige App Introduction (How it works with the menu system)(3)
Start recording equipment(0)
(IF AR) Perform the Hololens Introduction(4)
(IF AR) Perform the AR assisted test(15)
Stop recording equipment(0)
SUS and NASA TLX(3)
Test questionnaires form(3)
Start recording equipment(0)
(IF Traditional) Perform the Traditional test(15)
Stop recording equipment(0)
SUS and NASA TLX(3)
Start recording equipment(0)
Debrief participant with intervjue(5)
Stop recording equipment(0)
Thank them for their time and explain future of the project(3)
Kick out participant(0)
Collect and store data(3)
Prep next arrival(10)

(x) expected time in minutes

6.1.6 Contracts, Questionnaires and material

During the test session the participant needs to fill out forms and questionnaires. These contracts forms and exact questionnaires, along with other material displayed for the TP is located in the appendix section of this thesis.

6.2 Data collection

Yielding better results from the tests, is often done with planned data collection methods. For this test it will be done with objective data collection combined with subjective interviews and observation.

Objected data is gathered through the initial interview, memory test, SUS / NASA TLX, observation.

Subjective data is gathered through, open discussions, final interview, observation.

Table 6.5 shows which method is used to answer which research question and product goal.

Table 6.5: Collection methods

Question	Type	Method	Comment
To measure the learning quality of wearable AR in training scenarios	Objective / Subjective	Triage Test	Achieved with the triage test data comparison, and trough post test interview
To determine if wearable AR at the current stage, can be considered a real learning tool	Subjective	Interview / Observation / NASA, SUS	Post interview and observation of actions during tests
Design a UI compatible with professionals in the field	Objective / Subjective	Observation / Interview / NASA, SUS	Interaction struggles during tests and post test interviews. Objective information also gathered from data collection results
Create a UX compatible with users of different skill level	Objective / Subjective	Observation / Interview / NASA, SUS	Interaction struggles during tests and post test interviews. Objective information also gathered from data collection results
Seamless interaction with components and real physical tools	Objective	Observation	If the user managed to apply the physical “digitized” tools
Aim to create the usage, natural	Subjective	Observation, Interview	Observation of actions and movement during test and post interview

6.3 Test Results

Totally there were eight participants with different backgrounds, all however have ties to medical training in some way. Table 6.6 contains information about each anonymous participant.

Table 6.6: Traditional test

Id	Age	Sex	Glasses	Work Title	Medical skill	Technical skill	VR Knowledge	AR knowledge	Wearable AR
1	21	Female	No	Nurse, orthopedic	3	2	5, Tested	4	Tested
2	39	Male	No	Fire officer	3	5	4, Tested	4	Heard of
3	23	Male	No	Police student, Home Guard	3	3	4, Tested	3	Heard of
4	25	Male	Yes, for car	Security guard	4	4	5, Owns	4	Tested
5	42	Male	No	Ex Military, Ex Firefighter, Emergency Nurse	4	4	3, Tested	2	Not familiar
6	32	Male	No	Specialist Doctor	5	3	2, Heard of	3	Heard of
7	32	Female	No, has lenses	Ex Medical Doctor, Software developer	5	5	4, Tested	1	Not familiar
8	50	Female	Yes, reading	Nurse	4	3	3, Tested	2	Tested

With eight participants, four of them started with the AR application and the other four started with the traditional paper variant. The unweighted NASA TLX score shown in figure

6.1 represents the results from all the participants. Over all the results the AR system has a mean of M=41.8 and a deviation of SD=17.5 , while the traditional system has an M=28.5 and SD =8.8.

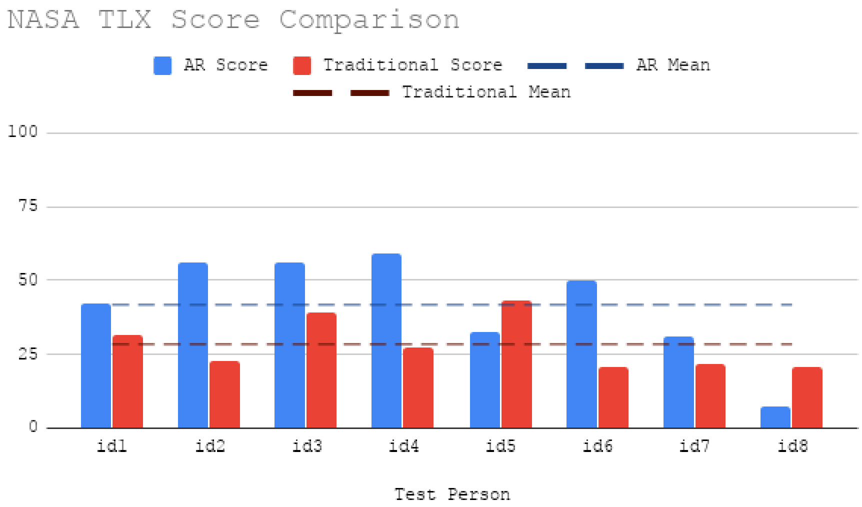
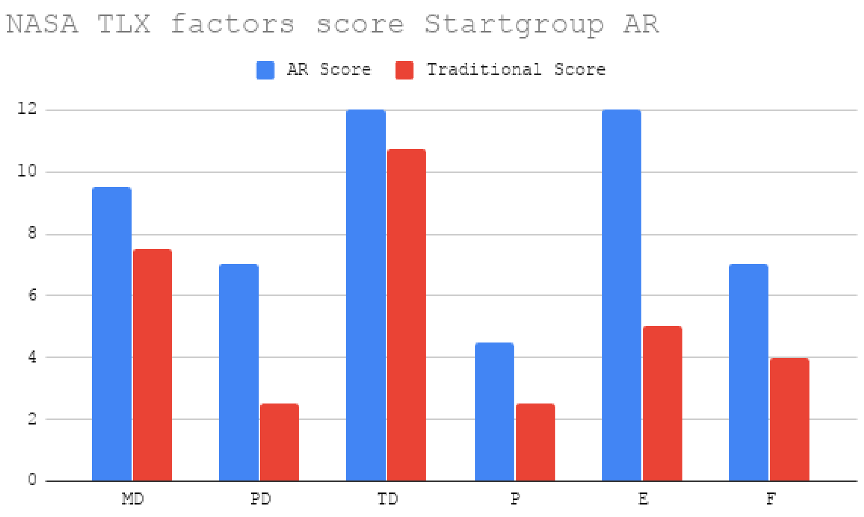
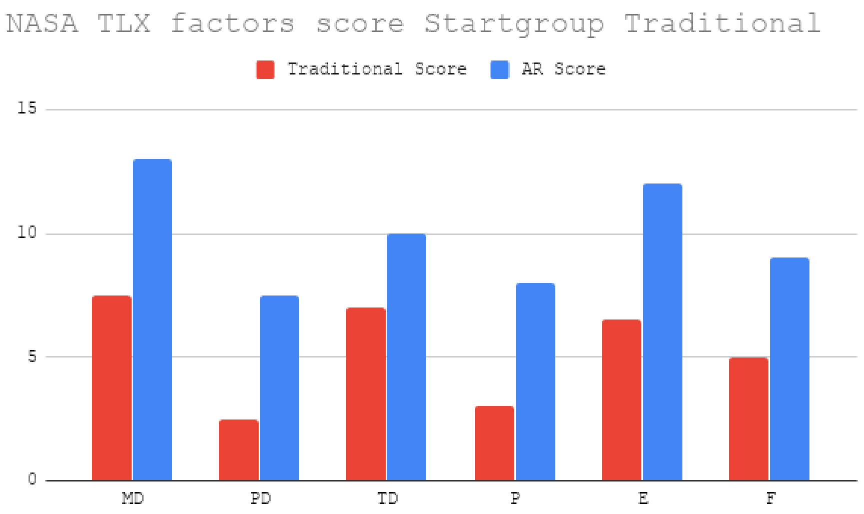


Figure 6.1: Total NASA TLX result from each participant

Figure 6.2 shows the NASA TLX scores separated into the respective start groups, e.g. which system they started. Each chart is split into the median subscores for the startgroup, consisting of four participants.



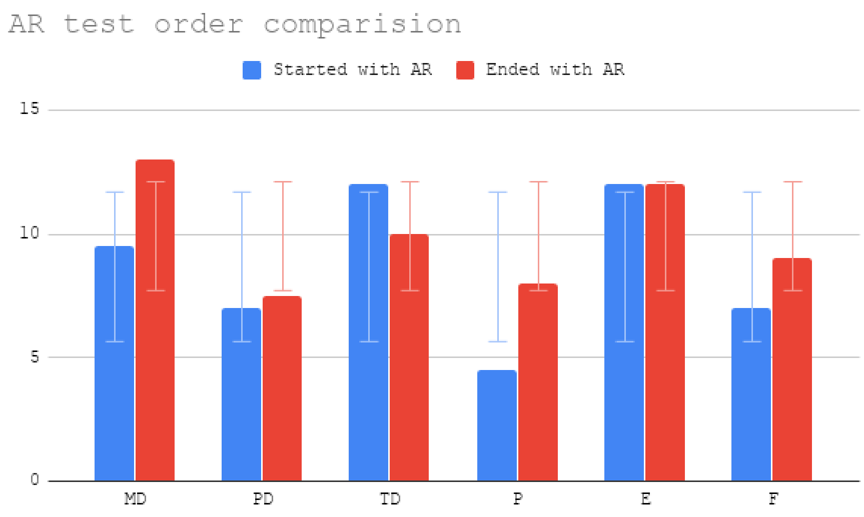
(a)



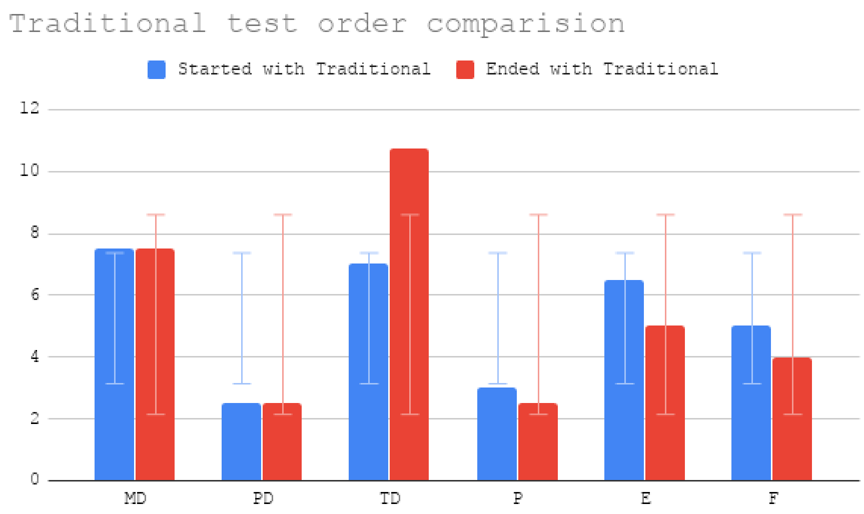
(b)

Figure 6.2: NASA TLX split into subscores for the AR startgroup (a), NASA TLX split into subscores for the traditional startgroup (b)

Figure 6.3 shows the same data as Figure 6.2, however this figure is aligned to show the subscore difference between starting with a system and ending with the same system.



(a)



(b)

Figure 6.3: NASA TLX split into subscores for the AR system (a), NASA TLX split into subscores for the traditional system (b)

Along with the NASA TLX questionnaire the test participants answered a SUS questionnaire in a similar manner. Figure 6.4 shows the overall SUS score from both systems. The AR system had an M=68.75 with a deviation of SD=11.2. Whilst the traditional had an M=77.2 , SD=8.4.

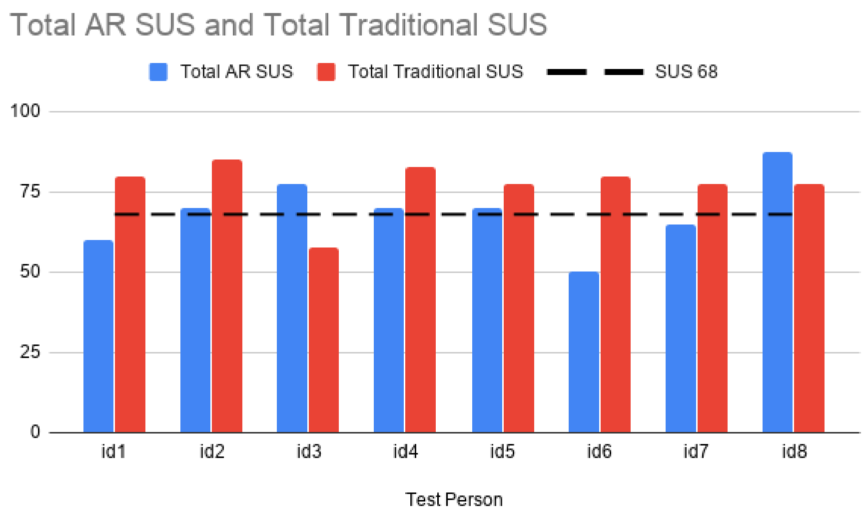
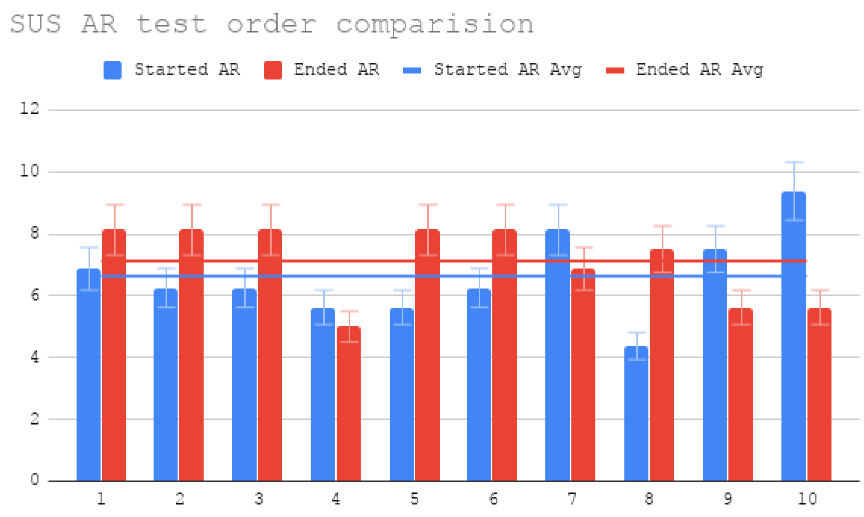
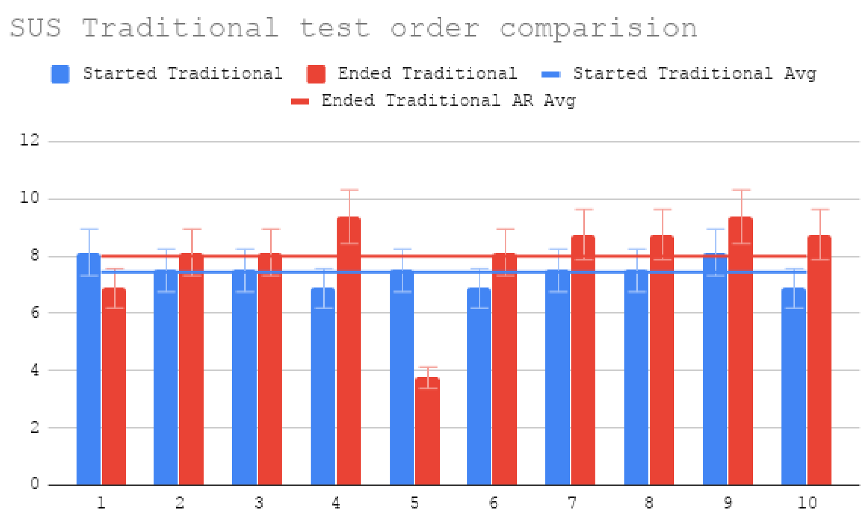


Figure 6.4: Total SUS result from each participant

Figure 6.5 represents the SUS scores for each question in the questionnaire, each system respectively.



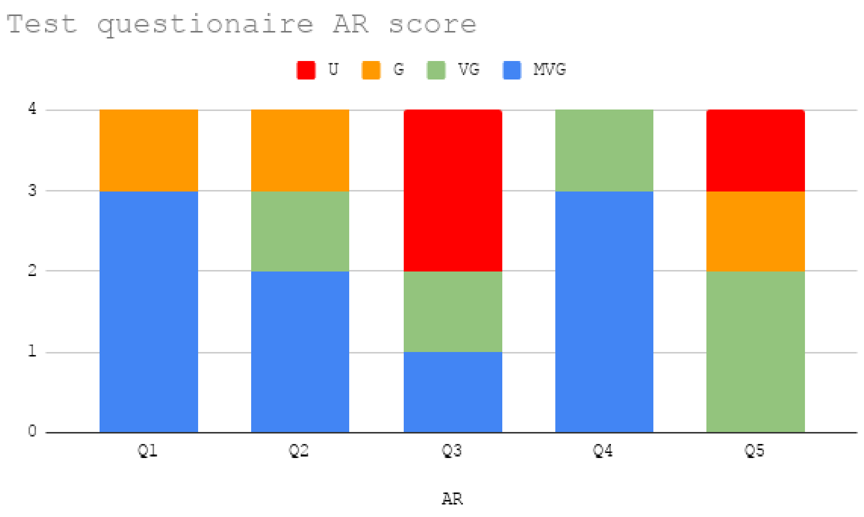
(a)



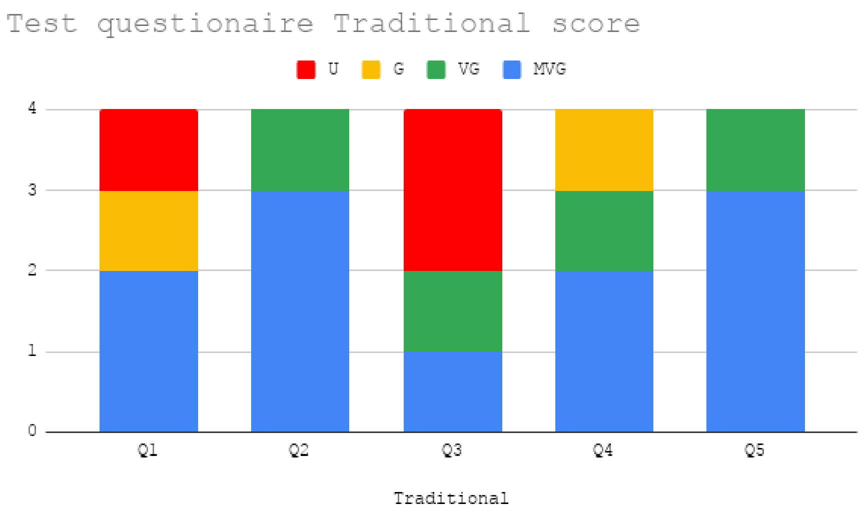
(b)

Figure 6.5: SUS results split into each SUS question for the AR system (a), SUS results split into each SUS question for the traditional system (b)

Each learning test was graded into U, G, VG, MVG (fail, ok, well done, very well done) depending on the answer and reasoning given. Figure 6.6(a) shows the results from the tests for those who started with the AR system, and figure 6.6(b) for those who started with the traditional.



(a)



(b)

Figure 6.6: SUS results split into each SUS question for the AR system (a), SUS results split into each SUS question for the traditional system (b)

Chapter 7
Discussion

Having completed the project and attained some results, this chapter will discuss the discoveries, problems and answer the initial goals set for the project.

7.1 Research questions and test

At the start of the project the main questions set for this project was two things: To measure the learning quality of wearable AR in training scenarios, and to determine if wearable AR at the current stage, can be considered a real learning tool.

Measure learning quality of wearable AR in training scenarios

From the test conducted with the AR applications in comparison to the traditional paper system, we can see that there is no substantial difference between the systems. A potential reason for this is the small group of participants who underwent the experiment since the current COVID19 pandemic, many of the intended test subjects were no longer available for testing.

However, what is clear from the test questionnaire is that amongst the eight test participants, five of them are seasoned veterans within their branch, all got at least one of the questions completely wrong. Whilst the younger people in the line of work, didn't get any question completely wrong. This is most notably seen during question three, and question five of the questionnaire.

Question 3 was created to see if the participant understood how to handle a non breathing patient. The correct way to answer the question is to check if the patient is breathing, if not clear the airways, if the patient still doesn't breathe it shall be counted as dead. Here a total of four people answered it wrongly, mostly because they refused to count the person as dead. Which is the most normal case for ER personnel, since it is what they are taught. If a person is not breathing they want to administer CPR. This seems to be most likely the result of them going back to what they were taught when they forget the steps in the triage sieve.

Question 5 faces similar problems, this question was designed to see how the participant would handle a complete triage situation with the longest possible path in the triage sieve. This tests if the user remembers the paths and what respiratory rates as well as pulse are counted as normal. Here many of the veteran users tended to drop out of the triage flow and answer what they were taught.

Another issue with measuring the learning quality is the time span between learning triage and answering the test. During this experiment, the user got to learn triage on six patients with the cheat sheet in their hand and directly answer the questions. Which would correspond to "surfaced learnt" knowledge. For a more accurate result, more participants would be needed, longer training period and the question should be answered on a separate occasion. At this stage, the measurement presented in this thesis is not enough to determine the learning quality of AR systems.

Determine if wearable AR at the current stage, can be considered a real learning tool
AR has most likely proven its potential capabilities during this thesis. Which is proved during the test, the interviews and the data collection.

On the other hand, the SUS responses show that the AR system got an average SUS score of 68.75, which means that the system can be considered average in learnability and usability, as perceived by the participants. A SUS score of 68 is considered average, anything above is considered good and below bad. The traditional system got a SUS score of 77.2 which was expected since the system is in its nature quite simple, non technical and is proven to work since it is in live use during training facilities. Much expected from the pre study prototype, the interaction and frustration along with the clicking showed in the SUS results and during observation. Notably on question four of the SUS questionnaire, which regards the need of a technical person where the AR system got a bad score. From the interview and observation, users had trouble clicking and understanding the boundaries as well as a combination with not understanding how to use the application. Question eight also showed some interesting results on the AR system. It would seem that the users who started out with the AR system rated the system as very cumbersome to use, whilst the users who first tried the other system rated the AR one as less cumbersome. This could imply that some users found the act of triage difficult to grasp and not the AR system itself. Since they would have prior knowledge of triage, seem to handle the system better. Another interesting note is that the traditional system on average got the same SUS score non dependent on the starting order. Whilst the AR system got a better score after a user had prior tried the traditional variant. This can be viewed as the users acknowledging AR as a potentially better system.

The NASA TLX score also shows results which could be expected when comparing a less technical system with a technical one. The overall NASA TLX score measures the workload on a user, with a lower score often meaning a better system. The results gathered proves that the AR system got an average worse score then the traditional paper variant. This is however very good results for this thesis. Since this proves that the AR system has a positive immersion impact on the user. In a real life scenario treating and assessing real patients, is naturally very stressful and very demanding. From the interviews by the veteran soldiers and firefighters the most affecting parts is knowing that the person could be close to death, which is also boosted by the visuals and sounds of the scene. Demanding actions are finding injuries on a person, whilst potential family members are crying or being aggressive. This is something that does not correlate well in the traditional system which lacks immersion all together, as some participants said "the need for a doll or actor" is not even needed since the information is available on the paper sheet directly. The AR system on the other hand, simulated stress inducing ambience, breathing / screaming patients and visual injuries. This seems to have resulted in a larger workload on each participant as the scenario being more realistic and a bit closer to the real thing. Thus the worse results received in the NASA TLX is actually positive for this particular system. The interviews also voucher for the AR system with all eight participants agreeing to have chosen the AR system if they needed to practise triage, even with Hololens G1 interaction flaws. Note worthy comments is that during observation 6 of 8 people acted differently when using the AR system. With the traditional they stood still and read out the information out loud, while when using the AR system they would move around and analyse the injuries, count the respiratory rate and heartbeat. They would instantly become more physically active during usage.

With this in mind, this thesis can conclude that an AR system at this current stage could be considered a real learning tool and a potentially good one.

7.2 Product goals

The project started with a set of goals towards the end product. These goals are listed in chapter one of the thesis.

Triage, Multiple Scenarios, customize patients, Audio simulation
The architecture for the application was created with all these goals in mind, thus succeeding in delivering just that. The audio simulation proved to be a key factor in the simulation during testing. All eight participants approved of the sound simulation which was spartialized in the 3D environment. This means that a user could hear an explosion coming from a certain direction relative to the headset, his accounts of the patient breathing as well. If the user was working further away from the patients chest, they would have trouble hearing the breathing and had to approach the patient. However the goal with quick customizable patients was only partly achieved. While developing, a framework was built to help the developer create new scenarios and patients and for a non developer without the Unity project and environment, this task would not be possible. In the future there needs to be an external UI for creating patients, scenarios and push them to the Hololens.

UI / UX user compatibility, seamless interaction, real physical tools
During the early stages of the project a lot of the end users were contacted and gave their input on how they wanted to interact with the system. The UI was designed to be as simple as possible to maneuver, and during the interactions some interfaces were redesigned for less clicks, since clicking is an issue for users. From the pre study prototype we noticed the difficulties of instructing a user to use a system we could see. Thus the Hololens intro was implemented, and each test user had to complete this before starting the test. From observation alone this seems to have improved the understanding for many of the new AR users even if the introduction was very short. The fixed interfaces compared to the pre study version improved the performance a lot, however not many users understood how to move the runtime triage panel itself. It's design oriented from Microsoft's explorer filesystem, and by selecting the top bar one could move it. This was something that needed to be redesigned or thought about in the future.

Interaction wise, seamless interaction could not be achieved. This is limited directly by the Hololens G1 clicking system. Out of eight users only three managed to successfully click without aid or hesitation after completing the introduction tutorial, created for this project. Thus during training with the AR device most of the subjects acted stale and at times stood still.

Physical tools proved to be a problem, only two users managed to put on the tourniquet properly for it to be registered in the simulation, however none of the users really understood what was happening. From observation it would seem that the users had trouble understanding the blue orb surrounding the tool as well as making it track the vuforia marker. This system would need to be properly redesigned for it to work flawlessly. On the plus side some of the veteran users put the tourniquet very high up on the thigh, which is the correct way of doing it. Though the simulation is required to put the tourniquet next to the injury itself which in retrospective is wrong. Even if the physical tool didn't work very well at all, every one of the users would have preferred it if they could do it.

7.3 Sources of errors

Setting up a perfect project without any possible errors is highly unlikley and in this experiment like many others, there are some forms of error source during testing and data collection. This thesis of course also has a number of flaws that could affect the end results directly.

COVID-19 pandemic
During the testing phase of this project the COVID19 pandemic hit the world and prompted major changes in communication, development and experimenting. Companies as well as schools had to adapt to new rules regarding human distancing which meant closing office buildings.

This thesis suffered as stated most during its testing phase since the target group was mostly no longer available for testing. The collaborations with local fire departments had to be put on hold thus not allowing me to perform the tests with on duty firefighters. This was also the case with the military and medical workers.

Limited participants
Due to the pandemic, a larger test study was not possible in the current timespan. Thus resulting in only eight participants from the target group. A larger group would have been preferred to detect extremities amongst the results.

Can't learn old dogs new tricks
This thesis aimed to train users in triage with the specified methods of actions described in the triage sieve. It is important to know that this particular triage sieve is not universally acknowledged, thus meaning that each branch has their own version of it, often depending on who is currently in charge in the respective branches or companies. With this in mind, some of the test subjects who were veterans in their line of work, always tended to act and work on the case as they are taught, thus not following the triage sieve given to them even if they are holding it in their hand as they are grading a patient. This behavior was most noted at test subjects who had worked for years.

Scenario setup and simulation functions

The scenario, which in itself was on the verge to extreme and featured a live warzone, could have affected how the users acted. The intention of the scenario was to stimulate extreme stressful situations, with a military scenario in focus. However in the end the test users were not military, thus they could run the risk of feeling uncomfortable in the situation. Scenarios such as a traffic accident would have been more accurate for the test participants during this thesis testing phase. The AR application could not simulate all the requirements in the triage sieve, through normal means. Such as checking the consciousness of a patient. This is done verbally and through reaction tests, such as the GCS or AVPU charts. Checking of consciousness was done by asking the test leader if the patient was deemed unconscious or not. This disturbed the flow and most likely the immersion of the simulation.

Chapter 8
Conclusion

So in conclusion this thesis project aimed to test if wearable AR could improve the learning experience within emergency response training, more specifically the process of triage for a certain triage sieve. The project started out by analyzing how triage is practiced today, interviews and discussions with organisations such as Swedish Armed Forces, Räddningstjänsten and hospitals. A pre-study prototype was built and tested to find potentials and problems with the wearable AR headset Hololens Generation 1, this prototype was demoed and tested at exhibitions. With the knowledge gained from interviews and the pre study prototype the work began on the real project.

With the NATO triage sieve as the learning goal the application was built using human centered design methodology. Three LoFi iterations were made and four development sprints were conducted which resulted in an AR application designed for a wearable device with the possibility to inspect, assess and treat a virtually generated person displayed on a doll. The application underwent user testing against a training system currently used today.

It was ultimately learned that a wearable AR device can definitely be used in the industry for practice training. It would seem that the possibilities for sound simulation and visual injuries increases the immersion effect during training thus improving the overall experience. With the results from the studies, the majority of the users got more engaged with the patient, the majority thought the system affected their stress and workload and every one would recommend the system.

Not all is good however, and it would seem that the major bottleneck in user interaction lies within the limited Hololens G1 interaction. The click gesture has time and time shown to be difficult for users, which ruins the immersion for many. For the first generation Hololens different control possibilities would be recommended such as the clicker device. The FOV the users get is also a problem since, users sometimes cannot see the virtual objects due to them not viewing the direct head on.

From a cost perspective, the more realistic a real field day simulation is, the more expensive it is going to get. Hopefully with AR devices this cost can in some way be reduced or put to better use by having participants already trained in the AR environment making the simulated field exercise much more valuable.

Chapter 9

Future work

After acknowledging potential errors of this project regarding whether AR increases the learning capabilities, the system needs to be tested on a larger participant group to rule out outliers. There should also be a longer testing period, potentially over more then one practice session and the memory / knowledge test should be taken during its own session. Perhaps then the results can actually show some interesting data.

Testing would also reflect our current day technology if the application was ported and adapted to the Hololens G2. Thus ensuring that the equipment is up to date and possible eliminating the interaction problems caused by Hololens G1. At the end of this thesis the application has already been ported over to the new device, however no official testing has been done with users.

Application wise, it was highly requested by some organizations that you could practice on more then one doll. By having three physical dolls we could project our patients profiles onto them, thus the user needs to walk between the dolls to arrive at the next patient, further increasing the immersion and realism.

Another feature that would improve the practice session is if the instructor could directly control which patients get displayed for the Hololens user.

Multiplayer between users is another definitive feature that would enable the system to be used in group practice. By having two people engaged in a patient the workflow would be more realistic as one sorts the patients whilst the other treats them accordingly.

During this thesis we had a pulse generator device which was manually controlled. This device should be connected to the Hololens over WiFi allowing the system to tell the pulse generator which pulse the patient has without having the instructor manually set the pulse. More advanced dolls such as simulation moving chests.

Chapter 10
Industry relevance

During the entirety of this project, it has been developed closely with people from different organisations all dealing with first responder tasks. Project has taken inspirations from interviews and demos where input has been given to be able for an end product which could reflect a need that this present in the industry of simulation training. AR has not been explored properly in regards to this sector and this thesis hoped to prove the different potential benefits of AR technology. Unfortunately the eight participants who contributed to the testing were not enough to determine if AR helped users learn better. However results show that each user's workload and immersions increased tremendously, this could potentially improve learning experience and enable training at a much lower cost then bringing in actors and applying injury makeup.

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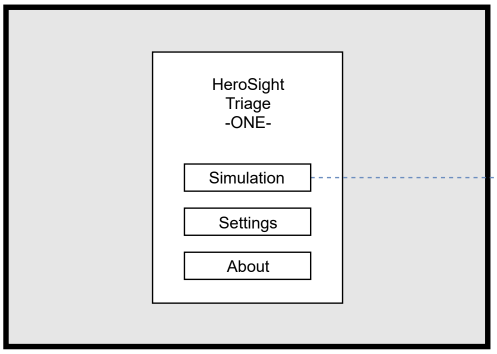
Appendices

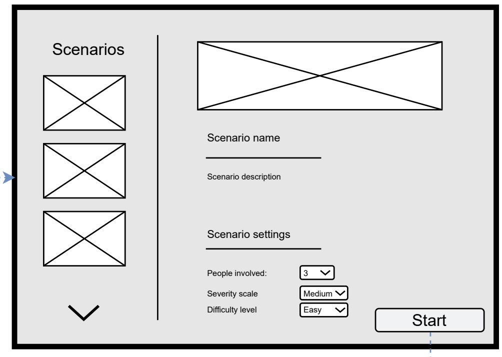
Appendix A
Final Storyboard version

HeroSight Triage ONE - Easy difficulty

Alpha. Main menu

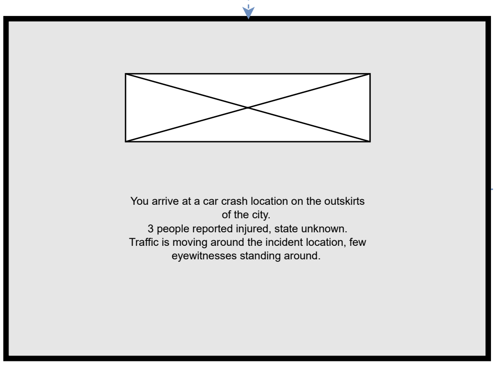


Bravo. Scene selection

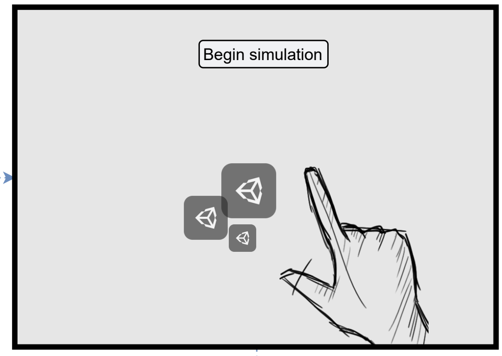


// Here is a selection of different simulation environments and settings for the currect case

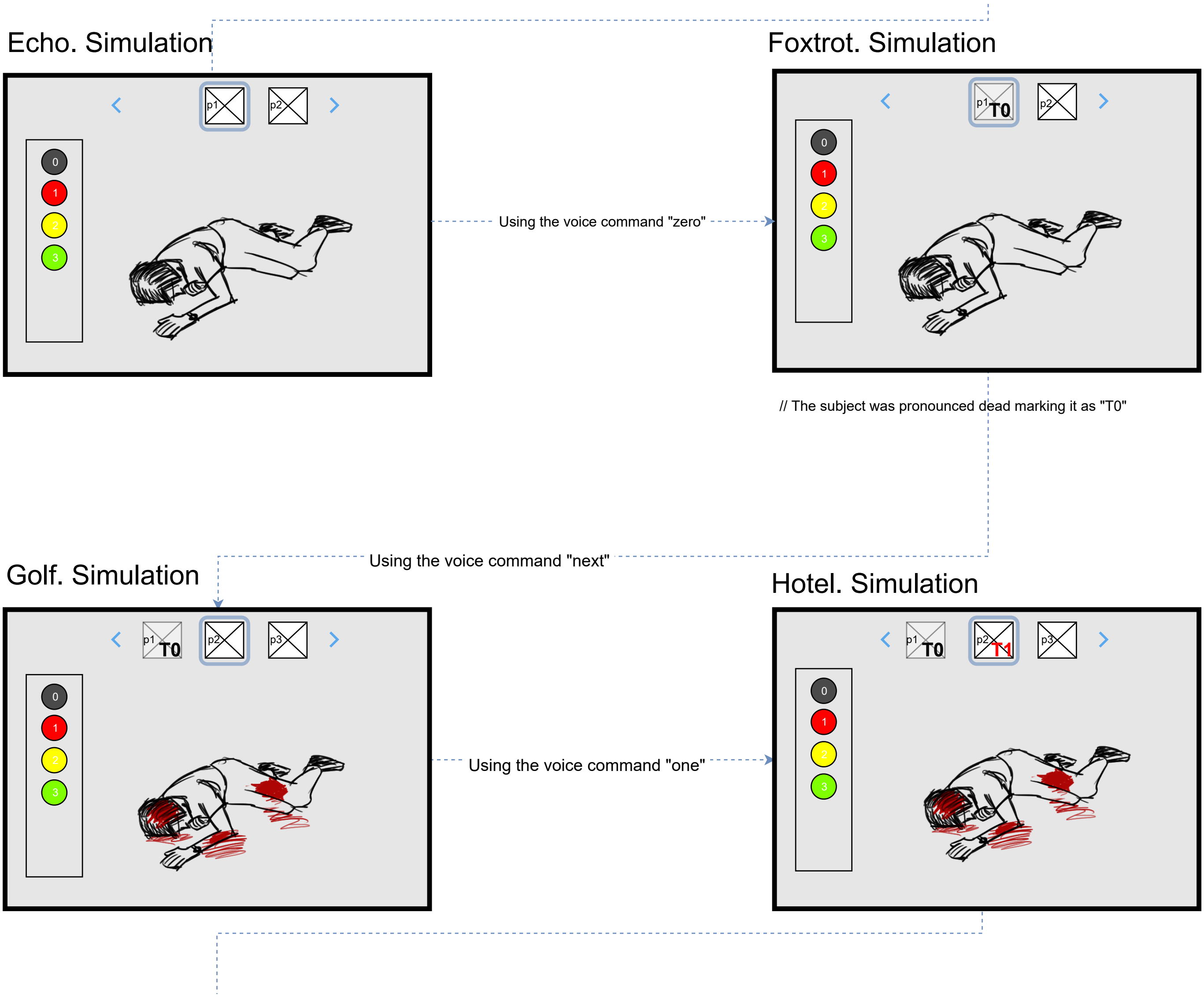
Charlie. Scene introduction

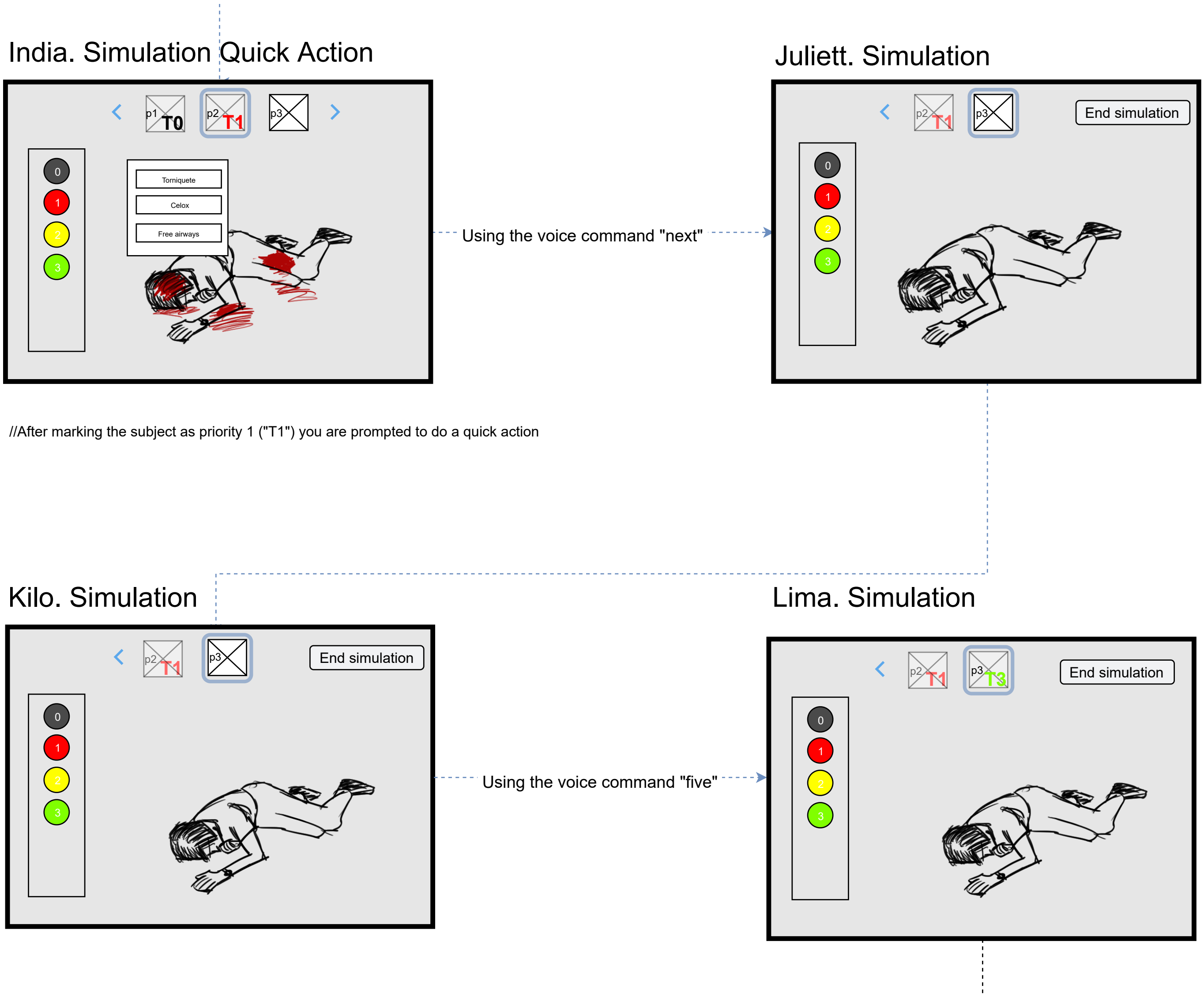


Delta. Prop placement

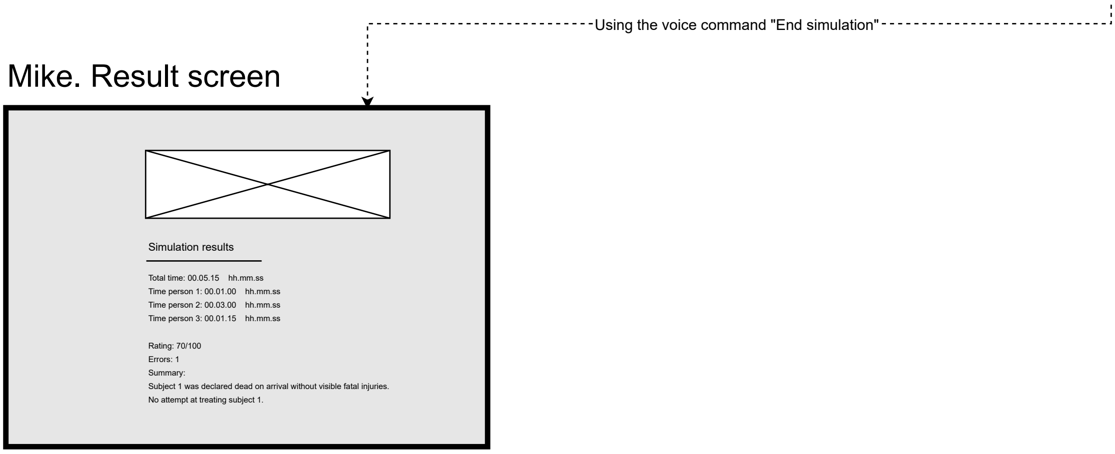


// If the selected scenes has any props in it, the user will need to place them before starting the simulation. If the scene lacks props this part will be skipped.


Echo. Simulation
Foxtrot. Simulation
Using the voice command "zero"
// The subject was pronounced dead marking it as "T0"
Using the voice command "next"
Golf. Simulation
Hotel. Simulation
Using the voice command "one"
p1
p2
p3
T0
T1
0
1
2
3


India. Simulation Quick Action
p1 T0
p2 T1
p3
Torniquete
Celox
Free airways
0
1
2
3
Using the voice command "next"
Juliett. Simulation
p2 T1
p3
End simulation
//After marking the subject as priority 1 ("T1") you are prompted to do a quick action
Kilo. Simulation
p2 T1
p3
End simulation
Using the voice command "five"
Lima. Simulation
p2 T1
p3 T3
End simulation

Mike. Result screen



// After simulation a review presents the user with results from the session

Appendix B
Testplan

HeroSight - Triage ONE

Test planning document

Author: Joakim Andersson

Date: 2020-02-24

Table of contents

Introduction

This document contains information on how the user tests will be conducted and how data will be gathered. This document can and should be considered the instructor's guide on how these particular tests explained here shall be conducted and recorded.

Questions to answer

Listed below are the questions that needed to be answered with the use of the tests. Categorised in major questions and minor.

Major questions

- Learning quality of wearable AR in training scenarios
- Determine if wearable AR at the current stage, can be considered a real learning tool in this area

Minor questions

- Can the user maneuver the interface efficient
- Can the user apply treatment to patients
- Can the user prioritize patients

Question Evaluations List

This list contains how each question shall be evaluated with the corresponding methods for data gathering.

Question	Gathering type
Can the user maneuver the interface efficient	Goal reached, grade, observation
Can the user apply treatment to patients	Goal reached, grade, observation
Can the user prioritize patients	Goal reached, grade, observation
Learning quality of wearable AR in training scenarios	Questionnaires
Determine if wearable AR at the current stage, can be considered a real learning tool in this area	Questionnaires, analysis

Test Assignments List

This list contains all the assignments that the user shall do during testing. The Assignment list is split into two parts, *AR* and *Traditional*. The "AR" part will contain tasks that the user completes with the use of AR goggles. The "Traditional" part contains tasks that the user completes without the goggles. Note that the tasks varies a bit, and the reasoning to that is because the usage process between the AR solution and the current manual practices are different. What also varies are the times that the instructor has to interact with the user.

AR assisted test			
Task	Description	Completed when	Instructor task
1	Start Simulation selection	User clicks / says Simulation	
2	Initialize Military Scenario	User Selects the Military Scenario and click start	
3	Reads and starts the scenario	Reads the information and clicks start when ready	
4	Treat P1	User sets prio. Clicks next	Triage seive. Set prio 2
5	Treat P2	Applies CAT. User sets prio. Clicks next	Check if user applied CAT. Set prio 1

6	Treat P3	User sets prio. Clicks next	Triage seive. Set prio 1
7	Treat P4	User clear airways. User sets prio. Clicks next	Check clear airways. Set prio 0
8	Treat P5	User clear airways. User sets prio. Clicks next	Check clear airways. Set prio 0
9	Treat P6	Applies real CAT. User sets prio. Clicks next	Check if user applied Real CAT. Set prio 1.
			Remove CAT
10	End simulation	Clicks end simulation	
11	Explain the results	User explains what the results mean	
12	Click Finish	Click finish button and return to main menu	

Traditional test			
Task	Description	Completed when	Instructor task
			Prepare P1
1	Treat P1	User sets prio. Clicks next	Triage seive. Set prio 2
			Clear. Prepare P2
2	Treat P2	Applies Real CAT. User sets prio. Clicks next	Check if user applied CAT. Set prio 1
			Clear. Prepare P3
3	Treat P3	User sets prio. Clicks next	Triage seive. Set prio 1
			Clear. Prepare P4
4	Treat P4	User clear airways. User sets prio. Clicks next	Check clear airways. Set prio 0
			Clear. Prepare P5
5	Treat P5	User clear airways. User sets prio. Clicks next	Check clear airways. Set prio 0
			Clear. Prepare P6
6	Treat P6	Applies real CAT. User sets prio. Clicks next	Check if user applied Real CAT. Set prio 1.
			Clear. Remove CAT
7	Receive score		Tell score

Test Equipments

- Paperwork
  - Informed Consent
  - System Usability Scale
  - NASA tlx
  - (No network) Participant test
  - Triage Sieve
  - Triage App intro
- 1x Hololens 1
- 1x Camera Tripod
- 1x GoPro Hero 7
- 1x Manikin
- 1x HeroSight App Kit (Markers, equipment)
- 1x Tradition Kit (Fake blood, equipment)
- (perhaps) 1x tablet
- 1x Instructor Laptop
- *x Blank A4 Paper for instructor
- 1x stopwatch
- 1x audio recorder

Test session workflow

Session Bulletin:

- Greet participant(1)
- Explain the tests and the reasoning for the tests(2)
- Have participant fill out Agreements(4)
- Have a simple intervjue about the participant and their knowledge of Tech, AR, Medicine(5)
- Inform that they are free to leave at any time. And warn them about gore…(1)
- (If needed) Perform the Basics of Triage Introduction(5)
- (IF AR) Perform the Traige App Introduction (How it works with the menu system)(3)
- Start recording equipment(0)
- (IF AR) Perform the Hololens Introduction(4)
- (IF AR) Perform the AR assisted test(15)
- Stop recording equipment(0)
- SUS and NASA tlx(3)
- Test questionnaires form(3)
- Start recording equipment(0)
- (IF Traditional) Perform the Traditional test(15)
- Stop recording equipment(0)
- SUS and NASA tlx(3)
- Start recording equipment(0)
- Debrief participant with intervjue(5)
- Stop recording equipment(0)
- Thank them for their time and explain future of the project(3)
- Kick out participant(0)
- Collect and store data(3)
- Prep next arrival(10)

(x) expected time in minutes

Below are a detailed instructions on important segments

Greeting script

None available

Agreement contract

Informed Consent

This is a user study as a part of a master thesis at Lund University and LTH. The study revolves around the learning quality of augmented reality within the medical field. This study consists of 2 tests, 3 questionnaires and 2 short interviews. The whole study will take approximately 60 minutes. We would like to ask you to participate in our study.

If you agree to take part in this study, you hereby affirm that you have been given the following information:

- I understand that all participation is voluntary and that I have the right to withdraw from the experiment at any time.
- I approve that the team can use data recorded, in presentation, publications and in other academic contexts.
- All data that is obtained will be kept confidential and anonymous
- If I wish I can receive information about the results of the study after the results have been obtained.

I, ______________________________________, understand the nature of this study and I agree to participate voluntarily. I give the researchers permission to use my data as part of their study and for test leaders to record video and audio data during the tests

Signature: ____

Date: __________________

Test leader signature:____

If you have any questions or wish to receive the results of the study, please contact any of the following:

Joakim Andersson, Project Leader - dic14jan@student.lu.se

Günter Alce, University Supervisor - gunter.alce@design.lth.se

doc - 2020-02-24

Informed consent form

Full resolution file located in another document.

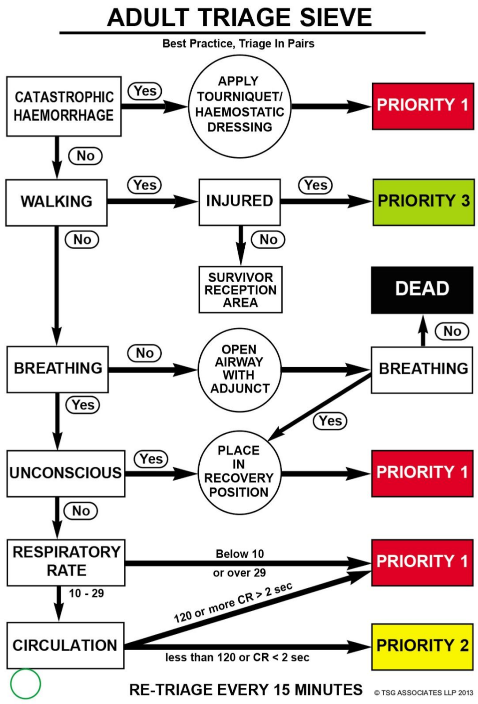
Intervjue script and Profile form

The goal of the intervjue is to profile the participants with their experience and knowledge of both medicine and technologies. They also get assigned an ID used for anonymous statistics during the testing. Important parts that need to be derived from the intervjue is the medical experience, and tech-abilities.

Participant profile	
ID	
Name	
Age	
Sex (visual), Eyewear	
Work title, details	
Medical experience (0-5)	
Tech abilities (0-5)	
VR knowledge (0-5)	
AR Hololens 1 knowledge (0-5)	

Basic traige script

Explain what is triage, how it's performed and show the participant the NATO traige seive and walk through each step of it. Explaining briefly.



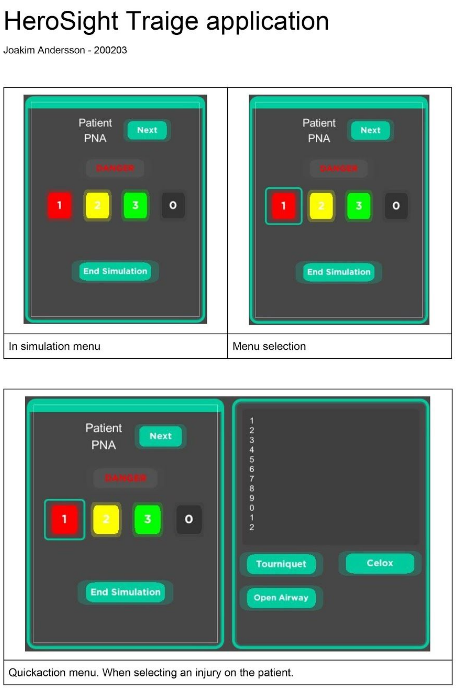
Triage Sieve

Hololens introduction script

Before the participant uses the Hololens tasks. The test leader starts the hololens introduction program on the Hololens, within the HeroSight traige application. The participant along with the test leader completes this tutorial.

App introduction script

A quick brief on how to prioritize patients with the application, and how to interact with its contents. Mainly go through the traige menu.


HeroSight Traige application

Joakim Andersson - 200203

In simulation menu | Menu selection

Quickaction menu. When selecting an injury on the patient.

App menu introduction

AR test

Patient	Injuries	Instructions
1	eX1_t2: RUpper Shrap, Chest Sharp	CH: No, Walk: No, Breathing: Yes, RR: 24 CR: 100 or <2
2	eX2_t1: RLower Leg Shin - Bleed, RUpper Leg Shrap. RLower Arm Shrap	CH: Yes, Walk: No, Breathing: Yes, RR: High CR: 130 or >2
3	eX3_t1: Chest StabKnife, LUpper stab	CH: No, Walk: No, Breathing: Yes, RR: High CR: 130 or >2
4	eX4_t0: Throat Glass, Chest Shrap, Stomach Blast, LUpper Arm Metal	CH: No, Walk: No, Breathing: No, RR: None CR: None
f5	eX5_t0: Head Bullet, Throat Cut, Chest Metal, LUpper arm Bullet, RLower Leg Shrap,	CH: No, Walk: No, Breathing: No, RR: None CR: None
6	eX6_t1: RUpper Leg Bone - Bleed, Stomach Blast, RLower Arm Shrap, RLower Leg metal	CH: Yes, Walk: No, Breathing: Yes, RR: High CR: 130 or >2

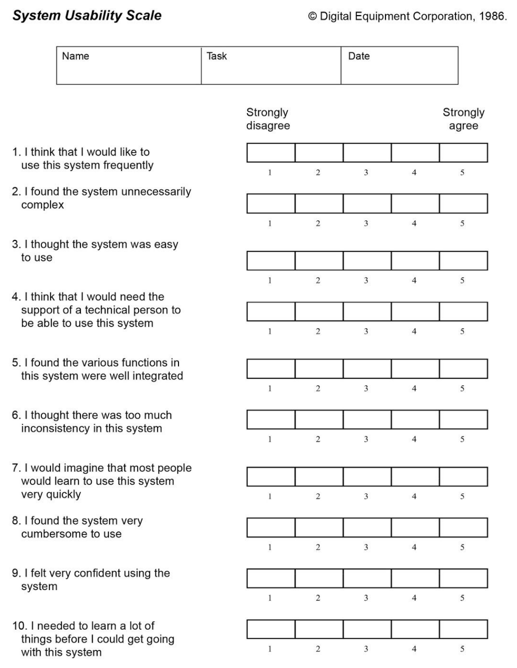
Traditional test

Patient	Injuries	Instructions
1	eX1_t2: RUpper Shrap, Chest Sharp	CH: No, Walk: No, Breathing: Yes, RR: 24 CR: 100 or <2
2	eX2_t1: RLower Leg Shin - Bleed, RUpper Leg Shrap. RLower Arm Shrap	CH: Yes, Walk: No, Breathing: Yes, RR: High CR: 130 or >2
3	eX3_t1: Chest StabKnife, LUpper stab	CH: No, Walk: No, Breathing: Yes, RR: High CR: 130 or >2
4	eX4_t0: Throat Glass, Chest Shrap, Stomach Blast, LUpper Arm Metal	CH: No, Walk: No, Breathing: No, RR: None CR: None
5	eX5_t0: Head Bullet, Throat Cut, Chest Metal, LUpper arm Bullet, RLower Leg Shrap,	CH: No, Walk: No, Breathing: No, RR: None CR: None
6	eX6_t1: RUpper Leg Bone - Bleed, Stomach Blast, RLower Arm Shrap, RLower Leg metal	CH: Yes, Walk: No, Breathing: Yes, RR: High CR: 130 or >2

Debrief script

- How did they think it went overall
- What did they think about the traditional test
    - Card system
    - Applying tools
- What did they think about the AR test
    - Overall
    - Sound
    - Inspections
    - Applying tools
- Did they like the Hololens
- Which did they prefer?
- How do they think the future of learning tools look like

Questionnaires

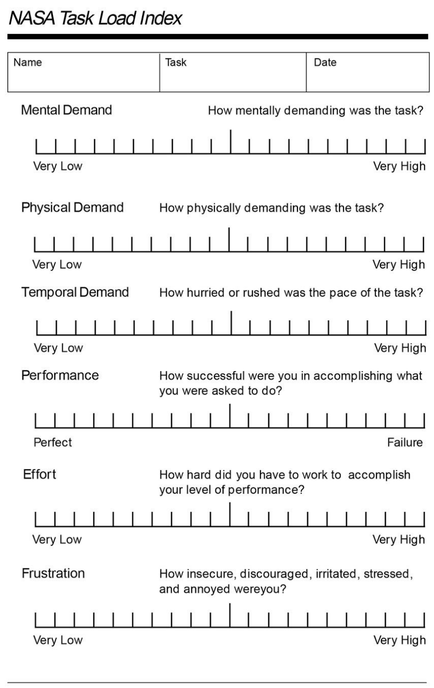


System Usability Scale © Digital Equipment Corporation, 1986.

Name	Task	Date

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

System Usability Scale



NASA Task Load Index

Name	Task	Date

Mental Demand — How mentally demanding was the task?
Very Low — Very High

Physical Demand — How physically demanding was the task?
Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?
Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?
Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?
Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?
Very Low — Very High

NASA tlx

Test form questions

1. S1 - You arrive at this accident scene. What is the first thing you look for at each patient at the scene?
2. S2 - This patient has a catastrophic bleeding from the right leg. How do you handle the patient and what prioritization would you give them?
3. S3 - At this scene a patient is unresponsive on the ground. The patient is not bleeding. The patient doesn't seem to breathe. How do you handle the patient and what prioritization would you give them?
4. S4.A - At this scene a patient is unresponsive on the ground. The patient is not bleeding. The patient breathing with a respiratory rate of 36. How do you handle the patient and what prioritization would you give them?
5. S4.B - Also at the scene is another patient. When you approach the patient you can see the following. Patient is lying still on the ground. There is many injuries but none of them are bleeding. How do you handle the patient and what prioritization would you give them? More info can be received by asking the test leader.

Full resolution files located in other documents.

Appendix C
Knowledge test

HeroSight test form

This form is used to test the systems learning capabilities and is not testing you, the user

This form will consists of x questions similar to the situation you just tested. The purpose of the form is to test the teaching capabilities of the system.

1. Participant ID

2. Date of testing

Example: 7 January 2019

HeroSight learning form

This form is used to test the systems learning capabilities and is not testing you, the user

Scenario 1

3. S1

You arrive at this accident scene. What is the first thing you look for at each patient at the scene?

HeroSight learning form	This form is used to test the systems learning capabilities and is not testing you, the user

Scenario 2

4. S2

This patient has a catastrophic bleeding from the right leg. How do you handle the patient and what prioritization would you give them?

HeroSight learning form	This form is used to test the systems learning capabilities and is not testing you, the user

Scenario 3

5. S3

At this scene a patient is unresponsive on the ground. The patient is not bleeding. The patient doesn't seem to breathe. How do you handle the patient and what prioritization would you give them?

HeroSight learning form

This form is used to test the systems learning capabilities and is not testing you, the user

Scenario 4

6. S4.A

At this scene a patient is unresponsive on the ground. The patient is not bleeding. The patient breathing with a respiratory rate of 36. How do you handle the patient and what prioritization would you give them?

7. S4.B (With test leader)

Also at the scene is another patient. When you approach the patient you can see the following. Patient is lying still on the ground. There is many injuries but none of them are bleeding. How do you handle the patient and what prioritization would you give them? More info can be received by asking the test leader.