CHALMERS

Immersive technology aided design operations

A virtual design studio at Volvo Cars Design

Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Department of Product- and Production Development
Division of Design & Human Factors

Master of Science Thesis

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Abstract

The study shows that with rapid development of immersive technology the gap between the real and the virtual world is closing in. For Volvo Cars Design that is dependant on reliable digital car prototyping techniques, the use of immersive technology shows great potential for being integrated in the design operations. The study shows that the activities with digital prototypes at Volvo Cars Design evolve around three use cases: to create, to evaluate and to collaborate. With future immersive technology, an alternative reality can be utilized for all these use cases with the opportunity to influence how employees at Volvo Cars Design interact with digital prototypes.

Despite the excessive cost of physical clay prototyping, clay models are still being used. The main reason is because they out preform digital prototypes in revealing possible bottlenecks of the designs and are experiences as important for improving innovation and collaboration. During the study the missing piece for making digital prototypes suitable as final decision support was explored. The user studies and literature studies made for this project shows that the missing piece for evaluation of digital prototypes is a body in virtual reality. Being present in an alternative reality without a virtual body impacts the cognitive performance of that individual because of embodied cognition. Therefor virtual embodiment is key for successful design evaluation with immersive technology.

The report provides examples of how to implement a virtual body in the vision for a virtual design studio. The vision of the virtual design studio also demonstrates how the an alternative reality can be used as a platform for creative and collaborative work between employees located in the different design studios of Volvo Cars Design.

The report suggests that not all things that are possible to do with immersive technology have a pragmatic value to the design process. The trade off between accessibility and immersion will have an affect on the solutions of the future. The immersive technology should not be viewed upon as replacing the real reality, but as a powerful communication platform that can provide new perspectives of the real world. Having this in mind will allow the use of immersive technology to focus on what it is best capable of achieving.

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01

Introduction

1.1 Background

The Volvo Cars Design department is dependant on collaborative design work of multidisciplinary teams across continents, with design studios based in Shanghai, Los Angeles and Gothenburg. At the different locations of the design studios, Volvo Cars is running projects that involve employees with diverse background, skills and work duties.

Visualization is a key function of the design operations at Volvo Cars Design, and the use of digital prototyping is integrated throughout the development process from reviewing early design proposals to creating marketing material for the launch of new products. Using digital resources offers benefits such as a decreased product development cost, as well as the opportunity for design teams to share work of projects without being at the same location.

Digital prototypes are becoming increasingly important for the design process; as they become more and more immersive and can better serve as design decision support. The gap between the real and virtual world is closing in, which entails the possibility to abandon or at least reduce the use of costly physical models, as well as finding alternative ways of utilizing digital prototyping. However, clay modelling that is a well-established prototyping technique in the automotive industry, still functions as important means to communicate and experiences product concepts.

Integrating immersive technology into the design operations has been done in the automotive industry for years, by using stereoscopic displays and Cave Automatic Virtual Environment

(CAVE). New available products on the market have put the technology under the microscope for large corporations as Volvo Cars that wants to be in the forefront of innovation. Immersive technology has become more accessible with the releases of virtual reality devices such as the HTC Vive, and mixed reality devices such as the Microsoft Hololens. Immersive technology is expected to take an even more important role in the future of design and the rapid development will uncover new potential use cases.

1.2 Project task

1.2.1 Objective

The purpose of the study is to investigate potential use cases of immersive technology in the design process of Volvo Cars Design.

The common perception in the automotive industry is that there still are aspects where immersive technology is not sufficiently replacing the physical clay prototypes, and the purpose of the study is to identify these aspects. Moreover it will investigate the explicit possibilities that immersive technology can enable for digital prototyping.

The study will identify when, how and to what purpose prototyping is used at Volvo Cars Design. Furthermore it will clarify the experienced benefits and disadvantages of using physical and digital prototypes. Here the effect on the individual perception of a product concept and the communication prototypes breeds within a group will be studied.

After conducting the study the aim is to create an approach to immersive prototyping in a product development context. A solution will be created that will strive to translates the benefits of physical prototypes to the digital context, as well as implementing the exclusive opportunities of virtual reality prototyping.

1.2.2 Scope

Research will be made in the context and perspective of Volvo Cars Design and the user studies will primarily concern the employees of Volvo Cars Design and the automotive industry in general. However, the result may be of interest for other product development branches.

1.2.3 Delimitations

The study will focus on the early stages of the product development process, connected to the operations at Volvo Cars Design, and will therefore not study e.g. ergonomic or manufacturing operations also connected to product development. The result from the study will primarily be stated as qualitative data that will be further used to analyse how immersive technology prototyping should be utilized. Due to the timeframe of the project the solution will not be an implemented system, but a concept that explains the functions of the developed solution.

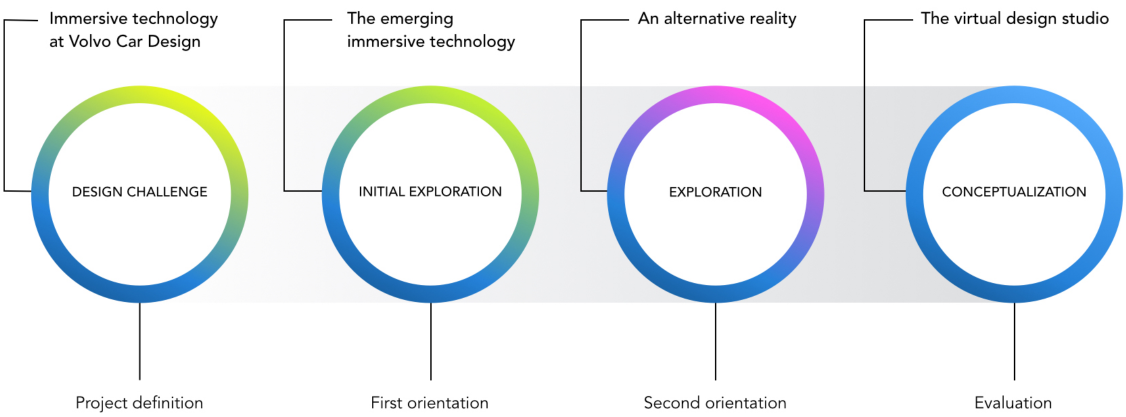
02

Process

Due to the complexity and unknown factors of the future as well as the uncertain pragmatic use of immersive technology in design operations, an explorative approach was chosen for this project. Important insights from the studies were used to help to guide the direction of the project. The project was structured around two phases; the exploration and the creation phase (figure 1).

The exploration was divided into two parts, where the first exploration aimed to explore the emerging immersive technology and the design process at Volvo Cars Design. The first part was followed by an orientation phase that aimed to point out a direction for the second exploration part of the project. The second part of the exploration aimed to give a more thorough understanding of the immersive technology user experience, in order to distinguish the possibility for use in daily operations at Volvo Cars Design. The second part of the exploration was followed by a second orientation phase that gave a direction for the creation phase and remaining part or the project. Each phase involved of a number of activities, methods and tools, which will be described in the following section.

Figure 1
Project process



2.1 Initial exploration phase

In the first phase of the project different aspects of the emerging immersive technology was investigated. Benchmarking of software and devices available on the market was made to learn more about the technology and to give insight of what will be available in the future.

In order to create a solution that corresponds to the daily activities at Volvo Cars Design, a study of the design operations and design process at Volvo Cars Design was made. Information was gained through interviews and a survey with the people responsible for implementing and developing the design processes. The goal was to identify the stages of the design process and learn about how concepts are produced, as well as when and how design decisions are taken.

Further the study investigated the role of the immersive technology operations implemented in the design process at Volvo Cars Design. The study aimed to identify what was regarded as the benefits of using the techniques of immersive technology, as well as the limitations. The insights were collected from interviewing the employees responsible for the implementation and development of the immersive design operations, as well as the individuals that use the immersive experience as support for making design decisions.

A SWOT analysis was conducted to learn about the prospect for implementing immersive technology into the design operations at Volvo Cars Design.

2.2 First orientation phase

During the first orientation phase the insights collected from the first part of the exploration was used to guide the course of the project. The insights were used to choose use cases of immersive technology to be studied in the next part of the exploration phase.

2.3 Further exploration

During the further exploration phase a literature study was made to learn about the principles and possibilities that exist for designing a system for the immersive environment.

From knowledge gained from the literature study, the use cases that were chosen in the first orientation phase where studied. This was conducted by user studies made at Volvo Cars Design, corresponding to the activities of the use cases for immersive technology.

2.4 Second orientation phase

The second orientation phase aimed to give a direction for the creation phase and remaining part of the project. The insights from the exploration phase were compiled into requirements for the concept solution made in the creation phase.

2.5 Creation phase

From the knowledge gained throughout the study conceptual solutions were created to represent the vision of how Volvo Cars could integrate immersive technology as a tool in the design process. The concepts were first made from constructing personas, idea sketching with pen and paper, and then moved prototypes built for the virtual environment.

The emerging immersive technology

03

Immersive technology

3.1 Different immersive technologies

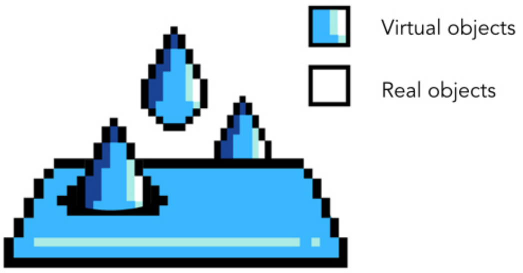
Immersive technologies offer the sensation of taking part in a simulated universe that can be a representation of the real reality or take the form of a fictive world. The terminology for immersive technology can be somewhat tongue twisting, and is not always used in a consistent way. This project will divide the immersive technologies into the areas virtual reality (VR) and mixed reality (MR).

To use computer generated virtual objects that allows the perceiver to feel present in an altered reality or an alternative reality, is common for the different areas of immersive technology. The visual content of an immersive experience is in the centre of the experience, however it can also involve the stimulation of the other sense.

Figure 2 gives an overview of two different approaches to immersive technology that were identified in the initial exploration phase of this project: an altered reality and an alternative reality.

Figure 2
Two approaches to immersive technology

ALTERNATIVE REALITY



ALTERNATIVE REALITY

TECHNOLOGY

Virtual reality
Mixed reality

EXPERIENCE

Total immersion
Divert from reality
No input/distractions from the surrounding
Possibility to control the environment

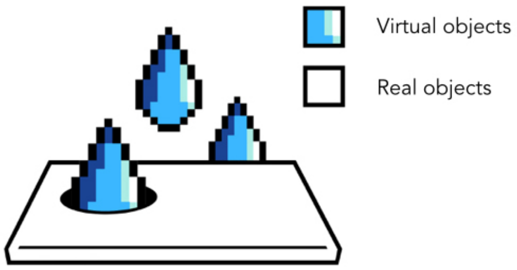
INTERACTION

Hinders user to interact with the surroundings
Interaction with virtual objects possible
Interaction with digital representations of physical objects

USE CASES

Role-play and storytelling
Emotionally captivating experiences
Context based on content
Explore alternative/unavailable environment

ALTERED REALITY



ALTERED REALITY

TECHNOLOGY

Augmented reality
Mixed reality

EXPERIENCE

Total integration
Enhance reality
Input/distractions from the surrounding
Possibility to manipulate the real environment

INTERACTION

User is not cut off from the surrounding
Allows the user to keep an eye of their surroundings
Interaction with the virtual and real world is possible
Virtual objects are anchored to the real world

USE CASES

Daily practical activities
Pragmatic use to see the unseen of real environments
Context tied to the surroundings
Enhance/improve the surrounding

3.2 Virtual reality

3.2.1 The basics

Virtual reality (VR) is an immersive technology that produces computer-generated environments that can be interacted with in a realistic and familiar way. The interaction is made possible by special electronic equipment, such as the head-mounted display (HMD) that delivers an image of a digital environment in front of the eyes of the person immersing the experience.

To create the immersive experience the virtual reality content is sent from a console or a computer to the head-mounted display. For mobile virtual reality devices the smartphone is slotted into a headset, and is used to both produce and display the image.

A pair of lenses is placed between the eyes of the user and the display, with the function to reshape the 2D images into stereoscopic 3D images that are aligned to mimic the way each eye views the real world. Sensors positioned on the HMD or on additional device track the movement of the user, which enables the perceiver to experience the virtual reality in real time.

Stereopsis can also be achieved by using stereo displays that creates the perception of depth in an image. The stereo display shows a merged image of two images, one intended for each eye. Using 3D glasses will filter the correct image to the left and right eye and divide the merged image of the stereo display. CAVE installations, commonly used in the automotive industry, project stereo image onto walls and use tracking sensors positioned on the 3D glasses to enable the user to turn their head and look around a virtual environment.

3.2.2 The Device

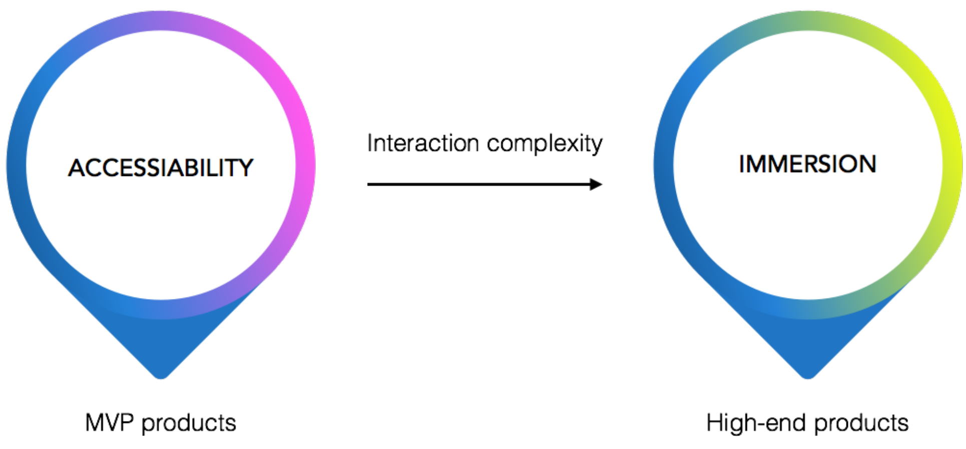
There is no standard platform yet, since developers are still trying to figure out what virtual reality is rather than finding the standards. On todays market there are two categories of products. The first is the minimum viable products (MVP) that are using the most reliable technology that is available for a majority of people, such as the Google Cardboard that uses the smartphone to amplify it into a virtual reality device. The other category it the high end products, such as the HTC Vive currently used by Volvo Cars Design.

The MVP platform is basically a shell with lenses where you place a smartphone inside. The two lenses of the headset separate the smartphone screen into one image for each eye. The benefits of mobile devices are low cost price making them accessible to a larger crowd, flexibility of no wire connected and the lightweight construction. However, mobile headsets available on the market have low performance compared to PC and game console devices.

The high-end platforms are threaded and connected with a wire to a computer or game console, which makes them a bit unwieldy. The threaded platform can offer a much more immersive experience, but has the disadvantages of being expensive and needs a powerful machine for processing. During the spring 2017 an add-on accessory to the high-end platform HCT Vive will be launched, that will enable the device to function wirelessly (Crecente, B. (2017).

The degree of immersion of the devices available on the market correlates to the accessibility and interaction complexity. High interaction complexity can achieve a high degree of immersion, but with available technology the device will be less accessible to the user. The high-end devices offer high interaction complexity, but are expensive and need to be connected to powerful computers. The mobile devices are more affordable and unthreaded, making them more accessible, but can only offer less level of immersion (figure 3).

Figure 3
Immersion and accessibility trade-off



3.3 Mixed Reality

3.3.1 The basics

Mixed reality (MR) merges the physical and virtual environment, allowing virtual objects to interact and coexist in real time with physical objects. In mixed reality virtual objects are anchored to a position in the real world. The integration of the virtual objects to the real world is important for the immersion of the mixed reality experience (figure 4).

Mixed reality can be made by a variety of techniques, stretching from advanced technology with computer vision that tracks and anchor virtual objects in the real world, to hologram displays and large projector installations. This implies that mixed reality can be created with different approaches.

One technique is based on the virtual reality HMD with additional camera sensors that capture an image of the real reality. The image can be used to both display the real world inside the HMD and with computer vision techniques also anchor virtual objects to the real reality image.

Another technique for mixed reality is to use transparent lenses in front of the eyes that allow the user to see the real world through a glass plate, such as the Microsoft Hololens. This differs from the first approach since there is no need to pixelate the whole image. The images of virtual objects are projected from a micro display through a stereoscopic lens and then on the transparent glass plate, which creates the perception that the virtual objects co-exist with the real world. Limitations with current devices that use this approach are that objects will appear transparent to some degree and the field of view is restricted to a square in the centre of the field of vision.

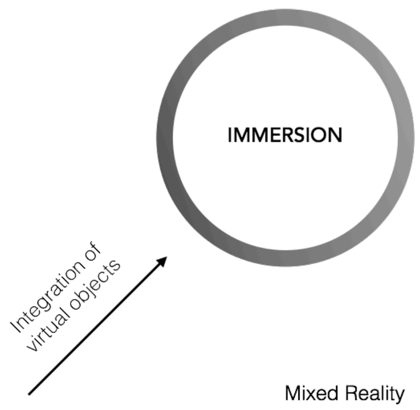


Figure 4
Immersion with integration of virtual objects in MR

3.3.2 The device

The platforms for mixed reality are still in much of a prototype stage or have recently been launched for developers and enterprises. The Microsoft Hololens is available to developers and enterprises, and Volvo Cars is one of the organisations that have been in association with the Microsoft Hololens project. The Hololens is a device that showcases the potential of mixed reality, but it still is a bit unwieldy to wear, has a limited field of view and comes with an expensive price tag (figure 5).

Figure 5
Microsoft Hololens

Magic Leap develops a mixed reality device not yet revealed to the market, which uses digital light field displays. The digital light field signals blends with the signals from the physical environment, so that the technology allows the brain to process the virtual images in the same natural way it would process an image of the real reality.

3.4 Level of freedom

Orientation and position tracking inputs are used in order to adapt the field of view in the virtual environment. There are two common levels of freedom in this context, the three-degrees of freedom and the six-degrees of freedom (figure 6).

Smartphone virtual reality platforms on the market are based on three-degrees of freedom (3 DFO), where rotations on the tree axels are tracked from an embedded gyroscope inside the smartphone. High-end platforms achieve six-degrees of freedom (6 DOF) by components that track the position in space and allow the user to walk around in the virtual environment. For positioning tracking the HTC Vive uses infrared diodes on the HMD that detects light signals form infrared light sources that are positioned in the room.

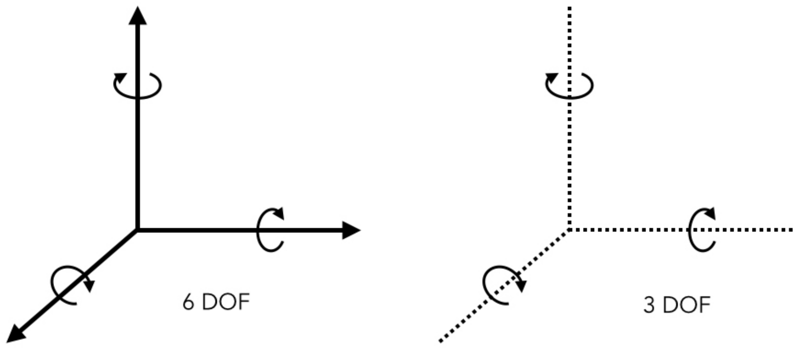


Figure 6
Degrees of freedom

3.5 Tracking motion

For current virtual reality devices the range of space is limited to the size of the physical environment, but also to the space that the tracking system is capable of mapping. This is due to that the tracking system has components stationary placed in the room, such as the Vive Lighthouse. These tracking systems are referred to as using outside-in tracking.

Mixed reality devices such as the Microsoft Hololens have the full tracking system embedded in the head mounted display, and allows for the user to walk around without spatial boundaries. Such tracking system is referred to as an inside-out tracking system.

To track objects or users in the real world in order to integrate them to the virtual environment, different technical methods can be used. The tracking systems are either based on optical tracking, that rely on camera sensors and computer vision. Optical tracking is used for the Microsoft Hololens. None-optical tracking systems, based on non-optical sensors such as accelerometers, gyroscopes and infrared diodes, are used in the tracking system for the HTC Vive.

3.6 Applications and use cases

3.6.1 Product development

Using virtual reality in product development includes the use of 3D modelling tools and visualization techniques as part of the design process. Reviewing 3D models of product concepts enables engineers and designers to spot flaws or potential risks for implementation. For this purpose it is important that the virtual reality can represent fine details of the product to maintain the illusion.

The Autodesk VRED software supports virtual reality for reviewing variants and making simple animations of product design. Autodesk VRED is the software currently used by the Visualization and IT unit at Volvo Cars Design to create virtual reality content.

3.6.2 Creative tool

Creating in the virtual space offers new possibilities as a platform for making digital content. Virtual reality sketching applications available have become a popular tool among artists and game designers.

Figure 7
Nissan Micra Tiltbrush advert

The most celebrated creative application is the Google TiltBrush. TiltBrush allows the user to create paintings in space, by using a range of different dynamic brushes. Nissan used TiltBrush in an advert for Nissan Micra, staring the artist Stephen Wiltshire, who used TiltBrush to draw the signature curves of the car in the virtual environment (figure 7).

Medium is a sculpting application for solid modelling. Artist Goro Fujita explains his experience working with Medium:

"In a way it's even more intuitive than sculpting with real clay. Being able to grab your model, scale it to the size you like for adding details all the way to spray painting it by grabbing the model with one hand and spraying with the other is just something you weren't able to do before. It's a truly magical experience and removes almost all the technical barriers that traditional software packages have and it lets you focus on what you want to create." (Nafarrete, J 2016)

3.6.3 Workspace

Using virtual reality for daily workspace is made possible by applications such as Virtual desktops. A virtual reality desktop is an application that allows the user to review a representation of their computer desktop in virtual reality. Many applications support working with multiple monitors. The virtual context is based on a 360° image environment and a curved projection of the otherwise flat monitor display. The virtual reality desktop is primarily used to launch other applications when wearing the HMD. These applications allow the user to browser through information on the computer and on the web.

In mixed reality demos, that showcases potential use cases of the device, workspace use is frequently seen. In these demos virtual desktops replace multiple physical screens in the office space.

3.6.4 Marketing

Marketers are finding ways of how to best utilize the virtual reality technology to achieve brand objectives. In marketing virtual reality is used to demonstrate product attributes, features and functionality as well as to communicate the values and mission of the brand. It can be used to help customers choose the right products before purchasing.

The IKEA VR Experience allows for costumers to enter an IKEA kitchen and change the appearance of the room. Customers can also walk around the kitchen and interact with virtual objects, such as the fridge and frying pan.

Volvo Cars has also used virtual reality experiences for marketing, such as the XC90 VR experience allowing the customer to test drive the XC90, and the 360 live video launch of the new XC60.

3.6.5 Entertainment

Virtual reality is well adapted within the gaming community, and gamers have been the primary target group for developing the available platforms on the market. The growing numbers of game titles are for both the high-end devices and mobile devices.

The lab is a virtual arcade game world. The Long Bow game is a very much appreciated experience, where the HTC Vive hand controls give vibration feedback when tensioning the bow to shot arrows at targets.

In traditional virtual reality, touching anything in the real world surrounding would break the illusion. The Void is a so-called hyper reality facility that merges state of the art virtual reality technology with real world physicality. Everything in the virtual world has a real world counterpart, such as physical walls and real world peripherals to intensify the tactility. In the Void two people can enter the same experience at the same location and interact with each other within the real and virtual space (figure 8).

Figure 8
A hyper reality in the Void

Mixed reality game demos with the Hololens shows building virtual Minecraft worlds in the living room space are other examples of entertainment use of immersive technology.

3.6.6 Film

Filmmakers are starting to embrace virtual reality as a tool for storytelling. Storytelling in virtual reality is very different from storytelling in regular film, since the perceiver is part of the story.

Mixed reality and storytelling is illustrated in the Magic Leap collaboration with Lucasfilm that in a demo shows two Star Wars drones interact with each other and the Magic Leap office (figure 9).

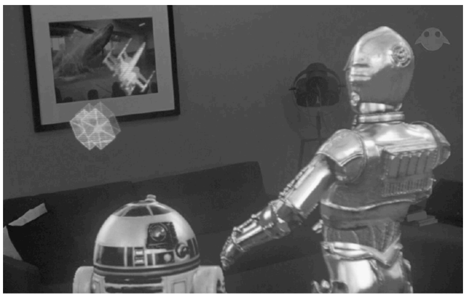


Figure 9
Lucasfilm and Magic Leap collaboration

3.6.7 Education

Education has adopted virtual reality for teaching and learning situations. The virtual reality device can present complex data in an accessible way that can be both fun and easy to learn. In virtual reality the students can interact with objects to learn more about them.

Lifeliqe VR Museum is a science education application for children. The Lifeliqe developers argue that using virtual reality for education enables more effective learning and deeper understanding of scientific knowledge. Using interactive 3D content for learning is said to be more effective than traditional textbooks and 2D recourses. Lifeliqe's studies show that students can improve engagement in their studies, with longer attention span and higher test scores (Lifeliqe, 2017).

3.6.8 Social Networking

As people spend more and more time interacting in virtual worlds, the question of how virtual reality will effect social interactions has emerged. The influence virtual reality and mixed reality will have in social networking and social media is uncertain.

A glimpse of what to expect in the future is illustrated in the Facebook Social demo (figure 10). Facebook presented the Facebook virtual reality social application, which is a virtual meeting room where people can socially interact. In the experience each participant is represented with an avatar that can make facial expressions and eye contact.

Figure 10
Facebook social VR demo

Mixed reality and social interactions is made possible with the Microsoft Hololens that supports Skype calls.

3.7 The future of immersive technology

There has been a lot of buzz recently around immersive technology and its potentials as a hardware and software platform. A variety of reports forecast an exponential growth of sales for the next few years.

”All the major players—Facebook, Google, Apple, Amazon, Microsoft, Sony, Samsung—have whole groups dedicated to artificial reality, and they’re hiring more engineers daily. Facebook alone has over 400 people working on VR.” (Kelly, K. 2016)

2016 was the year when virtual reality headsets were launched, and a variety of accessories for virtual reality are hitting the market. In 2017 the release of augmented reality devices are expected.

Magic Leap, a company that has not revealed any of their inventions to the world, landed a huge funding from investors Google and Alibaba. Many believe that Magic Leap’s technology, along with a handful of competing products, will change how we use computers (Kelly, K. 2016).

The interest in immersive technology from major players on the market hints a paradigm shift and the prospect for a change in the way we interact with digital environments. Up until now much focus for developers has been to develop the hardware of the platforms. For now the technology is being introduced to the market, and has shown a lot of potential for a variety of user cases. The next step for the industry is to go beyond demos and develop useful applications for these different user cases, as well as adapting the hardware to specific requirements based on the range of users.

If the introduction of immersive technology devices is compared to computers, mobile phones and CDs, these technologies it took about 15 years to adapt to corporations and the society (Alger, M. 2015) (figure 11).

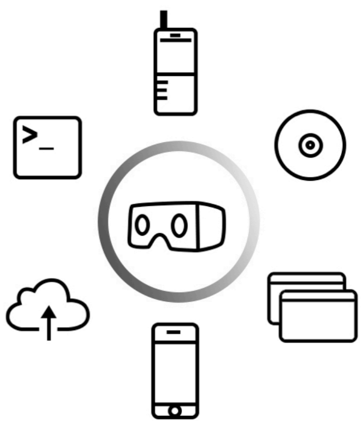


Figure 11
Adoption to technology

When the first computer was introduced the computer interface was basically a terminal, and now it has highly interactive interfaces with motion graphics and tools that enables users without excessive knowledge to use computer software. The mobile phone has developed into a smartphone that users bring everywhere in their daily life, allowing for inputs from touch and gestures. The CD gave users the opportunity to share and store data. Technology has come a long way, and today online cloud-based services are used to efficiently work with the same data.

Assuming a similar development for the immersive technology, suggests that only the tip of the iceberg for the potential of immersive technology has yet been discovered.

3.8 Insights and implications

The trends of the future indicate that only a small part of the potential of immersive technology has been discovered. This implies that the next few years will be of great importance for corporations and society to adopt and find utilized use for the immersive technology. If this estimation is true, earning experience and competence in the field will be necessary for large corporations as Volvo Cars in order to be a player on the competitive automotive market.

Many of the use cases of current immersive technology could be of interest for the operations at Volvo Cars Design. With current devices there is a trade off between accessibility and immersion. As for today using the high end immersive technology requires resources in both competence of the user and powerful machines. The mobile devices are easy to use, but cannot deliver the high level of immersion that is necessary for many of the described use cases. Likely the form factor of the immersive technology devices of the future will better suit the context of a design studio. Until then, a decision about when to favour accessibility or immersion needs to be made for all implementation of the technology in the design operation.

Today the two different approaches of immersive technology are not separated although they have fundamental differences. For now mixed reality and augmented reality can offer an experience that alters the real reality. Virtual reality and mixed reality can offer an experience of an alternative reality. In the future the use of these two approaches will likely correspond to their explicit possibilities.

3.9 Conclusion

The impact immersive technology will have on product design is uncertain, but the study indicates that it will be integrated in to many activities in the product design process. This points out the importance for Volvo Cars Design to act now, in earning competence and understanding of how immersive technology will affect the design process of the future.

04

Volvo Cars Design and immersive technology

4.1 Purpose and aim

This part of the exploration aimed to understand the operations at Volvo Cars Design and how the operations currently are connected to the use of immersive technology. The explorative study also aimed to briefly investigate the future of automotive design.

4.2 Method

The information for this study was collected from unstructured interviewers with employees of different professions at Volvo Cars Design, which were conducted throughout the study. Observations of daily activities at Volvo Cars Design were also done to learn about communication and the role of prototypes for the design process.

To gain further knowledge a survey about the design process, prototyping and communication was conducted. This was sent out via mail to all employees at the Volvo Cars Design department, and had 41 participants from a variety of professional roles.

Benchmarking was made to study the automotive industry and the future of automotive design. Finally a SWOT analysis was made to investigate the prospect for implementing immersive technology into design operations.

4.3 The Volvo Cars design process

At the Volvo Cars design department there are different divisions with various responsibilities. The divisions consist of employees that are surface modellers, visualisation artists, interior and exterior car designers, interaction designers, studio engineers and managers. The employees are assigned to teams and groups of individuals with team leaders, project leaders and managers that ensure the quality of the work.

Figure 12
Volvo Cars Design Employees

4.3.1 Designing the car

A range of different car projects is operated at the design department, that consider the development of concept cars and new car models, but also so-called face lifts of currently manufactured cars. The car projects follow a process where specified deliverables are met at different stages.

Early in a design process the car project consider the design proposals of different designers. Prototypes for evaluation such as sketches, low refined polygon models and if motivated clay models are made for each of these designs.

In the next phase one of the designs is chosen for further development. When this is done more refined surface models and clay models are made. The design is assigned different trim levels, with a set of colour and material, as well as interior and exterior details levels.

When the car project has entered this phase, the designers will work in close collaboration with the engineers to ensure the design will be manufactured and developed correctly. There is an on-going discussion between the designers and engineers that often consider the production cost of the car. The designers and engineers continuously work with cutting the cost without compromising the quality of the design. For communication and making design decisions the digital and physical prototypes are necessary support.

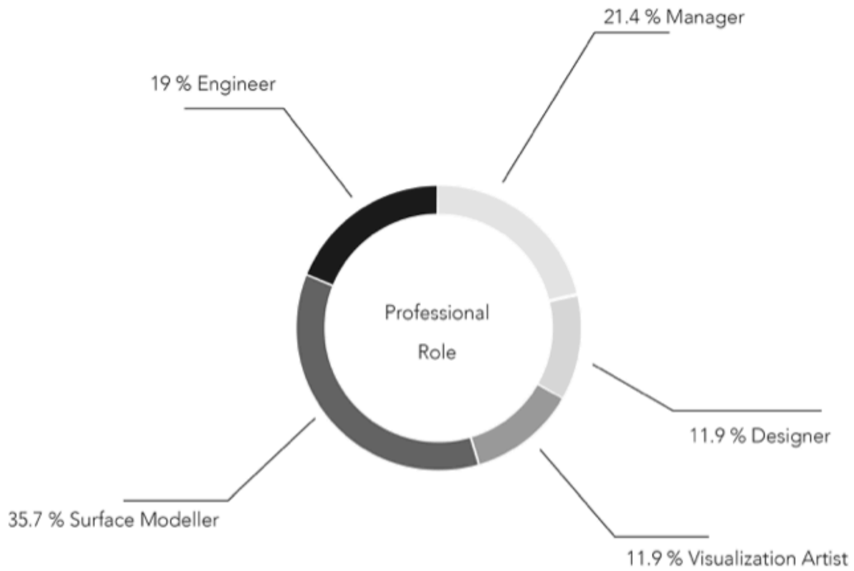


Figure 13
Professions taking part in the survey

4.3.2 Design presentations for evaluation

Figure 13 illustrates the different professional roles that participated in the survey made at Volvo Cars Design. The survey shows that the majority of employees attend design presentations on a weekly basis (figure 14).

Figure 14
Attending design presentations

The experience of the presentations differs for the employees, but common for most employees is the wish for more efficient and less time consuming presentations. Some of the employees experience the presentations as improvised, and wish they would be more prepared. The majority of employees appreciates that the presentations are organized and wish to keep it this way. They also express that the presentation should be more rewarding, less hierarchic and with more open discussion than they currently are (figure 15).

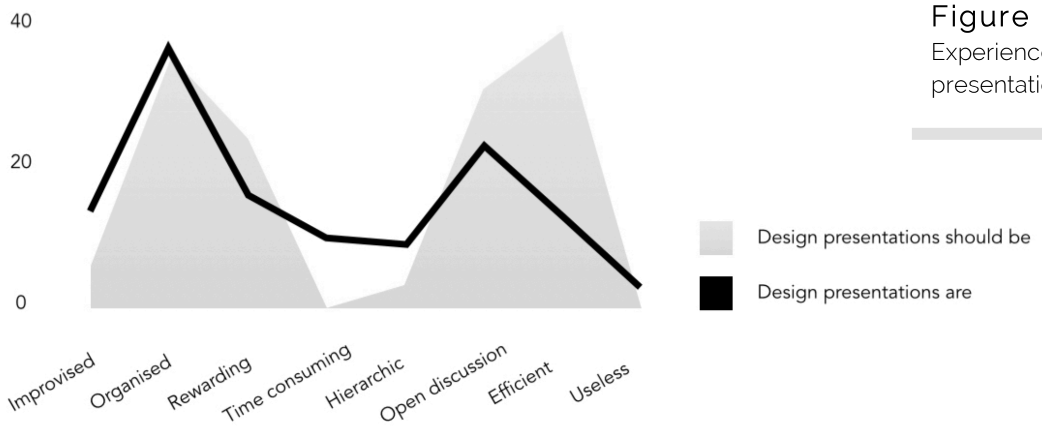


Figure 15
Experience of design presentations

The design weekly meeting is one of the recurrent presentations held at the Volvo Cars Design department. During design weekly meetings the design team presents their design proposal to the head of interior or exterior design, depending on who is concerned, as well as the head of design of the department. During the presentation the design team presents rendered images, animations and real-time presentations of the surface model, and a physical clay model if it has been made. This meeting is an opportunity to discuss the progress of the project and reviewing specific design features.

The design board is another recurrent meeting, were important stakeholders outside the design department are invited to review design proposals. Observations made during a design board showed that for the employees of the design department it was important that the presentation was perfect.

Before the visitors arrived to the showroom, a large warehouse like facility where the presentation was held, the atmosphere was tense among the designers and managers. An employee that attended the presentation as technical support expressed that the design team wants to avoid things going wrong during these presentations, and made sure to speak to all individuals that were to present material, so that the correct material was available on the computer desktop to quickly be able to switch between PowerPoint presentations and real-time presentations in Autodesk VRED.

"The designers don't like it when the presentation is interrupted if I have to minimize a program and show the desktop to enter another application." – Visualisation artist at Volvo Cars Design

When the visitors arrived they were first presented a full-scale exterior clay model, accompanied by pictures and sketches of the car design. Afterwards the visitors sat down in the VR room, a dark cinema room with two large projector screens. The head of design and head of exterior design continued to present the exterior of the car on the projection screen. Technical aspects and aerodynamics of the design where brought up, while pointing and making gestures towards the projected image. During the presentation the audience made interruptions to ask questions of how a certain form achieved a specific semantic expression.

Before finishing the exterior presentation a real-time visualisation in an environment outside the Volvo Cars design office was presented. The participants discussed engineering aspects of the design regarding the size of the car, and possible solutions of how components could be placed. The discussion continued while the head of the design department started to glance at his arm watch, probably concerned about not having time for everything on the agenda.

After presenting the exterior of the car, the head of interior design presented the interior of the car on the projection screen. To explain form and function graphical elements had been placed as overlay on the rendered images of the car.

Next the interior clay model was revealed from under a fabric drapery. A video was projected on the screen in front of the interior model to create an impression that the car was driving on a road in a city. A design manager stood next to the clay model to demonstrate a sensors camera angle with her hands.

After the presentation the visitors were very interested in the clay model and stood up to form a circle around the model. Some leaned towards the model while openly discussing the features of the interior, others sat down in the seat of prototype. When the presentation was summarized the participants were spread out and openly talking about the design proposal.

4.3.3 Communication and collaboration

The survey showed that the most commonly used channels for design communication at Volvo Cars Design are mail and unofficial meetings. Unofficial meetings are possible at Volvo Cars Design since the office has an open layout were it is easy to get together to discuss matters in the common spaces or at a work station. Mail is commonly used at the design department to share links on the intranet to access deliverables or material in progress, as well as to schedule and call for meetings (figure 16).

Most employees use mail and unofficial meetings on a daily basis, and attend scheduled meetings daily or weekly. Meetings are held in any of the meeting rooms, in the VR room, the showroom or the clay model studio.

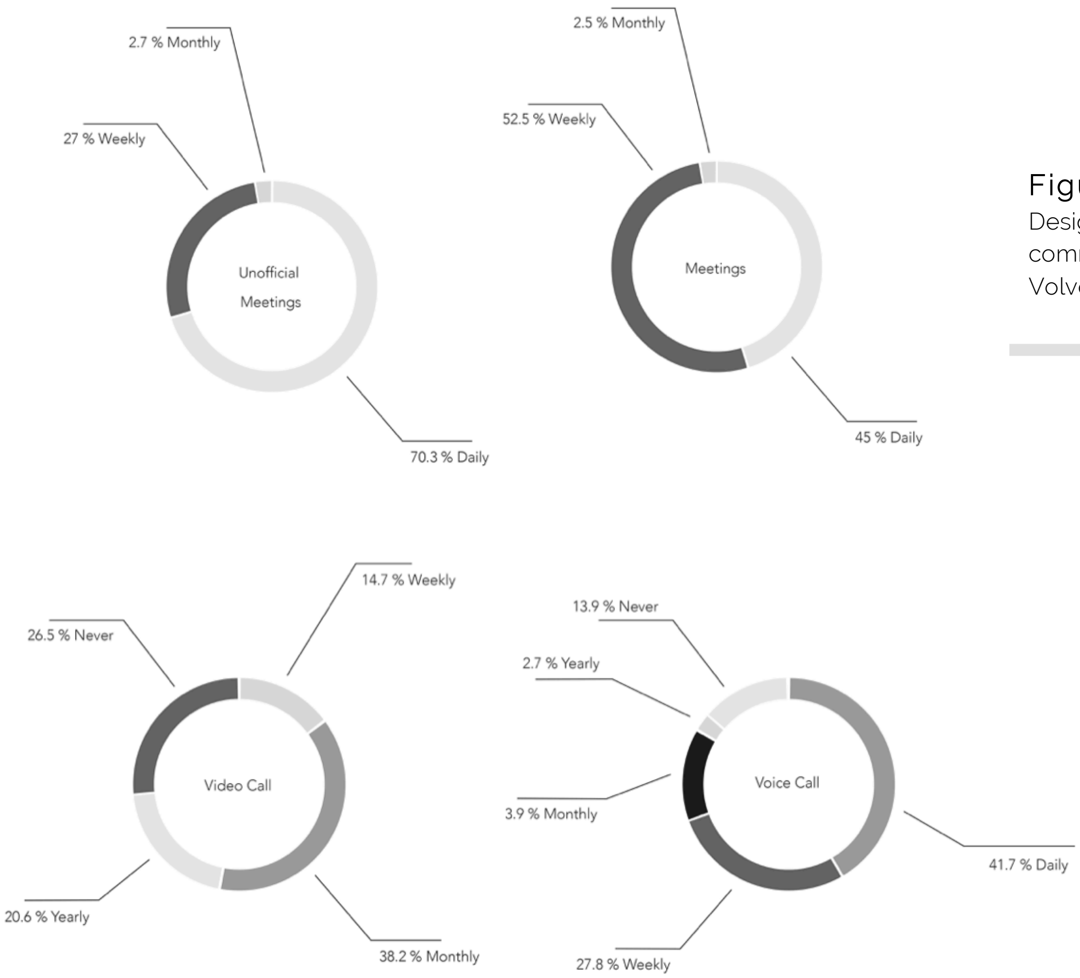
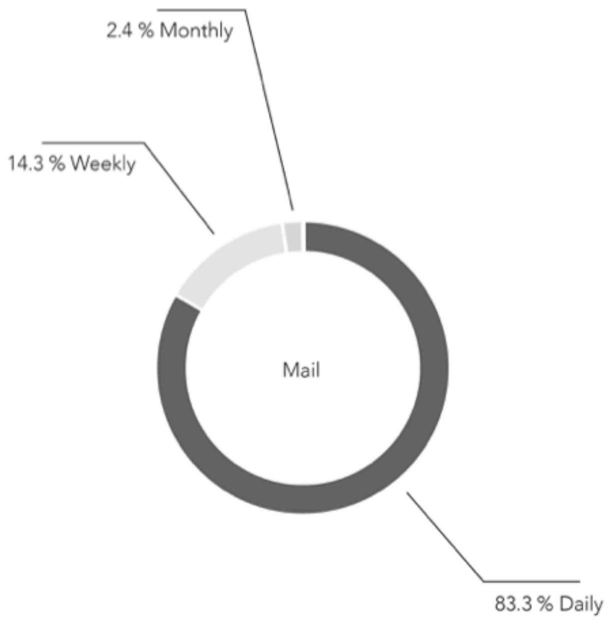


Figure 16
Design communication at Volvo Cars Design



The majority of the employees use voice call daily or weekly. All Volvo employees have a smartphone dedicated for work. Most employees do not use video call, however some use it regularly as a channel for communication.

The general opinion of how well the design communication is done at Volvo Cars Design is that it is average or good. This indicates there could be an improvement in how employees can connect around design work (figure 17).

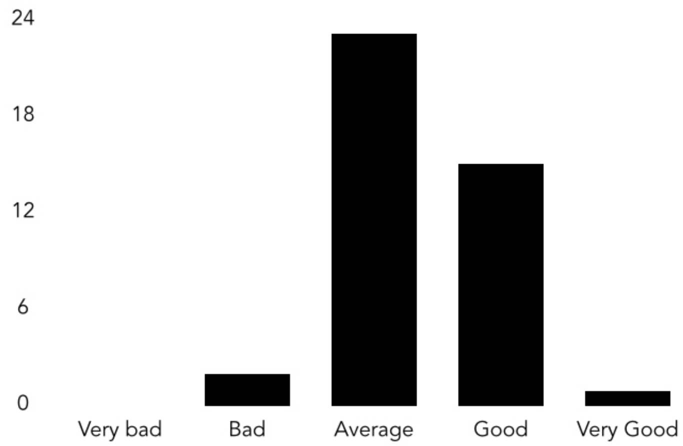


Figure 17
Impression of the design communication

4.4 Automotive prototyping

4.4.1 Level of abstraction

The survey, interviews and observations made for this study indicates that prototypes of different level of abstraction are important for the design process. Prototypes with high abstraction, such as inspiration material, samples and sketches are used early in the design process for generating ideas of the design. In a later stage of the design process more concrete prototypes are used, such as real time presentation of digital prototypes and clay prototypes. Abstract prototypes, such as sketches and rendered pictures, also serve as support for presentations when the concrete prototypes are reviewed.

4.4.2 Digital prototyping

The digital prototypes for each car project are made by a group of surface modellers working in close collaboration with the designers and engineers. The surface models are contentiously being updated, after design decisions have been taken.

A common scenario is that the designer or engineer attends design reviews, and then sits down by the modeller's workstation to elaborate on changes to the design. Creating high quality surface models requires very specific competence in advanced software, and the designer and engineers usually do not have the competence or time to modify them themselves.

"When you work on a computer, you have a tendency to zoom in, and you get too concerned with the details. You end up spending hours working on the radius of curve, when it's just going to get lost in the stamping." - Lloyd VandenBrink, modelling manager at Ford Truck Studio (Gibson, D. K. 2016)

A separate design team are in charge of the colour and material design that works in close collaboration with the visualisation team. A common scenario is that the colour and material designer brings a specification of the materials in the design, as well as material samples. The samples are used to replicate the material in the digital model. The specification is used to create variants linked to the different trim levels of the car.

The visualisation team creates content that is used for internal design presentations, as well as material used for product launches, exhibitions and car shows.

The operation with surface models puts high demand on an integrated system that handle all surface data, and makes it available for all involved parties.

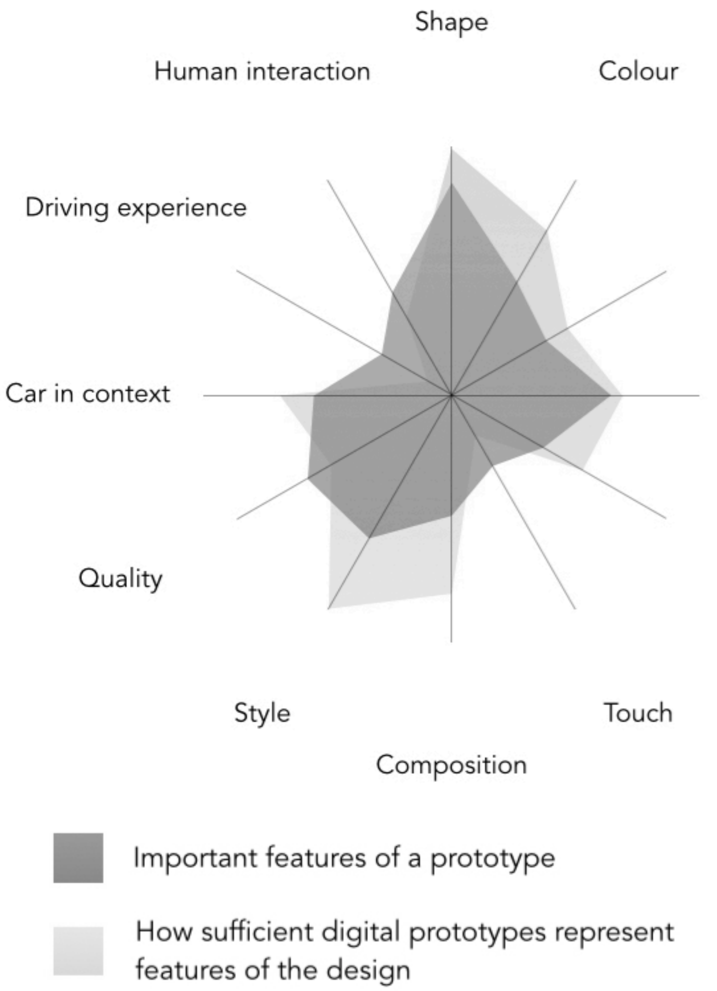


Figure 18
Important features of a prototype for design evaluation and how sufficient digital prototypes represent features of the design

In the survey the employees at Volvo Cars Design were asked about what aspects are important for them to evaluate from a prototype (figure 18). Almost all the employees agreed on shape being a very important aspect to consider in a prototype.

Quality, size and style were for the majority also regarded as very important aspects. Considering the other features the opinions between employees were split, from regarding it as important or very important. This indicates that the employees have different responsibilities and ambitions when evaluating the design, and hence have different needs of the prototypes. The least important features to evaluate were texture, touch, human interaction and driving experience.

Driving experience, human interaction and touch were regarded as the least sufficiently represented features of digital models. Quality and size, features regarded as important, were not experienced as sufficiently represented by digital models. The aspects that were considered as sufficiently represented by digital models were shape and style.

The importance of the features for evaluation cohered with how well digital prototypes represented these features. This result can either indicate that current digital prototypes are sufficient for design evaluation, or that the design evaluation has adapted to the limitations of the digital prototypes.

4.4.3 Clay prototyping

The clay model studio at Volvo Cars Design is a large facility with clay modellers working on a range of interior and exterior prototypes. The rough shape of the car is created from surface model data and using a milling device. The hands of the clay modellers will then prepare the surface of the clay model. Creating smooth surfaces and split lines are done by using scrapers and other clay modelling tools. If the designers decide to change the design of the car, clay can be added to the model and then be reshaped.

"Clay has two characteristics that make it good for use. It's easy to change — you just add it, or take it away. It allows you to be creative and come up with something quickly. 3D printing, on the other hand, is just that — printing. Secondly, it's a great collaborative tool. Everyone can get around it, brainstorming three-dimensionally." - Lloyd VandenBrink, modelling manager at Ford Truck Studio (Gibson, D. K. 2016)

A lot of work is put in replicating materials, which can be a complicated process. For this purpose a silicone cast of the original material is used. The clay models need maintenance, since the material can crack or material will come loose. In general clay modelling requires very specific competence. Because of the fragile nature of the clay model they are often based on see but not touch interactions, and they are sometimes accompanied with a sign that instruct employees not to touch the model.

In addition to using clay some components are modelled from 3D printing. 3D printing is often used for transparent material such as glass or complex details that is not possible to create from clay.

Function features, such as moving parts, are rarely prototyped in the clay studio even tough cars become more and more powered by electric components. For some models the driver seat is not made in clay, but is instead a real seat with the wrong design. This is a compromise made in order to be able to sit down in the interior clay model.

The clay model studio is a place that employees of Volvo Cars often visit to either experience the work they put in to a project, get informed about a projects status or to just become motivated and inspired.

"I often go down to the clay model studio just to see what the designers have been up to. From seeing the clay models I can be informed of the progress of a car project and be prepared for discussions that might come up during meetings." - Studio engineer at Volvo Cars Design

4.5 Immersive technology and automotive design

4.5.1 Immersive technology in the automotive industry

Benchmarking studies made for this study indicates that immersive technology is well adopted into the automotive industry.

"I don't know an automotive company that is not using a Vive right now, for design decisions, collaboration decisions and engineering decisions. The backside of it, not just the frontend showroom, but actually applicable use cases inside the business. Mock-ups for a car can cost upwards of 300 million dollars, where you are creating multiples of mock-ups of non working cars just to make design decisions." - Dan O'Brian from HCT Vive (O'Brian, D. 2016)

4.5.2 Immersive technology at Volvo Cars Design

Volvo Cars has been involved in the Microsoft Hololens project. In collaboration with Microsoft, Volvo Cars developed an experience for the Hololens where the XC90 can be displayed as a hologram. Microsoft has used the same experience for promoting purpose for the Hololens (figure 19.

Figure 19
Microsoft Hololens and Volvo Cars

A marketing virtual reality experience that consists of a car configurator has been developed to introduce Volvo cars to the market. The virtual car configurator is presented during car fairs and other events during the product launches. The car configurator is made by an external company, but is supported by the by the visualization unit at Volvo Cars Design. The visualisation unit provides the external company with the DigiCar, a data integration project that enables easy access to a production surface data of all variants of the car. The DigiCar makes the pipeline of making a virtual reality experience of production cars possible.

Volvo Cars Design has worked with virtual reality installations for the past five years. The department has installed two large projector screens that can display full size representations of car concepts. The projector display provides stereoscopic images and sensors that can detect the position of an individual wearing 3D glasses.

The design team at Volvo Cars also use a CAVE installation that can provide a holographic room scale virtual reality experience of car interior designs. The CAVE is a stationary and very expensive installation that requires multiple computers and large projectors to function. Last year the CAVE was updated, but the devices need to be continuously maintained. Volvo Cars Design believes that it will probably not be updated once again. Even though the experience is immersive and with high resolution, this indicates that the CAVE installation is going to be out-dated in the next few years.

Volvo Cars Design recently invested in two HTC Vive and has just begun to use the HTC Vive virtual reality experience to support internal design reviews. The high-end device HTC Vive was chosen for being the device on the market with the best performing tracking system.

To set up the virtual reality scene the software Autodesk VRED has been used. The interest in using virtual reality as design support is mixed, but more and more designers request virtual reality for real time presentations from the visualization team. As for today the HTC Vive is stationary set up in a small room, just large enough to enclose the room-tracking system. The set up has occasionally been moved to the large showroom, where the virtual car was placed inside a 360° image representation of the same showroom. Using virtual reality is open for anyone that requests it, but as for now the conditions for using it is not optimal and employees will need assistants from employees of the visualization team.

4.5.3 The future of automotive design

Cars have become lifestyle products that signify the individualities of their owners much like the clothes they wear. Today the ownership and experience of driving the car is in focus for the design of the car.

Shared mobility is a trend in the automotive industry and concepts for sharing has been revealed from different brands. UBER and Volvo Cars collaborate in a project where UBER uses Volvo cars and their own developed technology for autonomous drive to test self-driving taxis in San Francisco. Lynk & Co. is a new car brand of Geely that is based on the idea of sharing ownership of the car and share mobility with other people. Designing cars for shared mobility will potentially change the way cars are designed in a fundamental way.

Figure 20
Automotive trends

Self-driving cars is a huge trend in the automotive industry, and there is an intense competition of being the furthest advanced in this technology. Self-driving cars will have impact on the design, where concepts will be design around the activities that you can perform while the car takes you to the destination.

The designing of cars will not only be influenced by new demands of the users, but of available tools for creating design. In the future, designers will train their AI tools to solve design problems by constructing models based on their preferences. The designer will use social and creative intelligence that the AI lacks to design new products (Girling R. 2017).

Tools like Autodesk Dreamcatcher use algorithmic techniques to provide designers with a more abstracted interface for creation. Computer generated design will give designers new possibilities and perspectives of how to design products.

3D printing has made its way into fashion and furniture design, and allows for complex shapes and structures. Future 3D printing technology can enable design to be more human centred and less concerned of adapting products to manufacturing methods. Possibly, new high performance materials can even be shaped into durable and lightweight constructions from 3D printing.

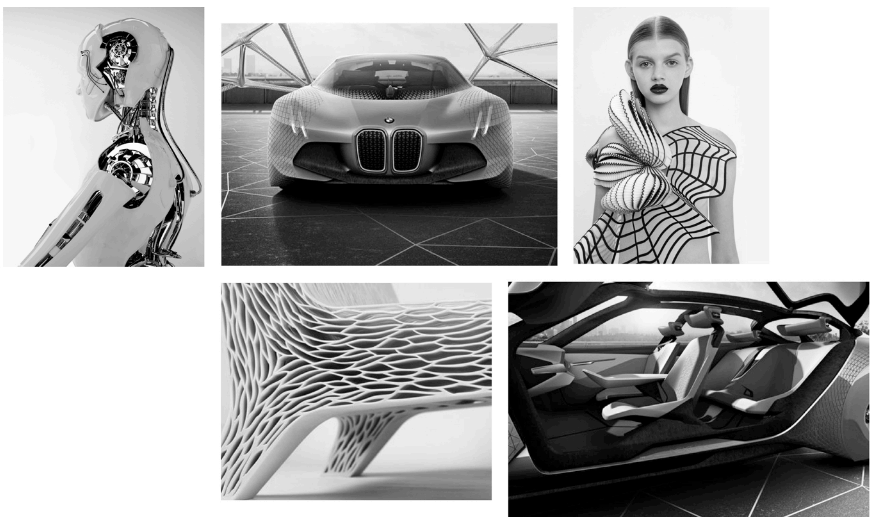


Figure 21
The future of design

4.5.4 SWOT analysis

The following section presents a SWOT analysis that concerns strengths, weaknesses, opportunities and threats for immersive technology aided design operations at Volvo Cars Design.

Strength

Volvo Cars Design is an organisation participating in the global market with the capability of influencing hardware and software suppliers for immersive technology. Employees at Volvo Cars Design have the possibility to give direct feedback to suppliers, by partnership and collaboration, and make sure the technology meets their specific needs and demands.

Volvo Cars Design can take part as innovators and early adaptors of immersive technology, since a lot of knowledge and competence have been earned in the field trough years of using high-end technology for visualization such as CAVE solutions and stereoscopic screens.

The influence, knowledge and an optimistic approach towards innovative visualisation technology will allow Volvo Cars Design to integrate immersive technology into business operations, without having to wait for of late adopters and late majority consumers.

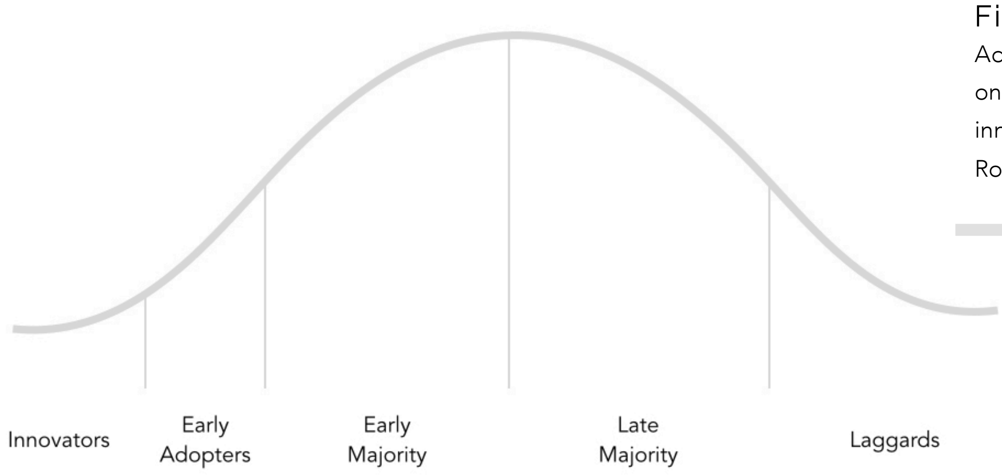


Figure 22
Adopter categorization on the basis of innovativeness (E, Rogers 1983)

Weakness

The form factor of available immersive technology is a disadvantage for Volvo Cars Design. Mainly since it is neither accessible nor convenient in the aspect of wearing or storing it in an open office environment. Integrating the use of the hardware into work situations can be a challenge, especially since the identity of Volvo Cars design studio is not in tune with the unwieldy and seemingly awkward HMDs on the market.

Volvo Cars Design has a need for the technology to give a highly realistic experience. Even though the development of immersive technology is going fast, it may take a few years before it can live up to the needs and demands of the department.

Strict processes and a conservative view of how cars should be designed can prevent the adoption necessary for implementing the use of immersive technology to the daily operations at Volvo Cars Design. Immersive technology has come a long way since the 1990s, but a common attitude is that immersive technology is a trend that will likely pass by. If this is the general opinion of employees of Volvo Cars Design it can make employees less interested in adapting to using immersive technology in their workspace and acknowledging the opportunities it enables.

Opportunities

Immersive technology has received a lot of media tension in recent days. The public has shown a great interest in the future of these new devices, and many are curious of the use cases that will evolve. The great interest in the technology will speed up the development of more capable software and hardware.

The Volvo Cars brand strives to be in the forefront of innovation and being a pioneer of immersive technology suits well with this ambition. Volvo Cars Design has the opportunity to be involved from the start and be engaged in developing systems that fits their operations.

The trend analysis made for this study indicates that in the future immersive technology will enter a vast range of different operations at Volvo Cars; anywhere from design, manufacturing and construction, factory production, safety and ergonomics as well as the customer experience. Being in the lead of the paradigm shift of digital visualization shows potential in how the brand will be perceived and give business opportunities.

Immersive technology gives an opportunity to create in space that can allow for ground breaking design. Designers and engineers will be in more control of their concepts, from seeing the unseen and discover potential bottlenecks of car projects earlier in the development process. The technology has the potential of optimizing operations with highly immersive prototypes, closing the gap between physical and digital models.

"Virtual reality could become such a useful tool, as the apprehension of the space around us will be completely different. The ability to sketch and quickly mock up in 3D will offer amazing opportunities, probably a more efficient process as well. The design process could evolve along with this technology and offer new and exciting opportunities. The ability to check stuffs without waiting for a milling or something could become very useful during some phases (even though it will never replace a physical model, but could come closer and closer). Exciting times are ahead of us!" – Surface modeller at Volvo Cars Design

A potential use case of immersive technology is to have it integrated into the product itself. In order to do this, experience and knowledge of such systems need to be obtained. Using immersive technology in the design operations will make the step shorter to offer such solutions to customers in the products.

Immersive technology has entered the marketing business for its power of storytelling, not least to be seen in the automotive industry. Using immersive technology as a tool for conveying the benefits of a product will likely play an important role in marketing in the future, considering potential customers, dealers and business partners.

The prognosis is that 5G will be offered in 2020, which will allow for wireless connection offering very low latency. This will have a major impact on the mobility and accessibility of using immersive technology. This gives the opportunity to make the use of immersive technology more adapted to the needs of employees at Volvo Cars Design, who depend on convenient and reliable tools to work with.

Using immersive technology and virtual meetings will improve the collaboration of design teams located in different design studios. This will strengthen the relations between the design teams and enable them to support each other's work in a more efficient way.

The use of immersive technology can make employees less dependent on working at a stationary computer. Being able to work where you like in space will allow for employees to move about and be less deskbound. This will enable workers to have better work conditions with less time staring at a fixed screen, and possibly make the Volvo Cars Design department a more creative and attractive workspace.

Systems with artificial intelligence support are a buzz in IT. A lot of parallels between artificial intelligence and immersive technology have been made, and the opportunities that lies ahead for this integration is vast. For a product developing company such systems give the opportunity to process big data concerning users and segments. An immersive technology system with artificial intelligence can give the designers and engineers a better understanding of their intended target group as well competitors on the market.

Threats

A possible threat is that technology does not meet the requirements of its users, and therefor fails to adapt to its systems and people. The hype has created high expectations and the limitations of what can be achieved might make people disappointed and cause the technology to flop.

The high competition on the immersive technology market might make the developers focus on other use cases than the automotive industry, such as low-end consumer products, which will make the product range less pragmatic for the automotive context because of less capacity.

There exists little research about possible side effects of using immersive technology. The psychological and physical implications of excessive use could be considered a threat for implementing the use of immersive technology in daily activities.

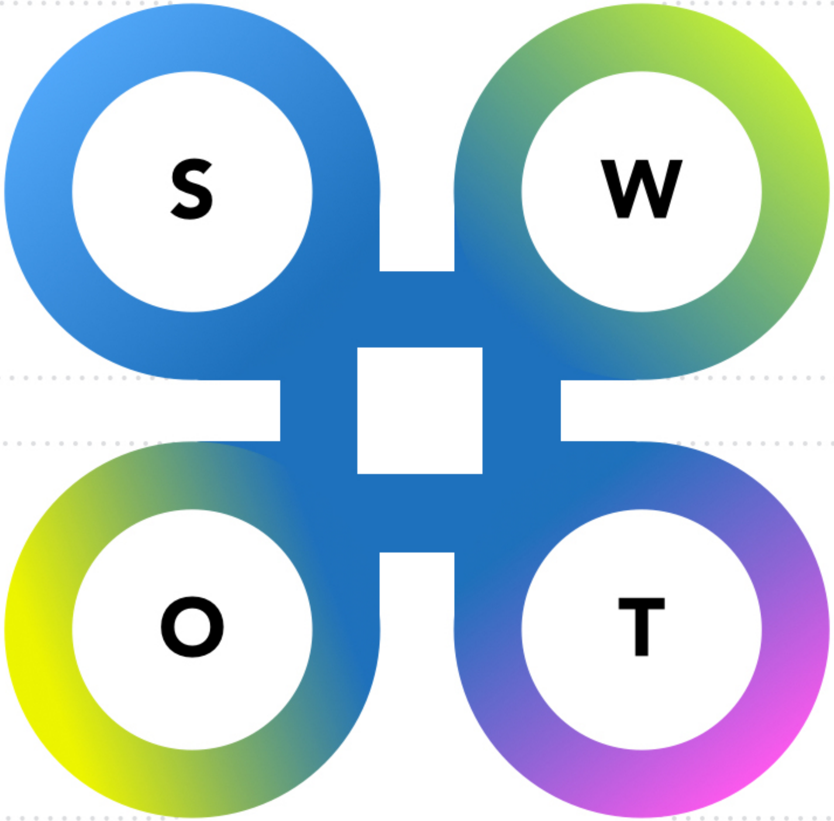
Figure 23
SWOT analysis

STRENGTH

Possibility to influence the immersive technology market. Prior knowledge and an optimistic approach towards innovative visualisation technology. Don't have to wait for of late adopters and late majority consumers

WEAKNESS

The form factor of available immersive technology is a disadvantage. It may take a few years before the technology can live up to the needs and demands of the department. A conservative view of how cars should be designed can prevent the necessary adoption.



OPPORTUNITIES

Will enter a vast range of different use cases. An opportunity to create in space that can allow for groundbreaking design. Improve the collaborative of design teams located in different design studios with virtual meetings. Being able to work where you like in space will allow for employees to be less desk bound.

THREATS

Technology doesn't meet the requirements of its users, and fails to adapt to its systems and people. Developers may focus on other user cases than the automotive industry, such as low-end consumer products. There exists little research about possible side effects of using immersive technology.

4.6 Discussion

The employees may have been biased when answering the survey. Especially considering how sufficiently digital prototypes are representing the features of a car, in relation to how important they are for evaluation. A possible reason for the similarity in the answers of the two questions is that features that can be represented sufficiently have become important features for evaluation.

The author of this report may be biased, because of pervious experience from working at the visualisation unit at Volvo Cars Design, which may have influenced the result of the study made at Volvo Cars Design.

4.7 Insights and implications

Volvo Cars Design has various car projects in different stages in the designs and is dependant on a structured process. In the design process both low and high fidelity digital models are needed to aid all stages in the development process.

With surface models that are continuously updated, reviewing prototypes in virtual reality is already implemented and accessible for designers and engineers. More and more designers ask for virtual reality prototypes for design reviews, which indicates there is a growing interest for the technology at the department.

Excessive zooming in on details with on-screen traditional mediums steals attention and time. Virtual reality can potentially give designers an overview of the model so that they can stay focused on what matters.

At Volvo Cars Design, digital models are experienced as sufficient support for many design aspects, such as shape and style. The digital prototypes are not experienced as sufficient in aspects that are often regarded as less important, such as human interaction and driving experience. However, aspects like quality and style were regarded as important but not sufficiently represented in the digital prototypes. In virtual reality the size of the prototype can potentially be better represented.

Because of the limitations of clay, clay models cannot represent functionality as efficiently as digital prototypes. Virtual reality could potentially be a sufficient medium to representing moving pats and functionality of a prototype.

Large facilities are allocated for physical prototyping and design reviews at Volvo Cars Design. Clay models require a lot of work and are partly hand made. Especially time consuming is materials for interior design. In general prototyping digital and physical models requires a lot of specific competence.

Physical clay models are easy to change and serve as a good collaborative tool. Clay models make employees enthusiastic and breed interactive communication. A presentation with a physical model makes participants less passive and more active during the presentation. Virtual reality models are potentially more flexible than clay models and could possibly have the same effect on the communication as clay models.

Even though designers have the possibility to have the design proposals explained by concrete digital prototypes and clay prototypes, abstract prototypes such as sketches and rendered pictures are important for the design process in a late stage.

Design reviews and presentations are used at all levels of the organisation, for unofficial meetings, weekly reviews and important stakeholder design boards.

Employees wish that presentations could be more time efficient, but they need to be flawless to live up to their demands. The presentations often lead to pressure and the attendants are experiencing stress.

During presentations the employees that are presenting material use a lot of body language to demonstrate, reflect and empathise. The current virtual reality experience is isolated to the individual and the own body is not present. Enabling several employees to participate inside virtual reality, and allowing employees to see and use their bodies, could have a positive effect on collaboration.

The unofficial meeting is an important channel for communication for all employees at Volvo Cars Design. In general face-to-face meetings are important for the design process. Virtual reality meetings could make employees less deskbound, and allow for simulated face-to-face meetings between the different design studios.

New demands of society and customers will lead to new ways to design shared and self-driving cars. In the future designers will have tools with artificial intelligence that support conceptualisation. Virtual reality could be a platform that meets the changes that the process of designing cars will face in the future.

The activities identified at the Volvo Cars Design department can be categorized into collaboration and communication, evaluation of design and creation of design.

4.8 Conclusion

The study confirms that virtual reality has vast possibilities for being implemented into design operations at Volvo Cars Design. As a platform it should be utilized as a tool for design evaluation, conceptualization, communication and collaboration.

05

First orientation

5.1 Narrowing the scope

The pre study of this project had a wide scope, to give holistic insight in immersive technology as well as the Volvo Cars Design organisation. In order to move further with the project, delimitations and decisions needed to be made. The decisions and delimitations that were made during this phase of the project considered what immersive technology approach to consider and what use cases to further investigate.

The conclusion of the initial study is that the integration of immersive technology to design operations should be explored. As for now an important aspect to consider is when in the design process, immersive technology is to be utilized.

The current approach at the Volvo Cars Design visualization unit is to provide immersive experience for all stages of the design process. However, most effort has been made to offer virtual reality experience for marketing purposes in the final stage of the design process and product launches. The integration of using virtual reality in a late stage of the design process is already advanced, and with the DigiCar project Volvo Cars Design has achieved much in making the virtual reality experience of production cars assessable.

For marketing purposes the virtual reality experience will not be developed within the Volvo Cars Design organisation, but via external companies. Therefore, for this project, marketing use cases of virtual reality will not be considered.

In the next exploration phase the use cases connected to the different stages of the design process will be considered. These use cases were compiled into the three different areas collaboration, creation and evaluation.

Experiencing an altered reality shows great potential for a variety of use cases. With the Hololens project the vast use cases at Volvo Cars of an altered reality is being explored. Since the platform is still in much of a prototype stage it has not yet been implemented into any design process. Because of the parallel and on-going project at Volvo Cars IT, that explores the use of an altered reality for the development of cars, an altered reality will not be considered for this project.

Because of Volvo Cars Designs aim to develop products that fit the global market, which entails the need to connect the employees that work at the different design studios and for designers to experience realities other than their own, an alternative reality will be the primary focus for this project.

5.2 Focus for the next exploration part

The activities that were identified at the Volvo Cars Design department as most frequent were collaboration, evaluation of design and the creation of design. These were also the use cases chosen to be further investigated in the following part of the exploration phase. A virtual reality experience in an alternative reality, shared with employees of all design studios, was decided as the focus for the next exploration part.

Current virtual reality devices are an adequate solution to use in the design process today, but the improvement of the technology will make the use even more pragmatic for experiencing alternative realities. In the near future techniques that will improve the virtual reality experience will be integrated to products on the market. These will be considered in the next exploration phase.

Designing for the virtual reality environment is less explored than traditional digital mediums. Understanding the principles for designing a virtual reality experience will therefor be a focus for the next exploration phase.

5.3 Conclusion

From findings made in the pre study, it was decided that the remaining part of the project would consider the following use cases for an alternative reality

- Design collaboration
- Evaluation of design
- Creation of design

The alternative reality experience

06

An alternative reality

6.1 A historical perspective of virtual reality

To realize the potential of virtual reality for product design is to understand the historical perspective of technological progress (figure 24).

Empathising science as a drive for technology has pushed the world towards a spiritual and ecological crisis. Up until now much done with technology is out of balance with nature, as well as making the people who use it less connected to their inner selves. The rapid development of technology has made people question if these innovations really are doing them good.

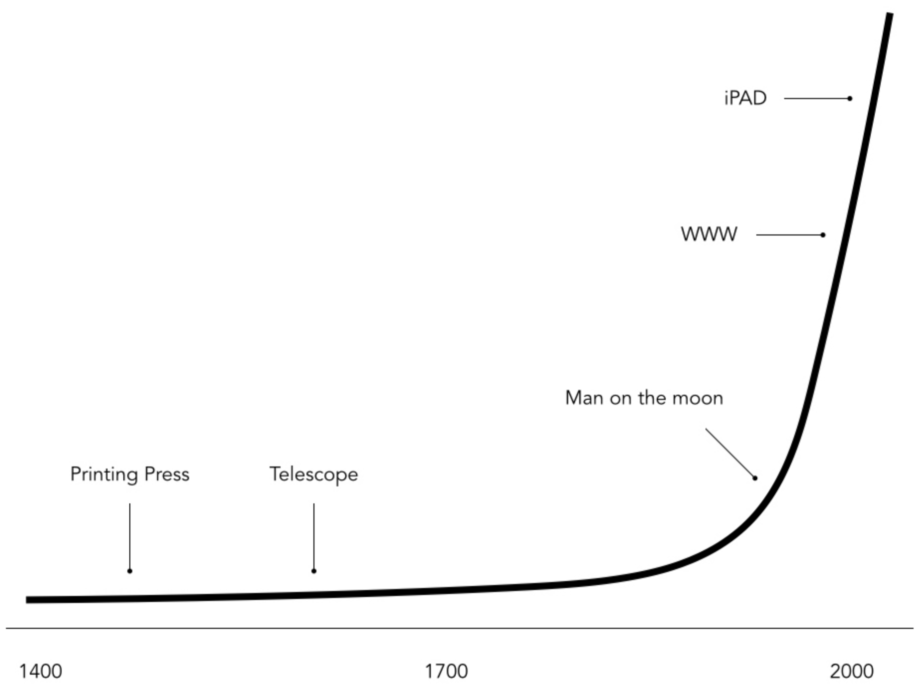


Figure 24
Technological progress curve

Modern society stands before embracing holistic thinking for innovation and cultural advancement. The world is moving from the information age to the experiential age that requires holistic thinking for designing products.

Designers and engineers that have direct experience of their creations gain holistic insight in the consequences of their creations, something that has been lacking for technological progress in the past.

The unique affordance of virtual reality is that it can mimic the real world and give rich direct experience. Potentially, the virtual reality experience can be used as a tool to shift the technological progress towards something that is more in harmony with people and earth.

6.2 The sense of presence

6.2.1 Immersion and coherence

The illusion of presence in virtual reality can be divided into two components (Slater, M. 2016). Place illusion is gained through sensory information, and plausibility illusion from observing the behaviour of characters and objects in the virtual environment. To achieve the plausibility illusion, the interaction with the virtual objects needs to matter and make sense. When both components occur, the perceiver of the digitally enhanced reality will react realistically towards it.

Research has been made to quantify the impact of the place illusion, referred to as immersion, and plausibility illusion, referred to as coherence, on the virtual reality experience (Skarbez, R. 2016). The research shows that the sense of presence is experienced the highest if both the immersion and coherence are strong. If either of them or both of them are experienced as weak the sense of presence will be low. The findings indicate that both immersion and coherence need to be present in order to achieve a strong sense of presence.

Skarbez also believes that coherence is the most fragile component. Immersion can be achieved with a lot of technical innovations such as frame rate and low latency head tracking. Coherence, however, is achieved from mental models and more or less needs to maintain

100 per cent logic in its construction. Most breaks of presence are due to breaks in coherence and can take time to recover from in a users perspective.

This implies that when designing a digitally enhanced experience with a photorealistic look and feel, it is important to achieve the same high fidelity in the sound design, the social and behavioural interactions of people, and perhaps even haptic.

For a virtual reality experience that is to be used by intermediate or expert users, as in the case for a system at Volvo Cars Design, the users are likely have expectations that correlates to previous experience of that system. This implies that the experience not necessary needs to live up to the first expectations of the user, but that is constructed around rules that the user quickly adapts to and recognizes.

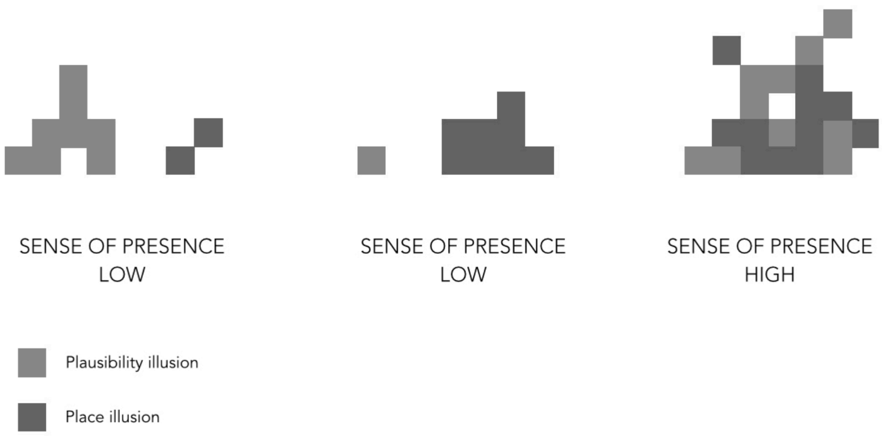


Figure 25
Plausibility and place illusion (correlation with the sense of presence (Skarbez, R. 2016)

6.2.2 An elemental theory of sense of presence

The elemental theory of presence (Bye, K. 2017) divides the components of the sense of presence of virtual reality into four parts. In the following sections this theory will serve as a theoretical framework to further explain the components of the virtual reality experience, and the factors that contribute to creating a rich direct experience.

- Embodied presence - The embodied presence lets the individual in virtual reality feel that the body is there.

- Active Presence – Active presence lets the individual in virtual reality express their agency in an interactive way.

- Social and mental presence – The social and mental presence allows for communication with other people, and stimulation of the mind for the individual in virtual reality.

- Emotional presence – The emotional presence is the ability to have emotional engagement in events.

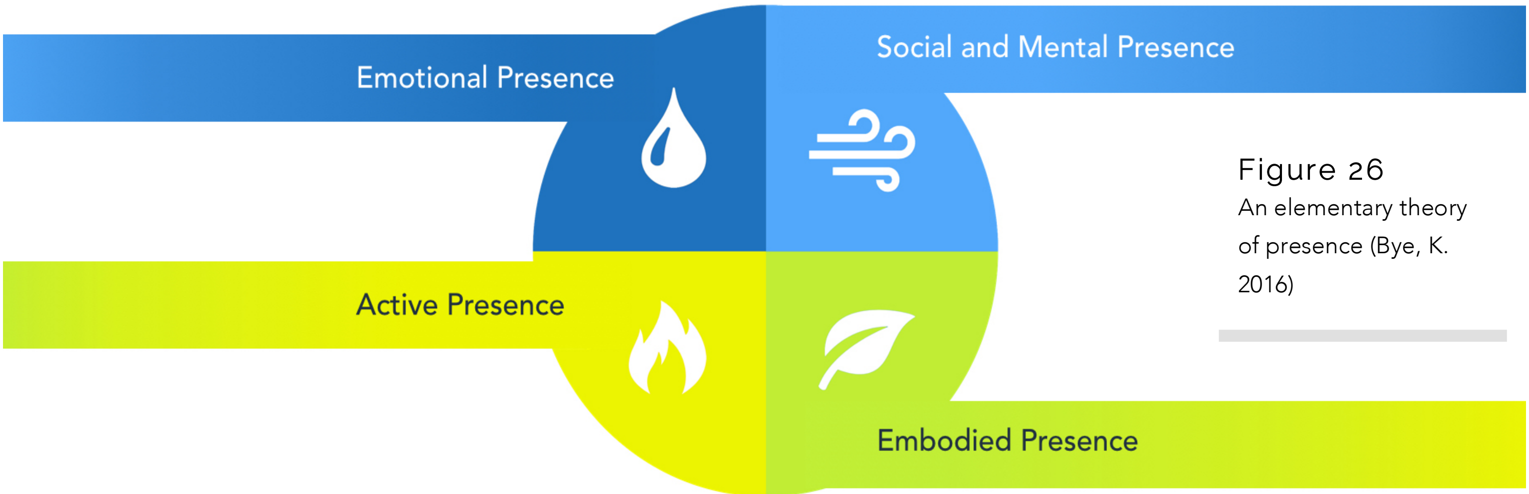


Figure 26
An elementary theory of presence (Bye, K. 2016)

6.3 Embodied presence

Embodied presence is an explicit affordance of virtual reality that cannot be accomplished with any other digital medium, which potentially makes virtual reality powerful as a product evaluation tool. This section will describe the following aspects and techniques that are of interest for the embodied presence; body ownership illusion, embodied cognition, hand presence and redirected touch.

6.3.1 Body ownership illusion

Virtual reality research has shown that people tend to react realistically towards situations and events in an immersive virtual reality (Event Lab, 2016). Research has studied to what extent people in virtual reality have the illusion that a virtual body is their own and the consequences of that.

In virtual reality people tend to adapt very fast to a virtual body. They look down and see a virtual body, replacing their own, and in a few seconds the brain accept the new body and they will behave accordingly.

One of the most famous examples of this body ownership illusion is the rubber hand experiment (Botvinick N. 1998). Synchronised strokes on a persons hidden real arm and an aligned and visible fake rubber arm can result in the illusion of ownership of the fake rubber arm so that the person will react to when the fake arm is harmed.

Not only the visual-tactile correlation is important for body ownership illusion. Visual-motor correlation and virtual body movement seem to play a more important role.

Research show that body ownership illusion can make test subjects perceive themselves differently. It is possible to induce the feeling of having a bigger belly or having an arm that is three times longer than a real arm, and even the illusion of having the body of a child. Test subjects can also change attitude and behaviour, when they temporary tend to take on personalities associated with the virtual avatar (Event Lab, 2016).

No other medium than virtual reality has the capability to put people into another body, give another point of view and create new perspectives on people's lives (Slater, M. 2016).

6.3.2 Embodied cognition

The embodiment thesis implies that many features of cognition are embodied. They are deeply dependent on the characteristics of the physical body of an individual, such that the individual's body plays a fundamental role in the cognitive processing of that individual (Wilson, R. 2017).

Four examples of the embodied cognition phenomena

- Individuals typically make gestures to one another, not just for communication but also for language processing itself

- Vision is often used for guiding actions. Bodily movement and the feedback it generates are integrated into some of the visual processing

- There are neurons in the brain that process not only when we do an action, but also do so when we observe another person doing the same action

- When using the body and even parts of the surrounding environment it is often possible to preform cognitive tasks more effectively, such as remembering

6.3.3 Virtual embodiment

Full-body presence is not implemented in any of the available consumer virtual reality devices on the market. However there exist technologies to give users in virtual reality a virtual body. The techniques for virtual embodiment either use optical or non-optical tracking methods.

Consumer virtual reality devices, such as the HTC Vive, use non-optical tracking devices to track the motion of the user's hands. The hand controls can either be represented as virtual hands or digital representations of the hand controls. Putting several similar devices on the limbs, such as the Vive Tracker, can achieve full-body presence.

The Xbox Kinect is an outside-in tracking device that uses optical tracking to track full body movement. This device can be used in combination with the consumer virtual reality devices to achieve full-body presence.

A device that enables inside-out tracking of the hands in virtual reality is the Leap Motion optical tracking accessory that is strapped to the front of the head mounded display. Leap motion creates a virtual version of the hands, so that they can be embodied in virtual reality.

6.3.4 Redirected touch

In virtual reality environments the virtual objects cannot be touched. A solution to this is to use passive haptics, which are physical props that virtual objects are registered to. The result of this is compelling, because when someone in virtual reality reaches out with a virtual hand to touch a virtual object, the real hand touches a real object. The limitation to this is that to make passive haptics possible all virtual objects need to have a physical representation in the real world.

Virtual objects have historically been mapped on to one, but redirected touch demonstrates that the mapping does not need to be one-to-one. It is possible to make a single passive real object that can provide useful haptic feedback for many virtual objects by exploiting the human perception (Kohli, L. 2013).

- The three categories of redirected touch techniques are
- Move the virtual world to align different virtual objects to the same real object in turn
- Move the virtual object into alignment with the real object
- Map motion of the real hand to different virtual hand motion

The fist technique, referred to as Redirected Passive Haptics, and enables individuals in virtual reality to touch multiple different virtual objects, with haptic feedback provided from one single real object.

The second technique, referred to as The Haptic Hand, attaches a larger-than-hand virtual user interface to the non-dominant hand and maps the currently relevant part of the interface onto the palm.

The third technique, referred to as Redirected Touching, warps the virtual space to map a variety of differently shaped virtual objects to a single real object. Luv Kohli's studied how task performance in cockpit training was affected by the third technique. The studies show that individuals adapt rather quickly to real-virtual discrepancy, and after the adaption the individuals perform tasks no worse with the discrepant virtual objects that with one-to-one virtual objects.

Research shows that when the senses are conflicting, vision is usually dominating. An individual that moves their hand along a straight surface while wearing distorting glasses, making the surface appear curved, will feel that the straight surface is curved. This phenomenon is referred to as visual dominance. Redirected touching uses visual dominance to enable the discrepancies between real and virtual objects to go unnoticed.

6.4 Active presence

The active presence relates to the agency of the user in virtual reality, and is important to consider for a virtual reality experience at a design studio where users need to focus on tasks and be productive. The following section will describe ways to interact and provide feedback in virtual reality with natural user interfaces, intuitive interactions, 3D user interfaces and conversational interfaces.

6.4.1 Ways to interact

The agency of the virtual reality experience relates to the possibility to interact with the virtual environment. As previously mentioned, Leap motion is a device that track hand movement and uses gestures as input for interaction (figure 27). The interaction involves lots of movement that can increase the sense of presence, however using gestures does not imply grasping anything physical.

Figure 27
Leap Motion gesture interface

Another example of a device that uses gestures for input is the Intel project Alloy. The Intel Alloy also provides a real image of the users hands into the virtual reality environment, although the field of view of this image is limited (figure 28).

Using hand gestures as input is not looked upon as reliable enough to use as main input. However, the technology is in constant development and can therefore be considered as a possible input source for future devices.

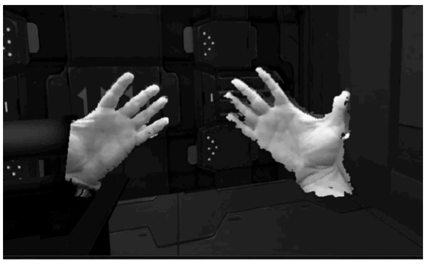


Figure 28
Intel project Alloy

Tracking is used for interactivity by the high-end developers and allows for intuitive interactions. A commonly used digital feature of the hand control is the laser pointer cursor that appears in the virtual reality environment when a button is pushed down. This is used to make selection in an interface and to manipulate interactive objects (figure 29).

Another device that uses tracking is the Vive Tracker, which can be attached to different accessories and track them into the virtual reality environment to make them interactive.

Figure 29
HTC hand control and HTC Vive Tracker

6.4.2 Feedback

Using audio effects in the virtual reality gives the possibility to add cues, where the audial experience brings more sense of presence. The audio can be designed as 3D spatial audio, which allows the user to know where the sound comes from. 3D spatial audio can be used to guide the user in what direction to focus attention.

The interactive devices have buttons for physical feedback and can also give haptic feedback in the form of vibrations. A product that can be used in combination with the Leap Motion is the kick-starter Gloveone. Gloveone is pair of gloves that allows for vibration feedback, when touching objects in the virtual reality environment.

6.4.3 3D user interfaces

In a world space interface users can move up closer and move away from the interface, which gives the users a choose how far away they like it (Alger, M. 2015). Managing attention of the user is important for the interface in world space, since it is not possible to put information in the top or bottom of a screen as for screen based interfaces. Interactive objects in the digitally enhanced environment should be placed within 0.5 m to 20 m (figure 30).

In addition to being pleasurable and informative, the immersive experience of virtual reality can be used for streamlining workflows. The main factor is more screen space that can give productive workflows, with fewer interruptions in tasks because of less time spent in cognitive navigating the interface. Virtual reality also allows for customizing the working environment, and the user can basically virtually be any place they like.

Similar to other digital platforms, actions with text descriptions are reached through menus in 3D interfaces. The menus can be projected in a plane in front of the user, or it can be a radial menu that associates with the hand or any of the body parts.

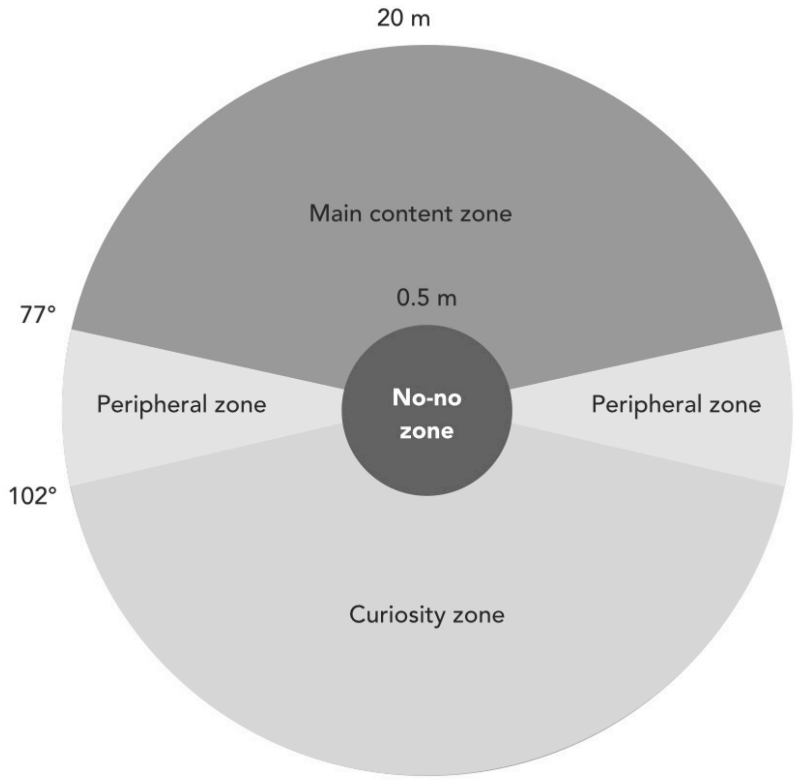


Figure 30
Placement of information around the user

6.4.4 Natural user interfaces (NUI)

The natural user interface is an interface that allows for direct and intuitive interactions that are consistent with the natural behaviour of humans. The benefit of natural user interfaces is that the user can use a broader range of basic skills, compared to interacting with more traditional graphical user interfaces (Mortensen D. H, 2017). The principle of the natural user interface is to use direct manipulations, gestures and natural language processing so that no controllers are needed to interact with the interface.

A conversational interface is a type of natural user interface. The conversational interface can understand the natural language of human users and will mimic the conversation with a real human. Instead of clicking icons and entering syntaxes, as in an ordinary interface, the user interacts with the interface by telling it what to do. Examples of conversational interfaces are the iOS Siri, and chat functions used for customer service in websites.

6.5 Social and mental presence

The virtual reality experience can be used to improve the performance of tasks by utilizing the social and mental presence. Social and mental presence is related to the cognitive and relational processing. The following section will describe cognitive enhancement and brain monitoring, which are two techniques for social and mental presence in virtual reality.

6.5.1 Cognitive enhancement

A lot of common software acts as cognition-enhancing environments, where the software supports to display information, keeps a memory and performs routine tasks. Such software tools make enormous amount of data, that the human perceptual system cannot handle, graspable. There is a growing interest in creating close links between the external system and the human user through better interaction. Software are becoming less an external tool and more of a mediating exo-self (Bostrom, N. 2009).

Virtual reality technologies can achieve cognitive enhancement, and can be used as a tool for the improvement of creativity, performance and understanding. Research argues that virtual reality can implement and optimize established individual and collaborative creativity enhancement techniques, while also offering new possibilities and combinations not available in any other context (Thornhill-Miller, 2016).

The research suggests that virtual reality can be used to enhance creativity and problem solving by changing aspects of the self and self-perception, by optimizing interactions and collaboration with others and by optimizing environmental conditions and influences.

6.5.2 Brain monitoring

Brain monitoring can be used in combination with machine-learned algorithms to detect drowsiness, engagement, stress, emotion empathy and cognitive load of individuals in virtual reality. The technique gives the possibility to enhance the memory and build stronger memories. It can be used for training and learning, by monitoring someone’s cognitive workload. Brain monitoring can enable custom tailored applications that adapts to how the individual is preforming.

6.6 Emotional presence

Design is often being evaluated from the subjective experience of the one who evaluates it. Therefor Volvo Cars design employees often rely on emotional engagement and storytelling to convey the message of a specific design during presentations.

Emotional presence relates to the emotional engagement in events. For emotional presence characters, music, ambiance and intuition are of importance. This section will describe the difference from storytelling in virtual reality to other digital mediums, and how tracking emotions with facial tracking can be used.

6.6.1 Storytelling in virtual reality

Storytelling in virtual reality is different from other digital platforms. In virtual reality the story is told for an audience, where the audience is also present within story (Newton, K. 2016).

For storytelling in virtual reality how the audience perceive their role and agency in the virtual context is an aspect that should be considered. The position of the audience will also have an impact on the engagement and interpretation of the story.

Looking gives the audience agency, not by changing the story, but by changing the direction they look and choose what part of the story to take in and create meaning of. Therefor it is of importance to draw attention to the most vital story points, in order to make the audience focus and remember the most essential part of the story.

6.6.2 Tracking emotions

Facial tracking can provide information about how people react emotionally, not just rationally and logically. Tracking sensors attached to the face gives the possibility to visualize facial expressions, which can be used improve interactions with other people in virtual reality.

Current facial tracking techniques can extract and detect six basic human emotions from different facial expressions; fear, sadness, joy, contempt, surprise, anger and disgust. This implies that from biometric data the emotional state of an individual in virtual reality can be registered.

Eye tracking is not implemented yet in any of the commercial virtual reality devices on the market, but has already been promised by some of the developers and will likely be introduced in the near by future. Eye tracking is made possible from infrared sensors that track the movement of the users eyes inside the HMD. The benefit of this technique is the possibility to know where in the field of view the user is looking (figure 31).

For virtual reality eye tracking allows for other individuals present in the virtual environment to more precisely react to where someone is looking (Villwock, C. 2017).

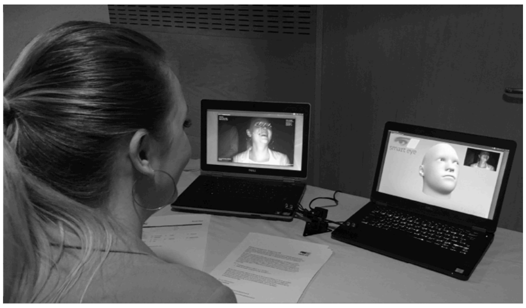


Figure 31
Eye tracking technology

6.7 Insights and implications

To create products that are in harmony with people and the earth, a holistic perspective is needed in product development. Virtual reality can be used as a visual communication tool that provides a rich direct experience of the choices designers and engineers make, and hence can give deep insights in the consequences of their creations.

The sense of presence in virtual reality is not only dependent on the level of immersion of that experience. The coherence of the experience also plays an important role in making it reliable. For Volvo Cars Design this implies the need to find an approach for coherence in the virtual reality experience, to counter the visual fidelity of the digital prototypes used in the virtual reality experience.

To give an overview of the components of the sense of presence, it can be divide into embodied presence, active presence, social and mental presence and emotional presence. The different elements contribute to giving a rich direct experience, and should all be encountered when designing a virtual reality system.

The embodied presence depend the sensory perception of the experience. Visual-tactile correlation is important for the body ownership in virtual reality, but the visual-motor correlation plays an even more important role. This combined with the effect of embodied cognition suggests the importance of a present virtual body with visual-motor correlation feedback for preforming design evaluations.

Using visual-tactile correlation would potentially constrain the virtual reality experience to physical props and a physical location, making it less accessible to all employees at Volvo Cars Design. Therefor the use of vision-motor correlation as an approach to create a direct experience of the car is preferable.

An individual in virtual reality can adapt to a new body, which suggests that the virtual avatar does not have to be a representation of the own body. However not having the own body in virtual reality can make users respond and behave differently. This could be regarded as an unwanted consequence in situations when an ordinary behaviour of an individual is necessary. However, Volvo Cars Design can use virtual body ownership to gain new perspectives and also to allow employees to act natural in the virtual context and feel comfortable in discussions and collaboration activities.

Redirected touch demonstrates how individuals in virtual reality can be tricked by their senses, because of visual dominance. This entails that it is not necessary to have a direct representation of virtual objects in the real world, in order to give necessary tactile feedback.

Active presence can be achieved with different interaction techniques. It is important to consider where in the field of view information is presented to the user, in order to managing the attention and not strain the cognitive load, as well as to be able to convey the message of the design.

Storytelling in virtual reality is different from other digital platforms and is of importance to understand in order to create an environment for virtual meetings with a desirable engagement of the participants. In virtual reality it is more difficult to guide the audience towards a specific message.

Gesture and conversational interfaces are possibly not suitable as main input today, but will likely be more reliable for interaction when the technology is further developed. For a virtual reality system used by Volvo Cars Design, these input methods can contribute to a system less dependent on physical objects and more adapted to the natural behaviour of the employees.

Virtual reality can be used to collect data of the individuals that use it, however, there are ethical implications of brain monitoring and detecting facial expressions. In order to implement such techniques, the impact it could have on the individual must be considered. It should only be used for purposes that the user can benefit from, and not to make people feel exploited or uncomfortable.

6.8 Conclusion

The result from the study indicates that the physical clay model is experienced as necessary for the design process because it provides the possibility for employees at Volvo Cars Design to use their body as a reference to relate to the car design. Not necessary by interacting with the model by touching it, but by experiencing it from seeing the own body in relation to the car design. A contributing factor to the current digital prototypes being less suitable as final decision support is the incomplete opportunity for embodied cognition.

In order for a virtual reality prototype to give the same direct experience of a car design as the clay model, virtual embodiment with vision-motor correlation of the user in the virtual environment need to be completed. For the system of virtual reality prototypes the vision-tactile correlation can be used to provide a more intense direct experience of the car design, however it is not necessary for the prototype to be as useful as the currently used clay prototype.

The study indicates that a system that utilizes prototypes restricted to digital properties can offer similar benefits to the design process at Volvo Cars Design as the clay models. Therefor Volvo Cars Design should focus on completing the visual and audial perception providing users with a virtual body, and secondary focus on tactile feedback to intensify the direct experience of the car design. The tactile feedback in the system should be regarded as added value, but should not be treated as a need to access the virtual reality experience.

07

Utilize the alternative reality experience

7.1 Purpose and aim

The purpose of this part of the study was to investigate the pragmatic use cases of virtual reality for the chosen use cases of first orientation phase. The study was made from the perspective of the employees and in the context of Volvo Cars Design, with the insights gained from the previous exploration.

7.2 Method

As part of the study literature studies, user studies, interviews and participation in demos were conducted. A literature study of what motivates employees in the working environment was made to learn about how organize work tasks.

Two user studies were held with the employees at Volvo Cars Design, to learn more about their attitude towards virtual reality and their thoughts about using immersive technology as a tool for design tasks. The first workshop introduced virtual reality to employees, where they were allowed to review a car concept in a virtual scene. In the second workshop employees were given the possibility to use virtual reality as a creative tool. The data was collected from short interviews and observations of the employees' behaviours during the user studies.

A third user study was made with participants not working at Volvo Cars Design. During this study participants were asked to join a focus group concerning using virtual reality for communication and collaboration at work. The data was collected from making notations of what was said during the discussions.

7.3 User study: Virtual reality as an evaluation tool

7.3.1 Process

During the first test session of the user study, employees from the design department at Volvo Cars were invited to try a virtual reality experience of an on going car project. The participants of the test session were designers, project leaders, studio engineers and modellers, curious about trying the virtual reality experience. The majority had never tried virtual reality before, or had only limited previous experience.

The duration of the test session was one hour, and the participants took part in turn in groups of 2 to 5 people. About 20 employees from different professions participated in the test session.

The context where the test session was held was the car showroom at Volvo Cars Design. This space is a large warehouse-like facility, where design reviews of physical car models often take place.

The virtual reality platform used during the test session was a HTC Vive, with Vive hand controllers and position tracking system. The scene was put up in Autodesk software VRED. Physical objects involved in the test were a car seat and steering wheel, tiled to the position of the objects in the virtual reality content. The setup allowed the participants to walk around the exterior of the car concept, as well as sitting down in the seat and rest the hands on the steering wheel to experience the interior of the car.

During the test session the only instructions the participants had were to sit down in the seat and inspect the interior of the car and to stand up and move around the car in virtual reality. They were also asked to use the hand controllers laser pointer function to activate an animation of the HMI device in the interior of the car.

7.3.2 Findings

From observing the employees engaging in the virtual reality experience, the general first reaction of the employees was positive and with great excitement. One of the participants said

> *"It is much more fun being in here, then out there"*

Most of the participants immersed themselves in the virtual world immediately, and quickly felt comfortable with the new experience. A few of the participants acted more reserved and wanted to go a little bit slower and take time to understand what was happening around them. The reason that some participants acted with suspicion and felt uncomfortable may have been the lack of previous experience in virtual reality.

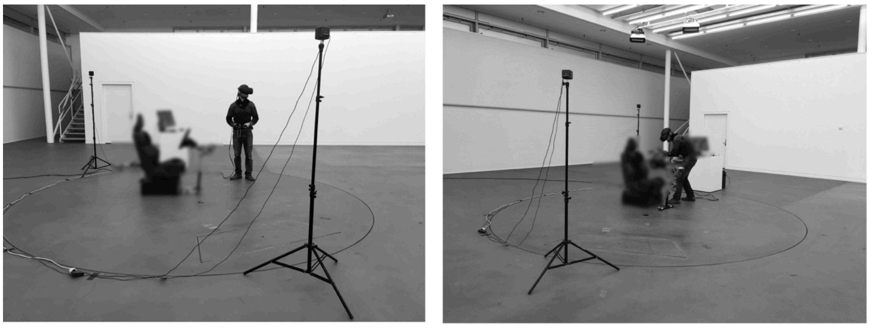


Figure 32
Interacting with a car in virtual reality

Some of the participants felt confused by the first interaction with the hand controllers. Mainly because they could not see their own hands as they grasped the controllers floating around in space. In a short amount of time, after being informed about the laser pointer selection function, they figured out how to use the controllers.

Many of the participants tried to grasp things, or expressed a wish to grasp things, which indicates that the experience did not live up to their expectations and was not coherent.

> *"I want to grasp things"*

Most participants interacted with the hardware in a similar way. The cord attached to the HMD needed to be handled in order for the participants to feel comfortable. The participants continuous checked were the cord was positioned to not trip over it. One of the participants griped it while walking around. This indicates that the form factor of the current virtual reality devices does not have a form factor that suits the use case.

When the participants sat down or stood up from the seat, they felt the need to take of the headset and observe how they were positioned in the real world. Not seeing the position of their bodies made it difficult to trust what they saw, and feel comfortable with sitting down or standing up.

The most common mentioned aspect for discomfort was related to the ground surface and the experienced position on the Z-axis. Some of the participants felt they were giants in the virtual reality, and some felt shorter. The perception of an in-accurate tracking of the own height stood out as the most frequently experienced aspect for breaking the immersion. Not seeing the own body may have contributed to the experience of not being grounded to the virtual scene. The absence of the own body also contributed to discomfort while the participants were sitting down in the car seat.

> *"I can't se my legs"*

When the participants immersed themselves in the virtual reality experience, employees that waited for their turn observed them. The atmosphere was joyful and seeing colleagues interact with the virtual context attracted laughter. Some of the observers expressed that the persons in virtual reality looked stupid, which made the participants engaging in virtual reality feel uncomfortable. Likely putting on the headset was not in line with the employees' self-image and not something they experienced as socially accepted.

> *"Don't laugh at me!"*

Another social aspect that was mentioned was considering hearing the voices of colleagues but not actually seeing them. The isolation in virtual reality made it difficult for the participants to divide what happened in the real world and what happened inside virtual reality, when inputs came from both at the same time.

> *"It is strange, you hear voices but when you turn around you can't see anybody."*

The setups with the tracking system on the stands were fragile. If someone accidently touched it, or stood in the way, the tracking would be distorted and had to be re-calibrated. This further indicates that the form factor of the current devices does not fit the context of the design studio.

7.4 User study: Virtual reality as a creative tool

7.4.1 Process

During the second user study designers and surface modellers got to try Google TiltBrush, a drawing tool in virtual reality. Employees at Volvo Cars Design were asked to join the discussion about working with virtual reality and got to try the 3D drawing tool TiltBrush on the HTC Vive. The participants were designers, managers, surface modellers and engineers. The majority had no or limited previous experience of virtual reality. Many of them had joined the previous workshop and were interested in trying out more virtual reality.

A virtual reality setup, similar to the one of the previous user study, was put up in the open office environment at Volvo Cars Design, where employees that walked by could join the discussion and watching colleagues interact in virtual reality, or try it themselves. There were about 20 employees of different professional roles that participated during the workshop. The user study occurred the middle of a common area with sofas and coffee tables, used for sitting down working, taking a break or having unofficial meetings.

7.4.2 Findings

Many of the walking by employees were interested in learning more about virtual reality and were enthusiastic about trying TiltBrush. Some of the walking by employees were interested but did not have time to participate, others walked by with the facial impression that said they thought it was silly and perhaps even a bit embarrassing to participate. Another notation is that there were only males joining the workshop.

Engaging in the TiltBrush experience was thrilling for the majority of the participants. They were amazed by the 3D dimensional depth effect that allowed them to create sketches in space. After some instructions they quickly understood the functions of the hand controller brush and pallet. A surface modeller expressed that he would like to have a HMD so that he could work with it from his desk.

An interior designer tried TiltBrush with the HTC Vive for the first time. After getting familiar with the functions of the hand controller and interface, the designer instantly started to visualize an idea for a car seat that he was working on.

> *"In TiltBrush I managed to get an understanding of my idea of a car seat concept in a very short time, much faster than I would from sketching it on paper and doing quick modelling in Alias." – Interior Designer at Volvo Cars Design*

The interior designer was very enthusiastic, and expressed that using similar software as TiltBrush as a tool for rapid conceptualization is something he would like to do in the future. Today he would make 2D sketches from scratch or on top of printouts of surface models, to gain fast insight of his ideas. He would also make quick surface models, or ask for assistance from an employee that works as a surface modeller. After finishing sketching the designer asked how he could access his work, and if it could be exported to Alias so he could show it to a surface modeller.

Figure 33
Tiltbruch as a creative tool

A lamp designer also picked up the hand controllers and rapidly drew up a sketch of a miniature car. When asked about the potential of using similar software as TiltBrush for quick sketches to conceptualize lamp design, he thought it could be useful to understand the different layers and complex structure of the parts inside the lamps (figure 33).

One participant was so exited by the experience that after he took of the HMD he asked when and how he could try it again.

> "This is the best thing I ever saw in my life." – Exterior Designer at Volvo Cars Design

When talking to a surface modeller about how the sketches are currently translated into surface models he responded

"In the start of a project it is not uncommon that a designer comes to me with a wide perspective sketch of one view of the car. In this stage the design is not fully thought through or in any way finished, and a lot of work is done to get all the missing pieces together in Alias. Sometimes the designer provides me curves to follow and that gives me a better start … when the designer wants to make changes to the design, I often have no visual material for guidance. The design is often modified from having a discussion while I am working on my model on the computer" – Surface modeller at Volvo Cars Design

The user study indicates that sketching software in virtual reality could be used for fast conceptualization and for creating material to support communication between designers and surface modellers.

7.5 User study: Virtual reality as a collaboration tool

7.5.1 Method

The user study of virtual reality as a collaboration tool was preformed with two activities; a focus group about the Facebook VR Social demo and a self-participating study of a shared reality demo with the HTC Vive.

During the first study a focus group about virtual meetings was conducted with a group of financial advisors that had experience of virtual communication and virtual meetings. The participants were invited to try virtual reality for the first time and to discuss virtual meetings in virtual reality, based on their prior experience of meetings via voice call and video call. The Facebook Social VR demo was used as a mediating mean for the discussion.

The HTC Demo with shared reality demonstrated how two individuals could coexist in the virtual reality experience while in the same room, as well as being represented with simplified virtual bodies in the virtual reality environment. The virtual body was represented with the shape of a head and transparent pattern representing a torso. From self-participation and observation, insights of the shared reality in virtual reality could be gained.

7.5.2 Findings

Facebook VR Social focus group

The participants expressed that when preparing for a virtual meeting it is important to plan the agenda and let the participants of the meeting learn about the agenda when the meeting starts. Building trust is the most important aspect for making a meeting successful. When you don't have a meeting face to face you cannot rely on that a yes in response means that the person has understood your message. When in a meeting and you disagree it is often because of misunderstanding. In that case it is good if you can take a step back and convey the right message.

> *"When you have a voice call meeting it is good to repeat the things the other person says and ask a lot of relevant questions. It is more difficult to explain things over the phone, when you don't have a whiteboard or something to help you … A positive thing about having meetings on the phone is that you always have your computer and can quickly search for answers for questions that you can't answer, even without the person on the other side of the line noticing it."*

The participants of the group interview believed it is easier to earn trust in a face-to-face meeting, but that it also requires more energy and preparation. Being face to face to someone creates confidence, but it can also make the people in the meeting be prejudice against one another. In a face-to-face meeting the first impression is very important and you have to think about what you wear and how you behave. Over the phone you can make white lies if necessary, that perhaps would not be possible in a real life meeting.

The participants agreed that even tough you can't see the other person on the phone it is easy to read the response from the person just from the sound of the voice. On the phone you have to choose your words more wisely, since there are less things to work with, such as eye contact and body language.

> *"In an online meeting you can be more effective, but it is also more common that an agreement on the phone is dismissed. It is as if the person you had a meeting with cools off when you hang up and changes their minds."*

Some of the participants used video calls on a regular basis. The benefits of using video calls was regarded as that you get to see one another and can use tools to visualize your message, such as explaining by drawing on a whiteboard. The reason for not using video calls was that is was inconvenient and they had not gotten used to it. Even though using video calls was regarded as a more sufficient tool than voice call, the tedious issue of getting the video call up and running was large enough to make them avoid using it for meetings.

After trying out virtual reality and having seen the demo video of Facebook VR, the participants were asked about the potential for having virtual reality meetings. The overall response was that it had potential. They liked the thought of being able to take people to places in virtual reality that concerned the meeting, instead of just referring to a picture on the website. They were a bit sceptic about using avatars, such as the ones used in the Facebook demo, and believed it could be awkward having a meeting with someone that looked like a cartoon character. However, they also believed that this is something you could get used to.

The HTC Demo

The experience of the HTC Demo was that you quickly recognized and interacted natural towards the virtual representation of the other person in the virtual environment, even tough the virtual avatar was only representing the head and a transparent torso of the individual that the reality was shared with. The experience was that you could make simple interactions with the other person, and from hearing the other persons voice you could also have a conversation.

During the demo it could be noted that in virtual reality users try to avoid breaking the illusion by for example to avoid walking through the virtual door of the car. Even tough it would be possible to walk through the door, the users consistently walked around it to seat themselves in the car seat.

7.6 Discussion

The focus of the project has not been to investigate improvements of the design process at Volvo Cars Design, but to identify the current needs and demands that the design process requires for the design operations related to prototypes. The study indicates that immersive technology has the potential to transform the design process itself in the future. The remaining part of the project will not consider changing of the design process itself. Instead it will implement the use of immersive technology based on the needs and demands of the current design process and operations with prototypes.

Participants in the study were mostly male and therefor not representative for all the employees at the Volvo Cars Design department.

The author of this report may be biased, because of pervious experience from working at the visualisation unit at Volvo Cars Design, which may have influenced the result of the study made at Volvo Cars Design.

7.7 Insights and implications

To motivate employees it is important to let them know the result of the work, as well as letting them experience responsibility for the result of the work and the work as meaningful or challenging. Virtual reality could be used to give more sense of meaning to the own preformed work, and how it correlates and contributes to the work of other employees.

The overall attitude towards virtual reality at Volvo Cars Design is positive and enthusiastic, although some individuals find it a bit embarrassing to engage with. In order for virtual reality to be a preferred tool it must cohere with the self-image of the employees.

Not seeing the own body in virtual reality made it more difficult to review the virtual car. Because of the absence of the own body going from exterior review to interior review was problematic for the employees. They felt insecure when they were to sit down in the car seat and kept on removing the HMD for this action. This implies the need for assistants in going from interior to exterior review. The problem can be related to the lack of vision-motor correlation feedback in the current virtual reality system at Volvo Cars Design, which further empathises the need to provide a virtual body in the virtual reality experience that aims to be used to evaluate design.

The isolation in virtual reality made it hard for employees at Volvo Cars Design to feel comfortable in the experience. Not seeing people you hear, and hearing them laugh, made them feel uncomfortable. This indicates is a need for a communication bridge between people in virtual reality and people in the real reality, for users inside the virtual reality to be aware of what happens in the real reality.

In virtual reality people tend to maintain the illusion and sense of presence themselves, by avoiding colliding with virtual objects, such as doors or walls. The study also shows that simple interactions can be made between people that share the virtual reality experience, that have simple avatars represented in the virtual environment.

The study shows that with virtual reality creative tools the employees could rapidly create three-dimensional sketches of their ideas, and earn insight of the concept that would not be gained from any other prototyping method in the same amount of time. Surface modellers and designers are in need of applicable tools to support the communication of how to create and modify a design. Virtual reality sketching could be efficiently used as such tool, for elaborating and sharing ideas quickly at Volvo Cars Design.

Building trust is described during the study as the most important factor for making a meeting successful. It is easier to build trust in meetings in reality, but it also requires more energy and time to prepare. In virtual meetings people tend to take agreements less seriously and it is easier to misunderstand one and other. In order for virtual reality to be suitable tool for collaboration and making decisions, making agreements and making sure they are implemented must be possible in the same way as in face-to-face meeting

In a meeting in reality the first impression is important, and it is easy to be prejudice against one another. In virtual reality norms and stereotypes have less influenced which can be used to create a creative and comfortable work situation for employees at Volvo Cars Design.

7.8 Conclusion

The study shows that the virtual reality experience could be utilized for the use cases investigated in this project. In order for virtual reality to be a reliable and efficient tool there are several aspects of the current virtual reality experience used at Volvo Cars Design that needs to be innovated.

08

Second orientation

8.1 A vision of a virtual design studio

At this point two directions could be chosen for the creation phase; to develop a virtual reality system that targets one of the professions at Volvo Cars Design, e.g. for advanced surface modelling, or to develop a tool that targets all employees, e.g. a communication and collaboration tool. The second opportunity for the creation phase was chosen and a vision for a virtual design studio took form.

The virtual design studio should favour accessibility, in order for it to become a tool that employees can use in daily activities. An approach that was decided for developing the solution was to avoid tying the solution to physical material and to a specific place. Hence the system should strive to utilize the possibilities that go with digitalization in order for it to be a collaboration tool to use by employees of the different design studios.

Activities in the virtual design studio have the possibility to not only replace real reality activities, but could also support tasks to enhance creativity and problem-solving with cognitive enhancement techniques. This could potentially enable designers and engineers to develop ground braking car design that is in line with the needs of customers and the environment.

Advanced virtual reality systems can collect biological fingerprints of its users. It could be used to customize the experience to the employee that is using it by brain monitoring, and by collecting emotional response from participants of a review to track the audience's emotional response.

In the design process there is a need for both abstract and concrete prototypes. The virtual design studio should be used to not only give direct experience of design proposals, but to showcase abstract prototypes such as sketches and inspiration material to convey an emotionally engaging experience of the design.

The virtual design studio should also be used by employees to learn about the different on-going car projects, much like they currently do at the clay model studio at Volvo Cars Design. When the clay studio is not accessible to all, a virtual reality version of it could be shared with all employees.

8.2 The components of a virtual design studio

The study covers many aspects of the virtual reality experience, from the physical space and the virtual space. To narrow the range of the solutions that could be explored in the creation phase, three components of the solution were identified from the findings of the study.

The solution will contain three components

- An immersive virtual reality system containing an natural user interface that allows for virtual embodiment of its users
- A virtual reality device with a suitable form factor and that enables virtual embodiment
- Physical props for posture support and tactile feedback

The physical props of the solution are only necessary when the user is in a seated position during a review of an interior car design. To narrate the scope the exterior design of the car will instead be targeted. Therefor the physical props will not be developed, but instead represented by a set of compiled requirements for such solution. The conceptualisation of this project will primarily focus on the virtual reality system and the device.

8.3 Focus for the creation phase

The focus of the creation phase is to design

(1) A solution that provides a rich direct experience, for the evaluation and exploration of car concepts in virtual reality, that support design decisions in harmony with the Volvo Cars customers and the environment.

(2) A solution in virtual reality that support collaborative design work, of employees with different professional role in different locations, and eliminates the effect of isolation and being constrained to the individual experience in the virtual environment.

(3) A solution that utilize virtual reality as a creative tool for employees at Volvo Cars Design, with the unique affordance of creating in the virtual reality space.

How to integrate the virtual reality system into the daily operations and the facilities of Volvo Cars Design will be considered for all three aspects of the solution.

8.4 Conclusion

The most critical problem identified with the current virtual reality system used at Volvo Cars Design is the experience of being a ghost in virtual reality. Ghosts are disconnected from the world around them, they cannot see their own body and are isolated to their own experience. A ghost is not a very successful creator or collaborator, nor does a ghost have the control or possibility to interact with their environment. In order to make virtual reality a pragmatic tool it needs to enable users to have fewer characteristics of ghosts and more of a human being.

For human beings to successfully preform cognitive tasks they need a body. They also benefit from having other human beings around them to discuss and come up with solutions to problems, as well as the assistance of external recourses that provides new insights and perspectives. A successful virtual reality system is smart and considerate, adapts to the natural behaviour of its users and helps them to achieve their goals.

The virtual car design studio

09

Needs and demands on a virtual design studio

9.1 Insights about the physical props

The possible solutions for the physical props can be divided into three levels of interaction complexity. The three levels of interaction complexity correspond to the trade-off between accessibility and immersion of the virtual experience of the system.

For rapid prototyping in an early stage of the design process, the accessibility of the experience is high priority. Therefor a lower level of interaction complexity is appropriate to use as decision support. For exterior design reviews, however, no physical props are needed for decision support in an early stage of the process.

In a later stage of the design process, when the design is more detailed and the immersion of the experience is a priority, physical props with more complex interaction can be used as decision support.

9.1.1 Level 1 – Proprioception posture

The first level of interaction complexity involves physical props that offer support for a proprioception posture, while seated in an interior of the car, and is dedicated for interior design review. This level includes no physical interaction with the design of the car, but gives the possibility for users to have a balanced seated position when experiencing the interior of a car design.

With this level of interaction the spatial features, size, style, colour, shape and car in context can be evaluated. These were the features that employees regarded as the most important for evaluating design proposals, and the first level of physical props will give sufficient haptic support to make experience of the prototype in the virtual design studio a see but not touch interaction, comparable to the experience with clay models that is used in the current design process.

9.1.2 Level 2 – Active posture

The second level of the physical props offers the possibility to experience the active postures that the driver can have in the car. The currently used physical props at Volvo Cars Design, that involves a car seat and a steering wheel, are incomplete physical props of the second level of interaction. To complete this solution a study of the active postures that a driver can take while driving the car needs to be made, and the physical props should offer support for the identified active postures for consistency reasons.

The study shows that in the current design process at Volvo Cars Design, evaluation of driving experience is not regarded as important. However, the new possibilities that immersive technology offers for evaluating the driving experience can potentially have an effect on the design evaluation process at Volvo Cars Design.

The active postures that the driver can take when driving have not been investigated in this project. Therefor a solution for the second level of interaction complexity will not be included in the conceptualization of this project.

9.1.3 Level 3 – Physical interaction

The third level of the physical props offers consistent haptic feedback for all interactions with the car, such as opening a door and pushing a button on the console. This level of interaction complexity can be used to evaluate touch and human interaction. These were features not regarded as important for evaluation by the Volvo Cars Design employees. However, the result from the study only validates the needs for the current evaluation process at

Volvo Cars Design, and does not imply that there is no value in evaluating these features for making design decisions.

The third level of physical props can be used late in the design process when details about human interactions are to be evaluated. Such evaluations would potentially be valuable for ergonomic evaluations of the design.

The third level could also be used for evaluations of HMI interactions, and would potentially add to a pragmatic system to review the design proposals from the interaction design unit at Volvo Cars Design. However, to demonstrate the design of a HMI interface, that does not involve excessive user testing, the first level of interaction complexity can be used.

The third level of interaction complexity for the physical props will not be investigated in the conceptualization phase, because the primary users of this solution would be Volvo Cars employees working in other departments than design.

9.2 Requirements for the first level of physical props

9.2.1 Function

The main function of the physical props of the first level is to support a balanced posture of the user while reviewing an interior of a car design and offer the possibility for the users to sit down.

The physical prop should be an add-on to the system and not necessary to access most of the features of the virtual reality experience of the virtual design studio. Hence the system should not be built around the physical props, but the physical props can be used to amplify the sense of presence of the experience.

- Offer posture support for all car seats in the car design for both situations with one user and with a group of users
- Be adaptive and align with car designs and differently shaped virtual prototypes
- Easy to store in the facilities of Volvo Cars design

- Be possible to move to the different facilities of Volvo Cars Design
- Easy to set up for all employees at Volvo Cars Design
- Possibility to upgrade, maintain and repair

9.2.2 Appearance

The physical props will be used in situations where it is important to maintain the illusion of the concept that is being presented in virtual reality. The appearance of the physical props should not be tied to a specific design, but should have the prototypical features that are associated with the seats of a car. The overall appearance of the physical props should align with the brand identity of Volvo Cars.

- Follow the brand identity
- Invite and appeal the user
- Have the prototypical features of car seats

9.3 Requirements for the system

9.3.1 Function

The main function of the system is to support the activities at Volvo Cars design that concern making design decisions, and to some extent also support elaborating and communicating possible ideas and solutions for the design.

- Support making decisions of the design
- Support the creation of ideas and solutions to the design
- Increase understanding
- Improve communication
- Increase the effectiveness and efficiency

The system should provide rich direct experience, for the evaluation, education and exploration of car concepts in virtual reality, that support design decisions in harmony with the Volvo Cars customers and the environment.

A rich experience of the car design

- Appearance – Style, colour, size, shape, material

- Functions – Interface, controls, human interaction

A rich direct experience of the ambient factors of the car design

- Context – Locations, weather, lighting, sound, infrastructure
- Users – Interactions, concerns, ambitions, aspirations

The system should also enable collaborative design work, of employees with different professional role in different locations, and eliminate the effect of isolation and being constrained to the individual experience in the virtual environment.

Means for employees at the different design studios to organize and preform tasks associated with the design operations

- Design evaluation
- Unofficial meetings
- Meetings
- Design presentations
- Creative sessions
- Documentation of discussions and decisions

Finally the system should allow the employees to preform creative work in the virtual reality space, for rapid prototyping and to quickly create content that can support collaboration and design decisions.

Create abstract prototypes to explore solutions

- Free 3D sketching
- Simple vector curves
- Capture views
- Document the work
- Review progress of a project

Create an ambient experience for presenting design

- User experience
- Sound
- Lighting
- Environment
- Abstract prototypes
- Storytelling

9.3.2 Affordance

The system should provide the user with clear affordance of the interactivity, so that they feel comfort and trust.

- To maintain the coherence and preserve the immersion of the system, clear affordance of the user's agency should be empathised inside the experience, about virtual objects that are interactive and not interactive

- To maintain the consistency and reliability of the system the user should receive clear affordance of what physical props that are available

- To keep the user informed of the surroundings, the user should receive clear affordance of what happens in the real world.

9.3.3 Appearance

The appearance of the system should cohere with the brand identity of Volvo Cars Design, and should not have an impact on the car design.

- Fit the identity of Volvo Cars Design
- Be subtle
- Possibility to customize
- Invite and appeal

9.3.4 Smart and considerate

The system should be smart and considerate to its users, by remembering, taking an interest and help the user to avoid mistakes

- Remember choices
- Anticipate needs
- Inform about system status
- Allow users to fail gracefully
- Reduce navigational excise

9.4 Requirements for the device

9.4.1 Function

The main function of the device is to provide a state of the art virtual reality experience where a body of the user is present. The virtual body will ensure that employees can act natural towards the virtual environment and have accurate embodied cognition during evaluations. The function of the device is also to provide channels for input that enables natural interactions with the virtual reality system.

9.4.2 Form factor

The form factor of the device should allow the user to be comfortable, both in the aspects of functionality and self-confidence. It should not distract the user and allow them to focus on their tasks.

- Be comfortable
- Be appealing
- Allow the user to focus on the task
- Easy to store

9.4.3 Input method

The input method of the device should be based on natural interaction, be easy to use as well as task orientated.

- Natural interactions
- Avoid skeumorphism
- Pragmatic
- Easy to use
- Reliable
- Fit the needs of the different use cases

10

Conceptualization

10.1 The Volvo House

The first step of the conceptualization phase was to ideate on the specific purpose of the virtual design studio. The purpose of the virtual design studio was decided as follows.

The virtual design studio is a place where employees from all the different design studios of Volvo Cars, to discuss, explore and share experience. The virtual design studio is accessible from all of the design studio locations, so that there is no need for on part to travel oversees to visit another. The virtual design studio is familiar and comfortable, here no one is a visitor and everyone can be a host.

The next step was to create a virtual location for the virtual design studio. The virtual location that took form was assigned the work title The Volvo House. To create an atmosphere where employees could thrive, as well as an environment that would complement the design presentations held within the virtual reality context, the Volvo Cars brand guidelines were used as means for generating ideas. An inspiration board was also created to illustrate the vision for the virtual design studio location.

Figure 34
Inspiration board The Volvo House

Sketches were made as a first step to test various designs of The Volvo House, where inspiration was gained from studying the Volvo Cars brand guidelines, the inspiration board and the facilities at Volvo Cars Design.

After making sketches on pen and paper, rapid prototyping was made in the software Tiltbrush to evaluate the ideas in virtual reality.

Adjustments were made to the initial concept based on virtual reality evaluation in TiltBrush. Thereafter a digital model of The Volvo House was made, that was also evaluated in virtual reality with the software Autodesk VRED.

Figure 35
TiltBruch sketches of the Volvo House

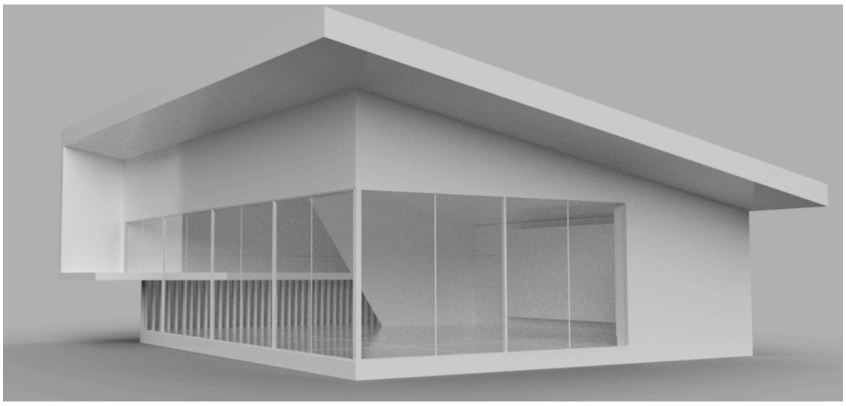


Figure 36
Early digital model of The Volvo House

10.2 The interface

10.2.1 Interaction

How the user would interact with the interface inside the experience was conceptualized. An idea generation of how the interface was to be controlled was made. Different gestures and different body parts or object to tie the interface to were elaborated from sketching with pen and paper, and from sketching in the software TiltBrush.

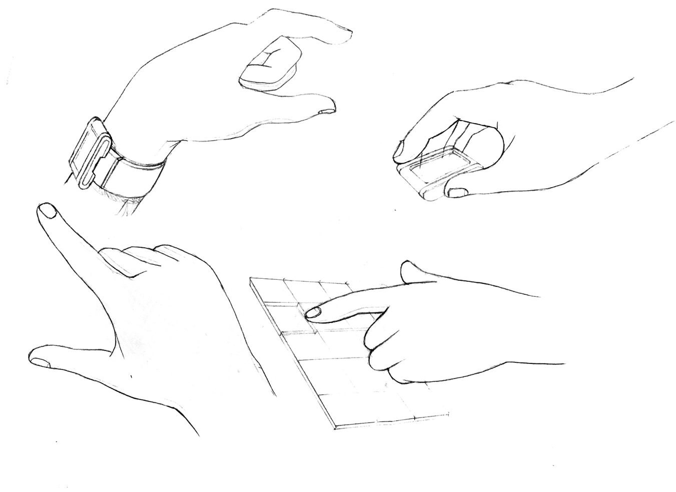


Figure 37
Idea sketching of the interface

Tying the interface to the arm wrist was the solution that during self-participating testing was experienced as the most pragmatic way for the use cases of the virtual design studio.

10.2.2 Affordance

An important aspect of the interface was to create rules that the user could depend on, in order to maintain the sense of presence. Different ways of providing the user with clear affordance between interactive and non-interactive objects and between objects that exist in the real world, and objects that only exist in the virtual world were explored.

Because of the need for the virtual design studio to provide users with a realistic experience of the car prototype, and because of the limitation in providing accurate haptic feedback from interacting with the digital prototype, the following rules were decided for the interface

- Interactive objects - Everything that has a non-realistic or virtual style can be interacted with e.g. holograms or high-polygon shape.
- Non-interactive objects - Everything that appears realistic cannot be interacted with.

10.2.3 Design framework

A design framework of the interface was created, in order to decide on a form factor and to structure functional elements and data elements into groups.

Figure 38
Design framework for the interface

DESIGN FRAMEWORK

FORM FACTOR

A virtual reality head mounded display for visual and audial output
Gestures and voice for input (NUI)

FUNCTIONAL ELEMENTS

To enter and exit the virtual design studio

To be aware of the physical and social surroundings

To prepare the virtual design studio
Choose lighting
Choose time of day
Choose weather
Choose location

To prepare the car design
Import car surface data
Place car in the virtual design studio
Choose variant/Create variants
Choose material/Create materials
Enable/disable surface data

To gain insight
Learning by seeing, from scenarios with virtual contexts and users
Learning about on-going projects
To collaborate
Have meetings
Take notes
Make a presentation
Give/receive feedback
Review surface models
Review abstract models
Review an experience

To evaluate
Measure
Rotate
Compare
Transform/move objects
Flashlight
Split

To create
Capture 360°
Capture view
Capture standard views
3D sketching
Vector curve

DATA ELEMENTS

Surface data car
Interior
Exterior
Wheels
Lamps
Rims
Variants
Materials
Abstract models
Captured pictures
Renders
Sketches (2D and 3D)
Inspiration material

Data about the user
User data/preferences
Biometric data
Avatar

Data about the virtual environment
The Volvo house
Lights
Environments/HDR
Sound/music
Information of the real world

Data about the car project
Project group
Stage in the process
Deadlines
Messages/notes

Customer data

Contextual data

Competitor data

10.3 The virtual avatar

10.3.1 Implementation of an avatar

The virtual avatar is an important feature of the virtual design studio and to be able to implement a virtual body into the experience, different existing technologies that could provide a virtual body were studied in the exploration phase of this project (see section 6.3.3). From the insight from the exploration, two different types of virtual avatars were identified for the conceptualization.

The avatar representation can be an image of the real body that is separated from the real image and integrated to the virtual world, such as in the Intel Alloy project that illustrated the integration of a real image of the hands into virtual reality (see section 6.4.1). It can also be a computer generated virtual body that is constructed from tracking the movement of the real body, such as the Vive hand controls that tracks the position of the hands and provides a virtual hand in virtual reality, or a real body image that is translated to a virtual body such as with the Leap Motion device.

In the virtual design studio, the system should provide users with an alternative virtual body, since the possibility to embodying another body than the own body is an effective method to understand the perspectives of others.

Figure 39
Two types of avatars

10.3.2 Avatar resolution

The different technologies have the possibility to provide different levels of refined virtual bodies. Therefore how the refinement of the virtual body would affect the use cases of the virtual design studio was investigated. The virtual avatar was divided into three levels of interaction and communication opportunities for the use cases of the virtual design studio.

- Low-resolution avatar
  The contextual and observing avatar

- Medium-resolution avatar
  The collaborative and interactive avatar

- High-resolution avatar
  The emotional and social avatar

The low-resolution avatar has walking, standing and sitting animations, and can be used for navigation and positioning in the virtual environment. The user that inhabits the low-resolution avatar has the possibility to observe the environment, and has limited capability to interact with virtual objects. In a shared reality the low-resolution avatars are reactive towards each other and can motivate actions.

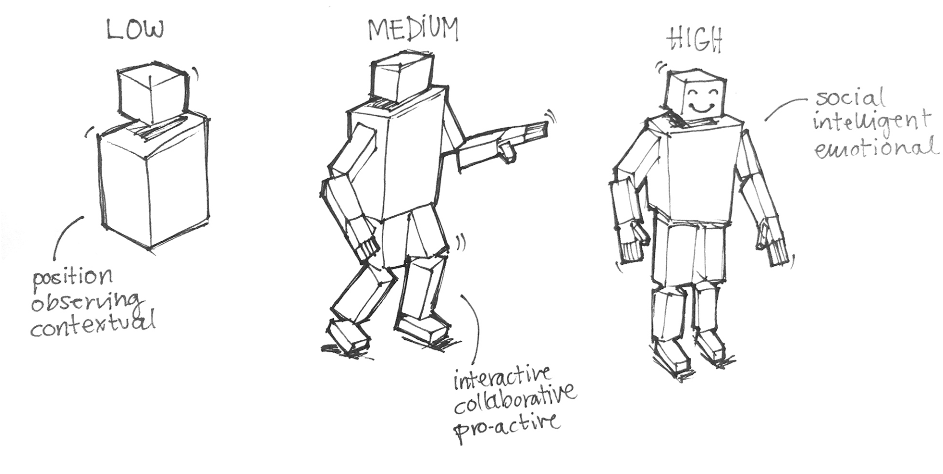


Figure 40
Avatar resolution

A head and a torso that follows the position of the user in the virtual environment represent the low-resolution avatar. This avatar also indicates to other users where the user is positioned and directing their gaze. The low-resolution avatar can stand alone only interact with the environment with gaze, but can be accompanied with conventional hand control to enable further interaction.

The medium-resolution avatar has detailed motion-captured animations, for complex behaviour and social attention. This avatar is adaptive and proactive, and enables the user to interact with virtual objects and other users in a natural way. The medium-resolution avatar will allow for embodied cognition to process information from the virtual context.

A full body that follows the precise movements of the user in the virtual environment represents the medium-resolution avatar. The medium-resolution avatar can interact with the virtual environment from gaze, making gestures and from using conventional hand controls.

The high-resolution avatar can represent speech, synthesis, emotions, dialogue and management with facial expression animations. The high-resolution avatar is intelligent, social and conversational and can communicate and interact with the virtual environment in a highly natural way.

The high-resolution avatar would have been ideal for the use cases, but because of the challenges in providing such avatar, a medium resolution avatar is sufficient for the use cases.

10.4 The device

The purpose of the device is to track the physical environment to prevent the user from harm, as well as keeping them informed of their social environment to prevent isolation from the real world. The purpose of the device is also to provide the user with a virtual body and the opportunity to navigate and interact inside virtual reality. The device should allow the user to communicate with other users with their voice and body language.

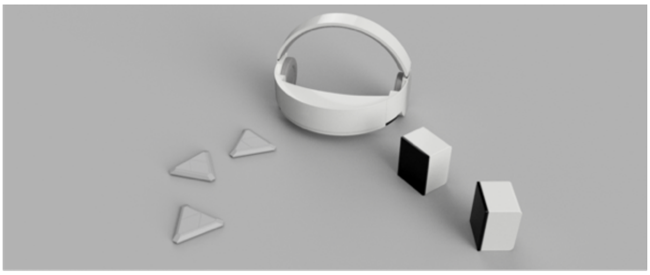
As described in the exploration phase immersive technology devices can either use inside-out tracking or out-side in tracking to track motion in virtual reality. It can also be based on either optical methods or non-optical methods (see section 3.5).

In the conceptualization phase the different technologies to track motion and track objects in the real world were investigated for the use cases of the virtual design studio, and three different concepts for the device were put together

Figure 41
Three concepts for the device

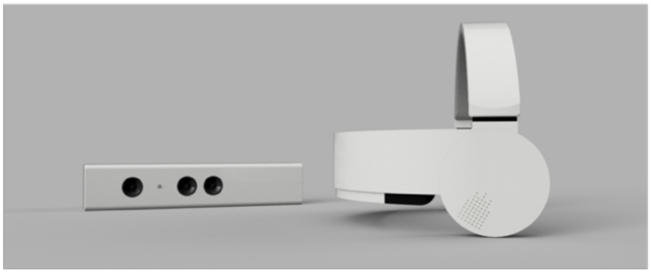
Concept 1

The first concept for tracking is based on outside-in non-optical tracking. The device relies on the same technology as the HTC Vive, where the smart trackers are placed on the body to detect motion.



+ Implementable with current virtual reality devices used at Volvo Car Design. Accurate and precise tracking that is not limited to camera resolution.

− Inconvenient to wear trackers on the body, and each tracker needs to be smart enough to calculate position and orientation. A stationary setup with cameras that is not possible to track hand gestures.



Concept 2

The second concept use outside-in optical tracking, and relies on the same technology as the Xbox Kinetic to track motion.

+ Convenient with no trackers attached to the body and is implementable with currently available consumer devices.

− A stationary setup with camera (although easier to setup than alternative 1), and requires CPU for image processing.

Concept 3

The third concept is based on inside-out tracking and optical methods for tracking motion. The technology used for the third concept is similar to the one used in the Leap Motion device.

+ An accessible solution that does not involve any setup and is convenient to wear with no markers on the body.

− Can lead to a limited field of view and CPU heavy calculations. The solution is not implementable with available consumer products and it can become a challenge to provide a full virtual body.

For a gesture interface optical tracking is the most efficient, as illustrated in the second concept. The first concept that is based on none-optical tracking is therefor not a suitable a method for the virtual design studio.

The most suitable form factor of the device can be achieved with inside-out tracking, illustrated in the third concept. There are several issues that need to be solved by developers of immersive technology devices before the virtual design studio can rely on inside-optical tracking for full body motion tracking. However, with the rapid technology progress it is likely that the third alternative is the most pragmatic choice for the virtual design studio. Until inside-out body tracking can be achieved, the second concept can be used as a substitute.

To fully support the use cases of the virtual design studio the device should enable a gesture interface. Since hand controls are necessary for precision tasks, such as making sketches, the third concept should also support the use of a hand held tool.

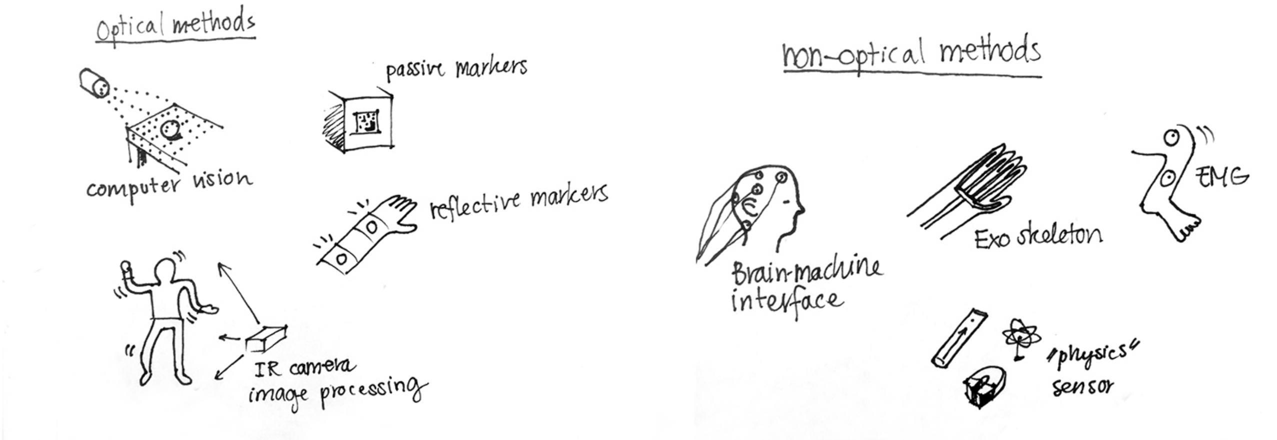


Figure 42
Idea generation for the device

10.5 The physical props

During the conceptualization phase, various solutions for the physical props of the first level of interaction were investigated (figure 42).

The first explored solutions were based on passive haptic, but the main issue with these solutions is that they make the virtual design studio less assessable. To make the virtual design studio truly accessible, the solution had to be found in the context of the use situation.

An object that is commonly found in an office environment is a regular chair. Instead of developing a solution based on a physical object, a solution for the physical props needed to be integrated into the digital environment of the system.

The problem with the physical props could be solved by using redirected passive haptic (see section 6.3.4) from using a regular chair and by avoiding tasks that would break the sense of presence of the user.

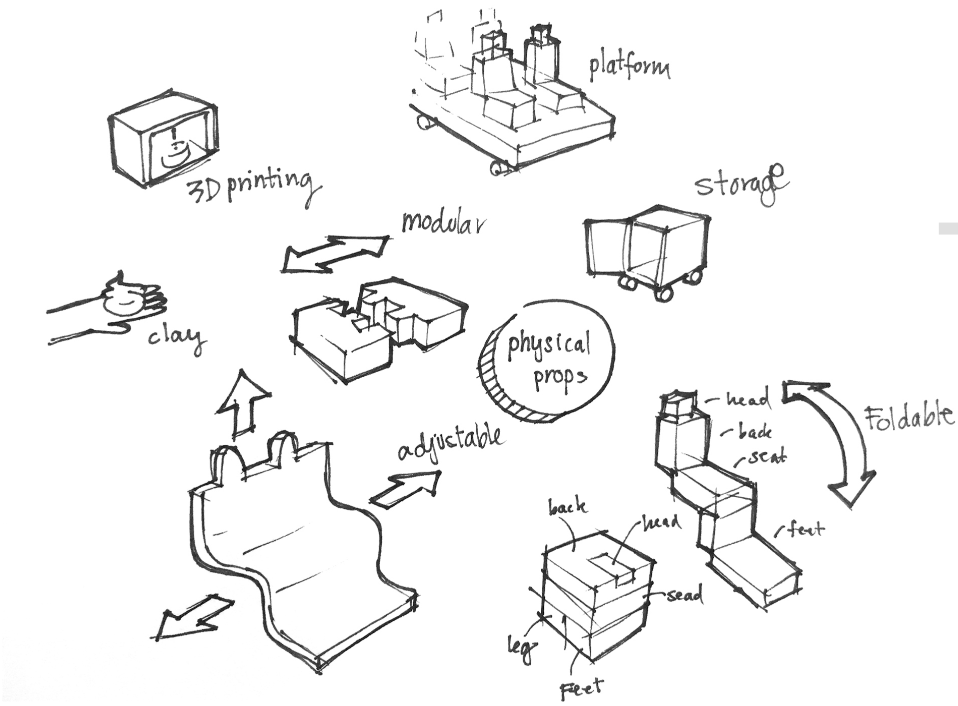


Figure 43
Solutions for the physical props

While the user is in a seated position in the car, redirected touch can map the user to a correct position inside the virtual design studio, however a challenging task is when the user is stepping in and out of the car. During the study made at Volvo Cars Design, this was also the task that made users the most uncomfortable in virtual reality. The study also indicates that interior and exterior reviews are usually preformed separated, mainly because interior and exterior design have different assigned design teams.

Stepping in and out of the car might force the user to collide with virtual objects, which is something that should be avoided. If the user safely can take a seat in the real chair before entering the virtual reality experience of the interior of the car, the experience of stepping in and out of the car would potentially be more comfortable.

Another obstacle is that the posture the user has in the real chair will not be identical to the posture inside the virtual car. The study indicates that a user can embody a virtual avatar that is different from the own body, as long as the avatar responds to movement in a correct manor (see section 6.3). This implies that the virtual avatar can have a different posture than the real body, and the user will still feel comfortable and accept the virtual body as their own. Using the effect of virtual embodiment can be a solution, however, the consequences for the use cases are not certain.

In a collaborative session the system should prevent users to take a seat in the same virtual car seat. If the users inside the virtual design studio are also located in the same physical space, the system should have this in consideration, so that users do not bump into each other in the virtual space or in the real reality. Allowing the HMD-devices to communicate and be aware of each other could solve this.

11

The final concept

11.1 The Volvo House

The Volvo House is the location where the activities of the virtual design studio will take place. The Volvo House can be used for all levels of meetings, from unofficial meetings to design boards, since it is always available to all Volvo Cars Design employees. It is also a place where employees can visit to be updated about current projects and to feel motivation and responsibility for their own contribution.

The house is furnished with power walls and canvases that employees can use to review abstract prototypes, such as sketches or inspiration boards.

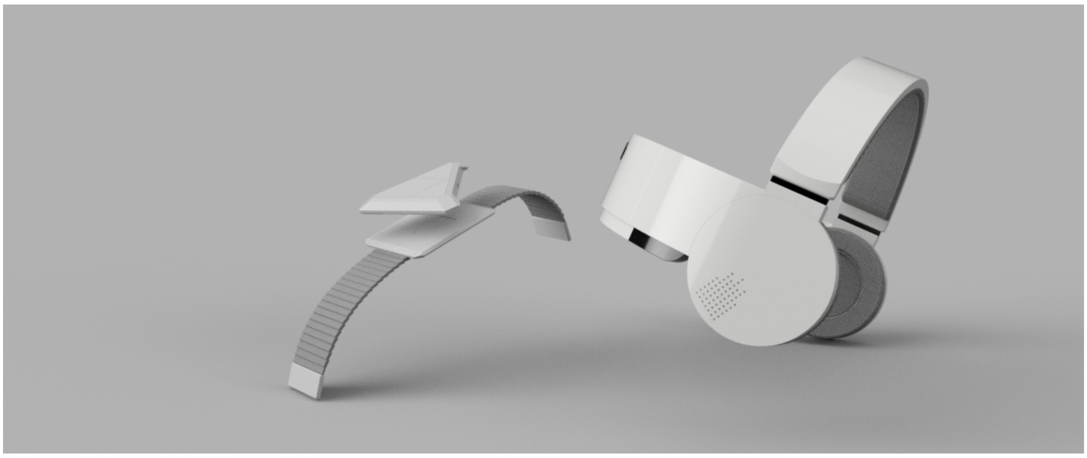
The user can manipulate the studio by choosing different lights, to transform the light signatures in the car paint, and rotate the car to find the perfect angle of the design. To get the right look, different themes of the interior of the house can be chosen. Inside the Volvo House, the user can also choose different viewpoints, such as up on the balcony or out side. The full concept of The Volvo House follows the metaphor cool inside, warm inside.

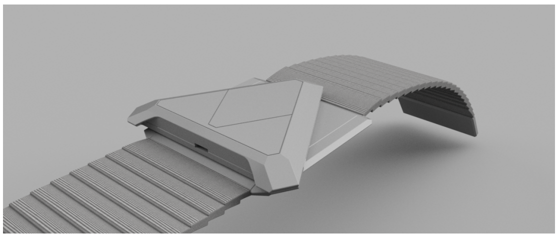
Figure 44
The Volvo House

11.2 The Device

The device is a wireless HMD with inside-out tracking, based on optical tracking methods. The HMD is combined with a wrist control that can be used to launch and control the virtual reality experience with gestures and touch input. The wrist control has a detachable hand tool that can be used for precision tasks. To track the position of the hand held tool, the HMD relies on the same cameras used for tracking the motion of the body. The HMD will detect infrared light that emits from passive markers on the hand tool to positioning it in space.

The HMD enables an alternative virtual body in virtual reality, as well allowing users to control the environment with gestures, touch input and voice control. The device is easy to store in the facilities of Volvo Cars Design, has a design that coheres with the Volvo Cars Design identity as well as being appealing and comfortable to wear for the employees.





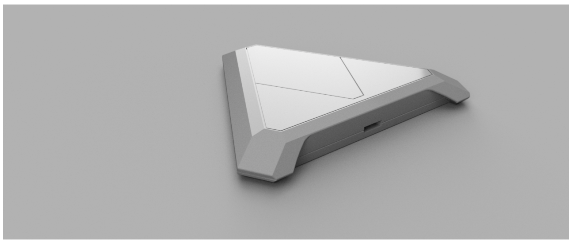


Figure 45
The Device

11.3 The natural user interface (NUI)

The NUI of the virtual design studio is launched from using the wrist control, and is tied to the wrist of its user. The interface has the shape of a wheel; with four circle sectors that divides the interface's functional elements. The four circle sectors are
The Volvo House, The Volvo Cars, collaborate and create or evaluate. In the middle of the interface there is a button to activate the conversational interface Ili.

The interface is individual and navigated from the arm wrist, which makes it available for the users at all time when walking around in the virtual design studio.

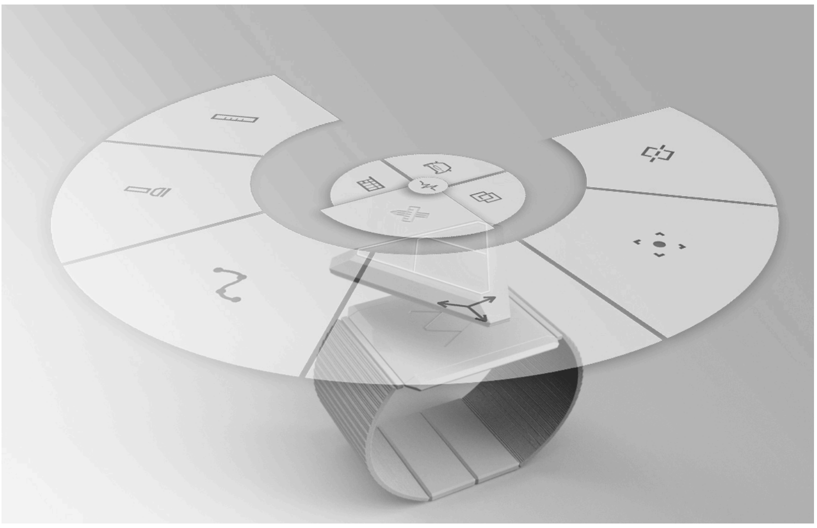


Figure 46
A NUI for the virtual design studio

The interface has a subtitle design that coheres with the appearance of the Volvo House. To give users the right expectation about interactivity, the interface has an unrealistic look that matches the rule that interactive objects look un-realistic in the virtual design studio.

The interface is primarily based on icons, because of the difficulty in reading text in virtual reality. Subtitle animations and spatial audio provides the user with feedback when interacting with the interface.

The AI assistant Ili, allows for natural language processing and adds to a conversational interface for fast interactions and short commands. For users, to use voice to call for actions from Ili feels more natural inside the virtual environment, than with conventional screen based devices.

The first circle sector, The Volvo Cars, allows for users to select surface data, change or edit materials and variants and activate and animations that demonstrate functionality.

The second circle sector, The Volvo House, allows user to control the environment were the car concept is depicted, from customizing light, materials, environment, viewpoints and themes. From this control the users can also review prepared experiences that provides a direct experience of user situations and user contexts.

The third circle sector, Collaboration, enables users to communicate and interact with other users in the virtual design studio, as well as allowing them to se a window of the real world. They can also enable the RR mode to be informed about the physical objects that exists in the real environment they are in.

The forth circle sector, Creation & Evaluation, provides the user with a set of tools that can be used to interact with the virtual car model.

11.4 The physical props

The solution to the first level of physical props is an office chair, supported by a system that can transform the experience in the real world to align with the experience in virtual reality. Since the first level of physical props does not involve direct physical interaction with the virtual car model, the virtual car model can be disabled and instead information about the position of the chair can be provided to the user when they are to take a seat. When the user is in a seated position they can then choose which virtual seat they want to be in and the virtual interior car model can be enabled tiled to the new position of the user.

Although the physical prop can be any chair, a concept sketch for an office chair that fits the brand identity of Volvo Cars Design, as well as having the prototypical features of a car seat was made in the conceptualization of this project.

Figure 47
The physical props

11.5 A forum for collaboration, new perspectives and to be empowered

The final concept of the Virtual Design Studio illustrates a vision for how Volvo Cars Design can work with immersive technology in the future.

The Virtual design studio provides a rich direct experience, for the evaluation and exploration of car concepts in virtual reality, and supports design decisions in harmony with the Volvo Cars customers and the environment.

The virtual design studio supports an efficient workflow, where employees can zoom out and see the whole picture of what they are designing to detect potential bottlenecks of car projects.

The accessibility of the virtual design studio makes it a platform that can keep employees informed and updated about the progress in design projects so that they find motivation and are well prepared for the challenges they are facing.

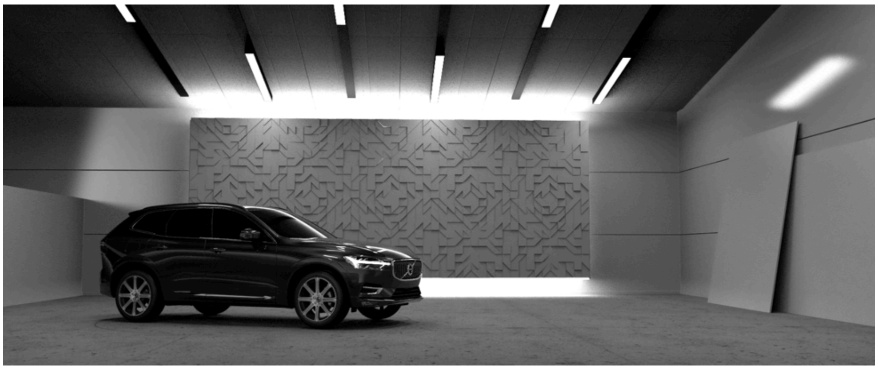


Figure 48
A rich direct experience

The virtual design studio supports collaborative design work, of employees with different professional roles in different locations, and eliminates the effect of isolation and being constrained to the individual experience in the virtual environment.

The Volvo Cars Design employees are developing the cars of the future, but with this come pressures. Meetings in person requires energy and time, and with the virtual design studio employees have access to a platform that enables them to interact with colleagues at any given time without requiring excessive preparation.

The experiences in the virtual design studio will allow the participants of the virtual meetings to be engaged much like with physical prototypes.

Figure 49
A place for collaboration

With the explicit possibility to create in space that is enabled with virtual reality, and with the assistance from computer generative design tools, the virtual design studio will support the Volvo Cars Design employees to develop the cars of the future.

In the virtual design studio employees can keep focus on their tasks and focus on information that is valuable, without distractions from the surroundings. Here the employees will feel empowered by a mediating exo-self, with a user interface that adapts to its users and provides them with tools to amplify their skills.

In the future cars will be design around the activities of users inside autonomous cars. The virtual design studio will be a suitable platform to simulate use situations, and give the employees the insights they need to develop car designs that are adapted to the needs of the customers.

Figure 50
A creative tool

12

Discussion and concluding remarks

12.1 Process and methods

This section discusses how the process and the chosen approach affected the project.

The project had a broad aim to investigate in what ways immersive technology could be used in design operations at Volvo Cars Design. Because of the broad scope it was important to initiate the project with an exploration phase. Since it was not specified in the beginning what direction immersive technology at Volvo Cars Design should be developed, the exploration made it possible to narrate the scope for possible solutions in the creation phase. Because of the broad scope the project took a strategic rather than an operational approach, by developing a vision for immersive technology at Volvo Cars Design, rather than a well-defined and refined concept.

A conclusion can be made that having a broad approach throughout the project was necessary to be able to find a solution that corresponded to both the technology progress of immersive technology and the requirements of Volvo Cars Design. However, such an inclusive perspective to the project meant for handling a significant amount of information, thoughts and ideas, which added to complexity and required time. Considering the time frame of this project, further narrowing the scope of the conceptualization phase may have been beneficial for the project outcome.

12.2 Result, insights and challenges

This section presents a discussion that evolves around the findings form the project.

The aim of the project was achieved through the excessive study made in the exploration phase, which gained knowledge about future opportunities and possibilities of the use of immersive technology. The parallel exploration of the Volvo Cars Design department made it possible to identify the use cases of immersive technology, so that the project aim to find an approach for immersive technology at Volvo Cars Design was achieved.

Much of the research regarding immersive technology is still in an early stage, and is far from explaining every aspect of the truth. Research used for this project about immersive technology needs to be validated with further research, and therefor the interpretation of the result of this project is that it indicates what the future will be, but that the result is not definite.

A reflection on environmental impact of using immersive technology in the design process is that designers and engineers will gain more insight from direct experience of their creations. From this product development can be more in harmony with people and earth. There will also be less material resources used for building physical clay models.

Working more efficiently with digital prototypes will be much more cost efficient than using clay models. However, the cost of implementing immersive technology will primarily be the time and resources invested to develop a valuable process and a system. For the development of the system Volvo Cars Design is dependent on external hardware and software developers. Therefor collaboration and exchanging experiences with stakeholders as well as enterprises engaging in similar activities will accelerate the development of a suitable process and system.

12.3 Recommendations for future work

12.3.1 General guidelines

Since there are few standards for the immersive technology, the first recommendation for further work at Volvo Cars Design is to follow the following general guidelines that were identified through out the work with this master thesis project

Sense of presence

- Neither coherence or immersion should be neglected in an experience in order to preserve the sense of presence
- The level of accessibility and interaction complexity correlates with the immersion of the experience, and a decision to favour accessibility or immersion need to be made for all use cases
- Integration of virtual objects and immersion correlates so that in an alternative reality experience, real world objects must be well integrated into the virtual environment to achieve immersion
- Users should not be forced to collide with virtual objects, because it can break the sense of presence. People often maintain the immersion themselves and avoid colliding with walls and doors, or step out of a cliff, even tough they can
- Objects in virtual reality do not have to be realistic, they only need to respond and behave consistently

Interaction

- Users in virtual reality should be allowed to interact in a natural way. As soon as users try to interact with something as they do in real life and it does not respond, the immersion is broken. Therefor it is important to construct rules for the virtual environment and be sure not to break them, so that users can have expectations accordingly
- There are a lot of unpredictable reactions from different people in virtual reality, therefor it is important to test the experience frequently

- Avoid being over literal (skeumorphism) and use cues from the real world when it is helpful, but take advantage of the fact that the physics and character of virtual environments are flexible

- Users learn from observing others preforming a task and is something that can be used in the virtual reality context

Feedback

- The more there is to see, the less the users remember. The users direct their own gaze and need guidance in where to direct their attention. The visual sense dominates, but the other senses can be used to give feedback and further direct the users attention

- Giving visual feedback about how the own body interacts with virtual object is necessary for the embodied cognition to function, and a virtual body should be highly prioritized in virtual reality

- Sound is a critical detail that should be used to help users situate themselves and to focus on their task

Comfort

- The user of the immersive technology system should be informed about their physical surrounding, to prevent confusion or harm

- In order for the user to feel comfortable in the virtual reality experience, clear affordance of what is real and what is virtual is needed

- Do not attach things to the view of the user, because it can be come uncomfortable if you can't look away from something

- Matching the height of the user to the users eyes is important since not being grounded will make users feel uncomfortable

- Anything closer that 0.5 m away is difficult to focus on. Anything further away than 20 m will lose depth and will be experienced as flat. Naturally with the current virtual reality devices, users will focus 2 m away, and therefor 2-10 meters is a comfortable distance to the user to place objects.

12.3.2 Recommendations

The next step for Volvo Cars Design is to determine the future purpose of immersive technology at Volvo Cars Design. This will be done from continuing to evaluate the operations that are already implementing immersive technology and from keeping informed about the progress technological progress of the industry.

Volvo Cars Design is very dependent on the different stakeholders specified in this project that are involved in creating the vision for the virtual design studio. To access a virtual design studio, Volvo Cars Design need to notify software and hardware developers about their needs and demands, so that the future of the technology can deliver a system that can realize the vision for the virtual design studio. Exchanging experiences with enterprises that engage in similar activities will also support the realization of the virtual design studio.

The immersive technology should not be viewed upon as replacing the real reality, but as a powerful digital platform that can provide new perspectives towards the real world, by improving e.g. collaboration and creative work. Having this in mind will allow the use of immersive technology to focus on what it is best capable of achieving.

A significant finding of this master thesis project is that having a virtual body in virtual reality is of great importance for the studied use cases. The current customer devices for immersive technology do not provide a full virtual body in the alternative reality. However, the possibility the for customizing the available devices to fulfil the need for a virtual body exists and is something that Volvo Cars Design should take advantage of.

The form factor of the future will make immersive technology more accessible than it currently is. This is something that Volvo Cars Design should keep in mind, to not overcomplicate the use and strive to make operations that involve immersive technology accessible and convenient to use for the employees.

Because of the complications in providing consistency in a system that have complex haptic feedback, it is important to find insight in when, how and why it is to be used.

Not all things that is possible to with immersive technology have a pragmatic value to the design process. Therefor Volvo Cars Design should find an approach towards using the methods explained in this master thesis to support the alternative reality experience.

12.4 Summary and concluding remarks

This master thesis uncovered several aspects that are of importance for establishing the use of immersive technology aided design operations at Volvo Cars Design.

The thesis divided the immersive technology into achieving an alternative reality or an altered reality, where the two are applicable for different use cases. Both an alternative and an altered reality indicated having value for the design process at Volvo Cars Design. To narrow the scope of the project, how to practice an alternative reality in the context of a design studio was further investigated.

The exploration phase indicates that immersive technology could be implemented into several operations at Volvo Cars Design, evolving around collaborative design work, design evaluation and creation of the design. In the near future, immersive technology will be able to provide employees at Volvo Cars Design with a rich direct experience of a car concept that in several aspects exceed the conventional clay models.

The report provides a basis for discussions about the future purpose of immersive technology at Volvo Cars Design, and the insights from this project should be used as guidance for further work with immersive technology, to develop practical and efficient design operations that are aided by immersive technology.

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Appendices

Appendix I: The survey questions for Volvo Cars Design

Appendix II: The vision for the virtual design studio

Appendix III: The concerns for the virtual design studio

Appendix IV: The natural user interface of the virtual design studio

Appendix I: The survey questions for Volvo Cars Design

Hey!

This is an anonymous survey regarding your experience of communication, presentations and digital prototypes. Your answers will be used in a student project at Chalmers University of Technology, that aims to study how immersive technology can aid design operations at Volvo Car Design.

If you feel that some questions are irrelevant for you just skip to the next, and don't worry, it will only take a few minutes!

General information

1. **My professional role**

   Markera endast en oval.

   - ◯ Designer
   - ◯ Manager
   - ◯ Surface modeller
   - ◯ Visualization artist
   - ◯ Engineer
   - ◯ Övrigt: ____________________

2. **I work with**

   Markera alla som gäller.

   - ☐ Interior design
   - ☐ Exterior design
   - ☐ Surface Modelling
   - ☐ Visualization
   - ☐ Material
   - ☐ Form
   - ☐ Engineering
   - ☐ Övrigt: ____________________

Communication

3. **I use the following channels for communicating design**

   Markera endast en oval per rad.

	Daily	Weekly	Monthly	Yearly	Never
Mail	◯	◯	◯	◯	◯
Voice call	◯	◯	◯	◯	◯
Video call	◯	◯	◯	◯	◯
Unofficial meetings	◯	◯	◯	◯	◯
Meetings	◯	◯	◯	◯	◯

4. **The internal design communication at Volvo Car Design is**

Markera endast en oval.

	1	2	3	4	5	
Very bad	◯	◯	◯	◯	◯	Very good

5. **To follow up what has been decided/discussed during meetings/presentations I (e.g. take notes, inform colleagues)**

____
____
____
____
____

6. **In general following up what has been decided/discussed during meetings/presentations is done**

Markera endast en oval.

	1	2	3	4	5	
Not sufficient enough	◯	◯	◯	◯	◯	Sufficient enough

Presentations

7. **I attend any kind of design presentation**

Markera endast en oval.

- ◯ Daily
- ◯ Weekly
- ◯ Monthly
- ◯ Yearly
- ◯ Never

8. **I prefer to attend design presentations in**

Markera alla som gäller.

- ☐ Meeting room
- ☐ Showroom
- ☐ VR room
- ☐ Cave
- ☐ Model studio
- ☐ Övrigt: _______________

9. **I recognize myself in the role of**

Markera alla som gäller.

- [ ] Preparing the presentation material
- [ ] Moderating the presentation
- [ ] Giving a presentation
- [ ] Giving feedback
- [ ] Listening to presentations
- [ ] Learning about the presented material
- [ ] Receiving feedback
- [ ] Taking notes
- [ ] Evaluating the design
- [ ] Making design decisions
- [ ] Asking questions
- [ ] Answering questions
- [ ] Övrigt: ____________________

10. **Presentations I attend are**

Markera alla som gäller.

- [ ] Improvised
- [ ] Organized
- [ ] Rewarding
- [ ] Efficient
- [ ] Useless
- [ ] Open discussion
- [ ] Time consuming
- [ ] Hierarchic
- [ ] Övrigt: ____________________

11. **Presentations should be**

Markera alla som gäller.

- [ ] Improvised
- [ ] Organized
- [ ] Rewarding
- [ ] Efficient
- [ ] Useless
- [ ] Open discussion
- [ ] Time consuming
- [ ] Hierarchic
- [ ] Övrigt: ____________________

12. **To presentations I bring (e.g. notebook, computer, printouts)**

Creative process

13. **In the creative process I am inspired by using tools such as (e.g. sketches, inspiration boards, simple prototypes, videos)**

14. **I prefer to conceptualize my design ideas with**
    Markera alla som gäller.

- [ ] Sketches
- [ ] Surface models
- [ ] Rendered pictures
- [ ] Posters
- [ ] Animations
- [ ] Real time visualization
- [ ] Virtual reality
- [ ] Cave show
- [ ] Quick and dirty mock ups
- [ ] Advanced physical prototypes
- [ ] Övrigt: ______________________

15. **It is important to me that prototypes are (e.g. accessible, representative of the design, opens up for discussion)**

Design Evaluation

16. **When I evaluate design the following aspects are**
Markera endast en oval per rad.

	Not important	Important	Very important
Shape	◯	◯	◯
Colour	◯	◯	◯
Texture	◯	◯	◯
Size	◯	◯	◯
Spatial experience (room)	◯	◯	◯
Touch	◯	◯	◯
Composition	◯	◯	◯
Style	◯	◯	◯
Quality	◯	◯	◯
Car in context	◯	◯	◯
Driving Experience	◯	◯	◯
Human interaction	◯	◯	◯

17. **How digital prototypes represent these aspects are**
Markera endast en oval per rad.

	Not sufficient	Sufficient
Shape	◯	◯
Colour	◯	◯
Texture	◯	◯
Size	◯	◯
Spatial experience (room)	◯	◯
Touch	◯	◯
Composition	◯	◯
Style	◯	◯
Quality	◯	◯
Car in context	◯	◯
Driving Experience	◯	◯
Human interaction	◯	◯

Thank you!

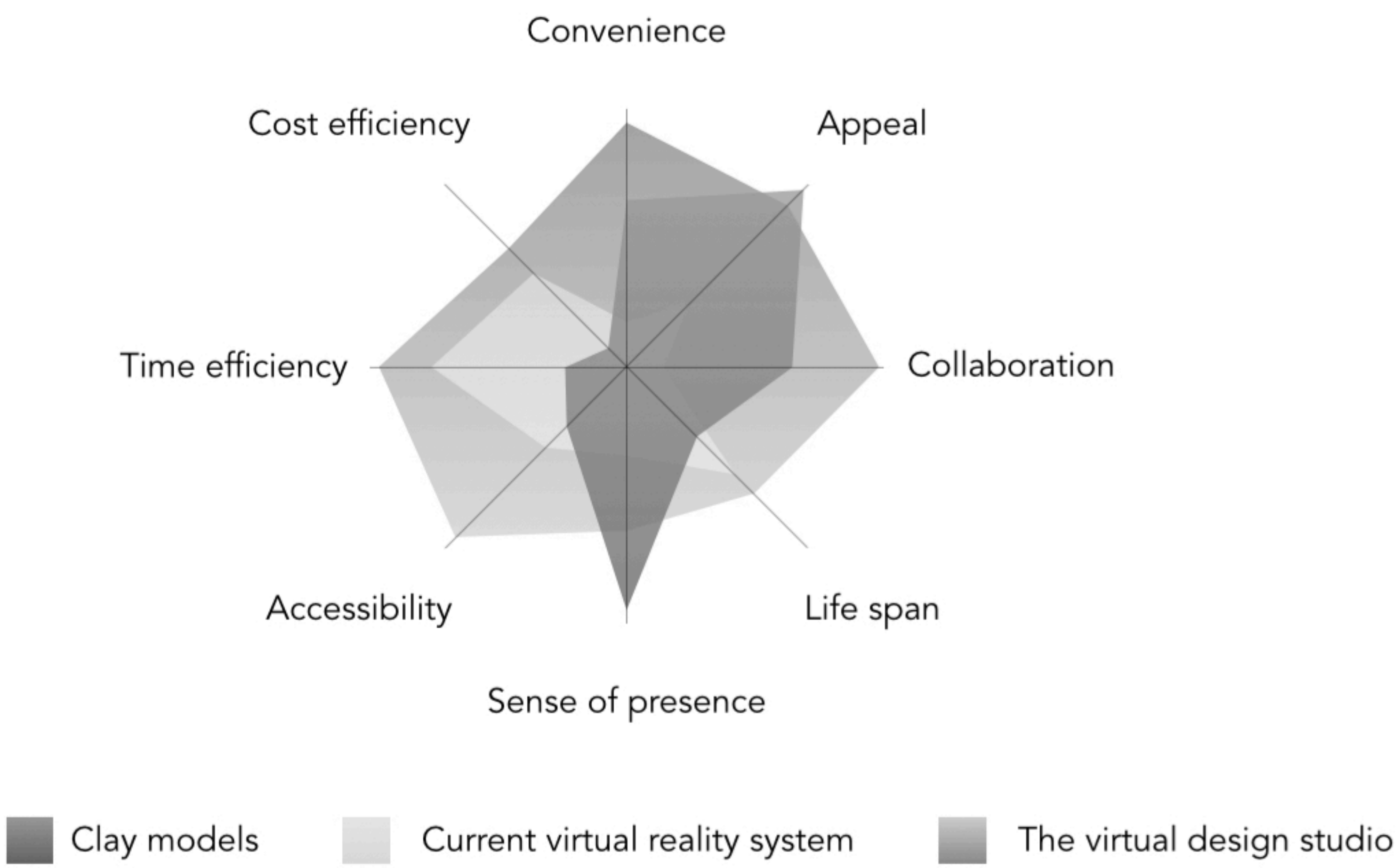
The aim of the study is to understand how immersive technology such as virtual reality can be used to support design operations in a better way. If you have any thoughts or inputs on virtual reality or prototyping in general, please, add a comment!

18.

Appendix II: The vision for the virtual design studio

The strategy wheel illustrates a comparison between the clay prototypes, the current system used for virtual reality and a vision for a virtual design studio.

- The virtual design studio should be more time efficient than clay. Further integration of data (DigiCar) will make it more time efficient than the current virtual reality system.
- The clay system is very convenient in presentation situations, but the virtual reality system is not because of unwieldy devices. The virtual design studio should become as convenient as the clay system.
- Either the clay prototypes or the current virtual reality prototypes are accessible. The virtual design studio should strive to make prototypes more accessible.
- The clay models are appealing in most aspects, whereas the virtual reality prototypes are appealing inside the experience but not in the real world. The virtual design studio should make virtual reality more appealing both in the virtual and real world context.
- Collaboration is a benefit from clay models. The current virtual reality experience is very isolated. The virtual design studio should give new possibilities for collaboration in the virtual context.
- The lifespan of the virtual design studio will be longer than clay prototypes, but similar to the current virtual reality system
- The sense of presence in the virtual design studio will be better than the current virtual reality system because of an increased plausibility and place illusion, as well as given a virtual body.


Convenience
Appeal
Collaboration
Life span
Sense of presence
Accessibility
Time efficiency
Cost efficiency
Clay models
Current virtual reality system
The virtual design studio

Appendix III: The concerns for the virtual design studio

Personas

Volvo Design employees, the primary users of the virtual design studio, have various background, skills, professional roles, gender, age, work location, as well as different aspirations and motivations. To understand the needs of these employees a persona for each professional role was put together. The personas do not describe specific personalities, but rather the different concerns of the different professions.

Designer

The designer's work is to find ideas of how the design should look, feel and behave. The main concern of designers regarding prototypes is to present the best side of the work and the possibility to convey a message of the design.

Does the design fit?

Brand
Segment
Trends
Customers
Context

I want to…

Ideate
Create
Be inspired/inspire
Refine
Discuss
Have feedback

Manager

The manager makes decisions about how the design should look, feel and behave. The managers main concern is to push the boundaries of what can be created, in terms of an extraordinary design that can also be produced.

Does the design fit?

Segment
Competitors
Brand
Trends
Customers
Context

I want to…

Experience the design
Communicate the design
Make decisions

Engineer

The engineer's work is to find solutions to how a design can be manufactured. The main concern of the engineer regarding prototypes is to understand how the design can be realized.

Does the design fit?

Segment
Ergonomics
Manufacturing
Cost

I want to…

Understand
Explore
Evaluate
Make a decision
Discuss
Explain

Surface modeller, Visualisation artist, Clay modeller

The surface modeller, clay modeller and visualisation artist provides material to realize what is being designed. The main concern of these employees is to understand what the designer wants to achieve and if the right recourses are available to do so.

I want to…

Discuss
Understand
Prepare
Maintain

Brand identity

The core values of the brand were studied from reviewing the Volvo Cars website, market material and products. The values that were chosen as guidance for the conceptualization phase of the project were style, quality, heritage and performance (figure 36).

To understand the brand identity of Volvo Cars the Volvo brand guidelines were also studied. Cool outside, warm inside is a phrase used to describe the Volvo Cars brand identity. Cool outside stands for sleek design, precise lines, sophistication, functionality, innovation and respect for nature. Warm inside symbolizes the care for interior space, humanity, comfort, safety, relaxation, empowerment, tranquillity and intuitive experience.

Internal stakeholders

Volvo Car management
(users)

Volvo Car Design management
(users)

Volvo Car Design employees
(users)

Volvo Car employees
(users)

Visualization unit management
(enablers)

Visualization unit employees
(enablers)

Volvo Car IT (enablers)

External stakeholders

Virtual reality and mixed reality hardware developers
(suppliers)

Virtual reality and mixed reality software developers
(suppliers)

Automotive software developers
(suppliers)

External companies involved in the projects at Volvo Car Design
(enablers/suppliers/users)

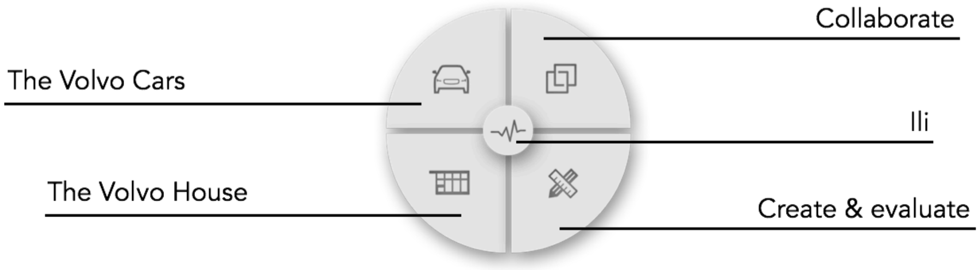
Automotive industry
(competitors)

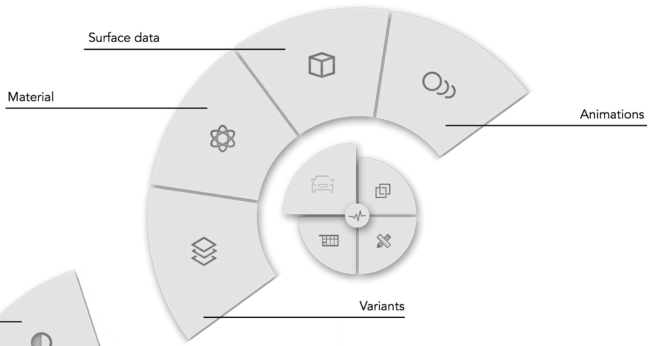
Companies with virtual reality and mixed reality development operations
(partners)

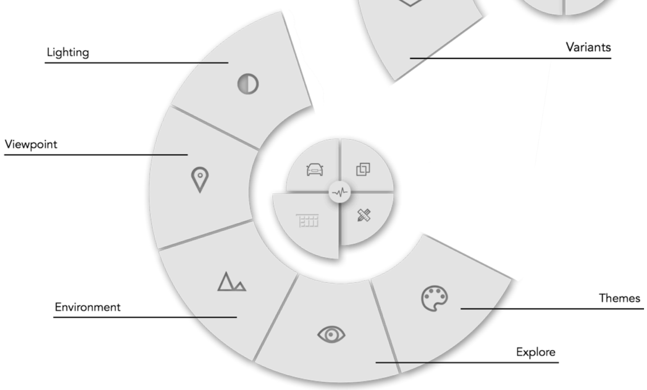
Stakeholders

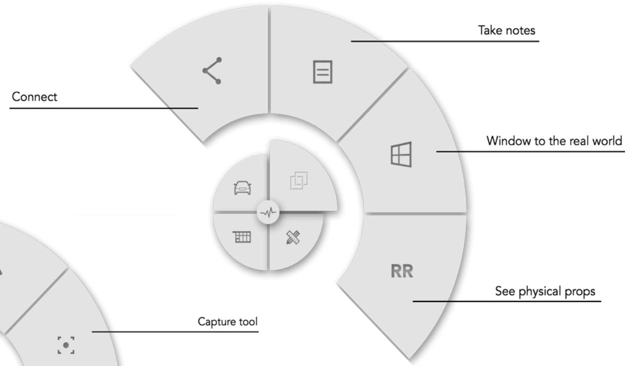
To identify the different parties that could be involved in the implementation and use of the virtual design studio, an analysis of internal and external stakeholders was made. Volvo Cars Design is the primary user and enabler for the virtual design studio, but employees from other departments of Volvo Cars are secondary users of the system. The visualization unit at Volvo Cars Design are responsible for maintaining and managing the system. The external parties will also have an impact on both the use and implementation of the virtual design studio (figure 37).

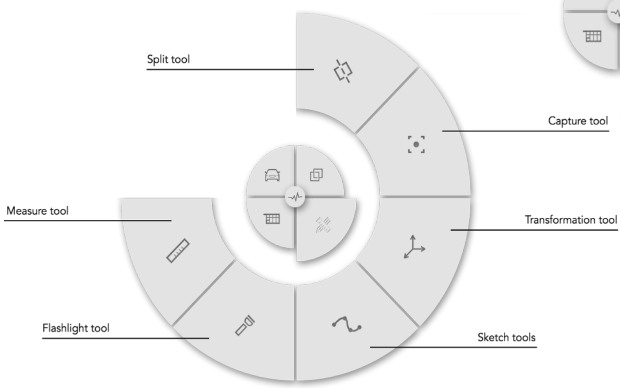
Appendix IV: The natural user interface of the virtual design studio











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