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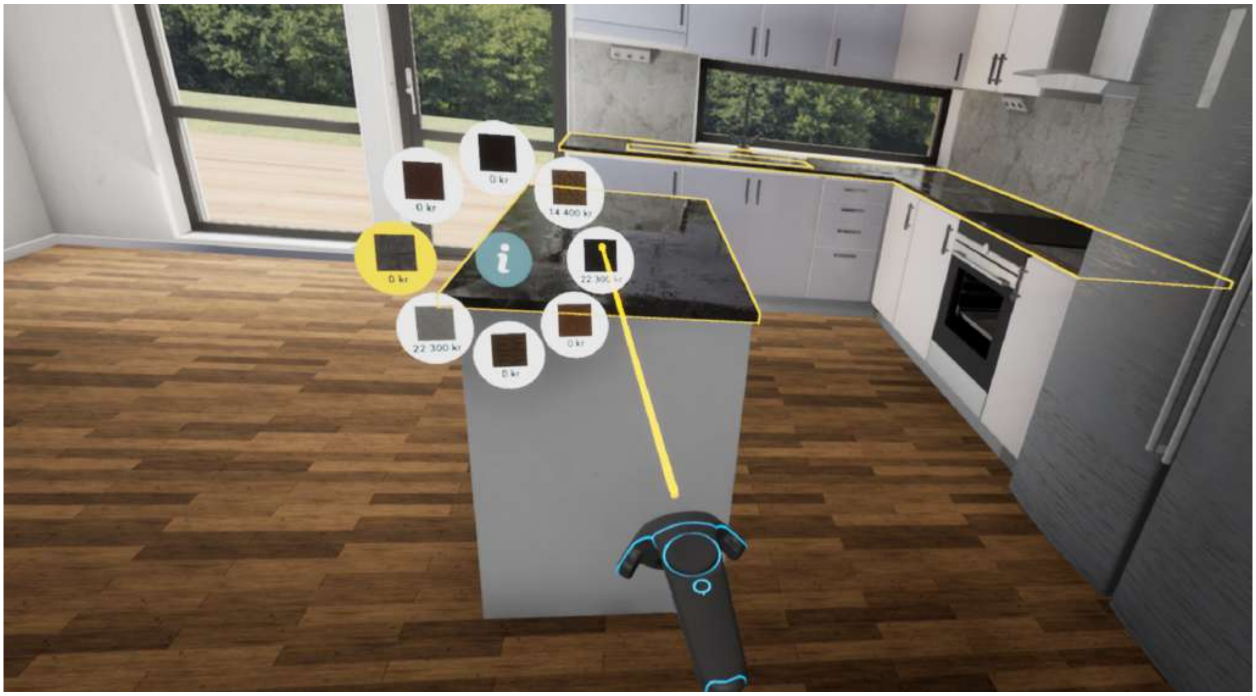

Differences in user experience comparing virtual reality and screen based interactions

Comparing user experiences when making design choices for prefabricated houses using either a virtual reality or screen based system

Master’s thesis in Interaction Design and Technologies

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Gothenburg, Sweden 2019

MASTER'S THESIS 2019

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Cover: Screenshot from VR prototype made in the study, a user is making design choices using a circular interface menu.

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Abstract

Virtual reality (VR) is an increasingly popular technology among the public but it is also fairly new in that the latest era of modern VR devices are not more than five to seven years old. This has led to a significant difference in knowledge on how users experience VR interactions differently compared to screen based counterparts. This study investigates what factors of interaction benefits from being experienced through VR rather than a screen based system. The factors the study is based on are perception, understanding and confidence. A system which allows users to make design choices in the process of buying a prefabricated house was chosen for this investigation and a prototype of a VR system allowing for this was designed. Due to VR being a new field of research, there are few guidelines which can be followed in VR design. Therefore, the study also investigates guidelines for design of VR systems intended for inexperienced users.

Halfway through the process a user test was held in order to make improvements to the VR prototype and find guidelines for design. Six guidelines were found from analysis of the tests results. In a second test, interaction with the VR prototype was compared to a screen based version of the same system. Analysis of data from this test found six system dimensions in which VR and screen based systems differ, of these all but one were perception based. These results show that users of VR experience visualizations differently than users of a screen based system. VR users experience that visual properties of design choices are of greater importance and they have an increased spatial understanding of the digital environment. A difference in how understanding and confidence could not be found.

Keywords: VR, design choices, interaction design, interface design, prefabricated houses, unreal engine 4, user experience

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Rasmus Davidsson & Martin Dehmer Östebo, Gothenburg, May 2019

Abbreviations

VR - Virtual Reality
HMD - Head Mounted Display
SB - Screen Based
SFA - Significance through frequency analysis
H_o - Null hypothesis
H_1 - Alternative hypothesis
UE4 - Unreal Engine 4

1
Introduction

Virtual reality (VR) is defined by Jason [1], author of “The VR Book”, as “a computer-generated digital environment that can be experienced and interacted with as if that environment were real”. The users’ experience of the virtual environment, and their interactions with it, is enabled by a head mounted display (HMD). In addition to this, sensors track the users’ motions, translating those motions to movement in the virtual space. VR experienced through an HMD has existed since the 1960’s [2], when Heilig patented the first head mounted device [3] and research on the technology has continued since then. However, VR systems for the consumer market entered what Jason describe as a “VR winter” from 2000 to 2012 [1, p. 27]. In these years mainstream media gave little attention to the field, not until Facebook acquired Oculus in 2014 [4] would the interest in VR be revitalized and become as popular as it is today. The interest in VR among consumers has continued to grow since then, the number of sold VR devices increased from 3.7 million units 2017 to 4.5 million 2018 [5] and by 2023 the industry forecast predicts a sale of 68.6 million units [6].

Customers relate differently to products depending on the technologies which are used to promote or advertise that product [7]. This study seeks to investigate which such differences may occur in user experience comparing VR and screen based (SB) interfaces both designed to allow customers to make personal design decisions about a product which they intend to buy. A VR prototype fulfilling the same user needs by using the same functions as an SB interface is designed in the study, and the two interfaces are compared following the principles of experimental research [8, p. 25-44].

Prefabricated houses are modular buildings, manufactured off-site in a factory prior to construction. The house is usually compartmentalized into sections, which allows for easier transport to be brought to, and assembled, directly on site. When buying a prefabricated house there are many design choices the customer may make regarding how their house is to be built in order to personalize it. Such choices include, but are not limited to, surface materials, furnishing models and technological specifications, house extensions, etc. Today, as a complement to visiting a retailer, these choices are generally reviewed using catalogues [9] or screen based visualizations [10]. In Mars 2019, during the time of this study, one housing company in Sweden also introduced a program which allows customers to experience design choices using VR in their purchasing process [11].

1.1 Problem description

Modern VR technologies which has recently become accessible to public users, such as the Oculus system, uses forms of interaction and visualizations not found in previous types of VR systems. Design research on these types of systems has therefore only been conducted for about five to seven years, making knowledge on how VR visualizations affect users experience sparse compared to SB counterparts. For someone planning to make a design, there are few commercial examples or studies showing the pros and cons of investing in a VR program, tool, or visualization compared to a similar SB system. Any field of design in need of visualizing ideas and concepts to stakeholders could benefit from having such knowledge in the process of deciding which medium to use. This is especially true for fields in which designs are difficult or expensive to prototype using traditional means e.g. architecture or automotive. There are studies showing that it is likely that a difference in user experience exist between different media [7], but it has also been shown that when presented with a real life scenario in VR users do not act differently in the digital environment compared to real life [12]. These contradictory claims indicate that there is a lack in understanding how users experience VR systems differently compared to SB counterparts. Processes in which customers are to make personal design decisions regarding a product prior to purchase is a specific category of customer services which could benefit from deeper understanding of customer experience in relation to different mediums.

The novelty in the way's users are able to interact with interfaces in VR makes designers unable to use many of the guidelines learned from the making of 2D interfaces. Researchers, professionals, and major companies have begun to share recommendations and frameworks on how to implement VR interfaces [1], [13-15]. Unlike those for 2D, these guidelines have not yet had time to develop through generations of iteration. It should also be expected that developers will encounter scenarios where theory may not match reality and situations and problems unaddressed by research must be solved. This is likely to happen when designing for a limited target group where research may be sparse. One such target group, inexperienced users, are planned to be addressed in this project.

1.2 Research question

Given the limited understanding how VR impact customer choices and experiences this study aim to answer the following question:

1.
“What factors in interaction are experienced differently when making design choices in terms of, perception, understanding, and confidence when using a virtual reality interface compared to a screen based interface?”

To answer this question, a VR interface with beginners as target audience will be created through a design process. In this process the study will also need to answer the following question:

2.
“Which guidelines should be considered when designing virtual reality interactions for inexperienced users?”

1.3 Delimitations

Customers are able to make personal design decisions about products that they purchase in several different markets, however this project is limited to only research customer experience from a housing market perspective. The study is also limited to only research a set number of non-architectural interior design decision found in a private housing purchasing process.

The study will be limited to making a prototype using Unreal Engine 4 (UE4) [16]. UE4 is chosen due to its support for developing VR programs. There are other game engines and development environments with similar support, UE4 was chosen in favor of these due to our prior knowledge in how to develop using the engine.

Just as there are several engines that support building software for VR there are several different types of systems through which to experience VR. This project will be making a prototype that is developed for HTC VIVE and Oculus Rift due to that hardware being available throughout the project period. This means that the prototype and its interface will be developed to be experienced using a VIVE or Oculus system.

1.4 Stakeholders

Seven major stakeholders have been identified for the study and are presented below. These stakeholders were defined as parties having a direct relation to the execution of the study or those which could potentially be affected by its results.

1.4.1 Companies

With VR becoming more common and increasingly popular, companies will benefit from knowing if the technology is worth investing in. Any company providing a service which include personal design decisions by customers would also benefit from deeper understanding of the ways in which VR could affect their customers. In some cases, this will also affect the companies serving as retailers of design choice to the company providing the customer with the ability to choose. In a scenario where VR is used more these retailers will see an increased need for providing more and more complex digital versions of the product they are providing to be used in visualizations.

1.4.2 Architects

There already exist several programs intended to allow architects to design using VR but none of those are focused on showcasing such designs to customers. Architects would also benefit from knowing the difference it would make to visualize a design using VR compared to SB as this would allow them to use the medium best suited for each separate situation.

1.4.3 VR designers

With guidelines on how to design for VR being sparse, VR designers will benefit from more studies being made on the subject. In this study, an example of how to design an interface for making design choices, interact with the environment, and visualize different types of information is presented through the prototype from which designers may draw inspiration. In addition, the guidelines presented as part of the study's result can serve as a baseline and advice for designers when creating a new VR interface.

1.4.4 Future customers

The customer whom in the future could be able to review personal design decisions using VR when purchasing a product is a stakeholder. If VR visualization of products are shown to affect customer experience in a way that is beneficial to companies, it is likely that it would become a part of the purchasing process available to them.

1.4.5 ESSIQ

ESSIQ is a consultant company situated in all three of Sweden's major cities, Stockholm, Gothenburg and Malmö. This study was conducted at ESSIQ's headquarter in Gothenburg (ESSIQ West) which main clients consists of companies active in automotive business. ESSIQ has supported the study by providing a workspace, research supplies, VR equipment and testers. ESSIQ in turn will take part of the results of the study.

1.4.6 Chalmers University of Technologies

The results of this study will be published in databases at Chalmers and the report will be indirectly representing Chalmers. Hence, the report must follow Chalmers quality standards. Chalmers has also supported the study in occasionally providing VR equipment and help in the form of supervision.

1.4.7 Thesis authors

Completing this study is part of the requirements the thesis authors are to fulfill in order to graduate from Chalmers University of Technologies.

2
Background

In this chapter the research area and the fields related to the process of answering the research question will be described more thoroughly. This includes the process in how prefabricated houses are bought. The technology that will be used to create and use the prototype in VR is described, and how it relates to other similar technologies. Work related to this project is also presented. This includes VR applications capable of visualizing architectural design choices and methods for displaying customer design decisions in a house purchasing process today.

2.1 Prefabricated houses

Prefabricated houses are modular houses which are manufactured off-site in a factory in advance. They are usually compartmentalised into sections to be easily transported and assembled directly on site.

2.1.1 Purchasing process

This chapter is following a general purchasing process from a-hus [17] and Myresjöhus, both are housing companies which has been in the house industry from early-mid 20ths century and are currently providing prefabricated housing services [18], [19]. One of the first but recurring steps in the process of buying a prefabricated house is to meet with the seller. The sellers provide information about possible options and additions to the house. In an email conversation, a representative from Myresjö highlighted that even on the first meeting they show what kind of design choices the buyer can make, but the process of making choices continues throughout the whole process, nothing being final until the purchase order is made. In an interview, another representative from Myresjö expressed that the customer usually needs 2-3 informative meetings about choices and the purchase in general before wanting to proceed with planning the house. When finished with all the initial meetings and after signing an agreement, the process enters a phase a-hus calls coordination phase. This phase include communication with all the different providers, who manufacture everything from doors, isolation, appliances, and more [17]. It is at this point the housing company set up meetings with the providers to decide additions and design choices with the buyers. An order is made, and the building process is started. Once a buyer and housing company has signed a purchase agreement it can take more than 60 weeks, completing a 20-step process, before the house is finished being built and ready to be moved into [17].

2.1.2 Personal design choices

Some of the steps in the purchasing process involves the customer making a series of personal design choices regarding the house they are buying. The customer meets with the seller, discussing available choices, usually presented in a catalogue.

Choices the buyer can do may include, but are not limited to, house expansions, roofing, windows, inside and outside doors, frames, floor material, stairs, closets, appliances and more. Every housing company has their own set of design choices and agreements with providers. Different choices will have an impact on the look and functionality of the house, but the quality and longevity of different materials are also affected. National Association of Home Builders (NAHB) [20] created a general guideline which targets life expectancy of home components. An example from their guideline show that all-natural type of wooden floors has a life expectancy of at least 100 years, while engineered wood or composite floors has a life expectancy of more than 50 years. This implies that one of them is of better quality and more sustainable. This information alone can have an impact on decision making.

2.2 Modern VR devices

To start using VR the user will generally need an HMD with motion controllers and sensors. Smartphones can also be used as VR hardware, serving only as the display of an HMD without any interactable controllers. This is cheaper but a weaker and less immersive VR alternative. Mobile Phones only translates head movements to the virtual world, thus are limited in controls and interactivity. More advanced HMD hardware consist of dedicated VR-goggles. These have two screens which together compose a 3D-effect, in addition, the HMD will display a fully immersive world by tracking the user's head movements. Controllers are the medium used to interact with the virtual world, they are used for tracking the user's hand movement, making it possible to interact in VR using the buttons on the controller. Sensors synchronizes with the controllers and the HMD; this tracks the user's location in the room. The sensors map the play area and creates a wireless connection, tracing the scene coordinates of HMD and controllers in real-time [21]. Additionally, these VR systems requires a compatible computer, or a gaming-console.

Some of the companies that manufacture VR system equipment today are Oculus VR, HTC, and Sony Interactive Entertainment. The corresponding headsets are named Oculus Rift, HTC VIVE and Playstation VR. For mobile other HMD’s are needed, examples of those are Samsung Gear VR which is owned by Samsung and Google Cardboard which is owned by Google.

2.3 Unreal Engine 4

A game engine is a software which provides basic code-based features commonly used when developing games. A game engine also provides means for visualizing graphical game elements and make renders, the visual elements are then possible to connect using code. Given that game engines provide system structure, base development components and rendering, such programs are used not only for developing games but other types of software as well. There are only a few free game engines which supports development of applications for VR. One such engine which is commonly used is Unreal Engine 4 [16] (see figure 1), published by Epic Games. The advantage of UE4 is that it is free to use, with a 5% royalty on gross product revenue after the first $3,000 per game per calendar quarter, but only from commercial products [22]. The game engine is paired with well defined documentation, and forum which can help solve potential problems encountered when developing the prototype in this study.

Figure 1: Unreal Engine main interface. Adapted from [16].

Unreal Engine 4 supports C++ programming as well as their own programming language called Blueprints. Blueprints is a visual script language that uses a node-based interface to create components and elements for gameplay [23] (see figure 2). The nodes are converted to C++ code and executed when running from the engine. Not having to use syntax makes the scripting language quick to use for rapid prototyping and easy to learn by non-programmers.

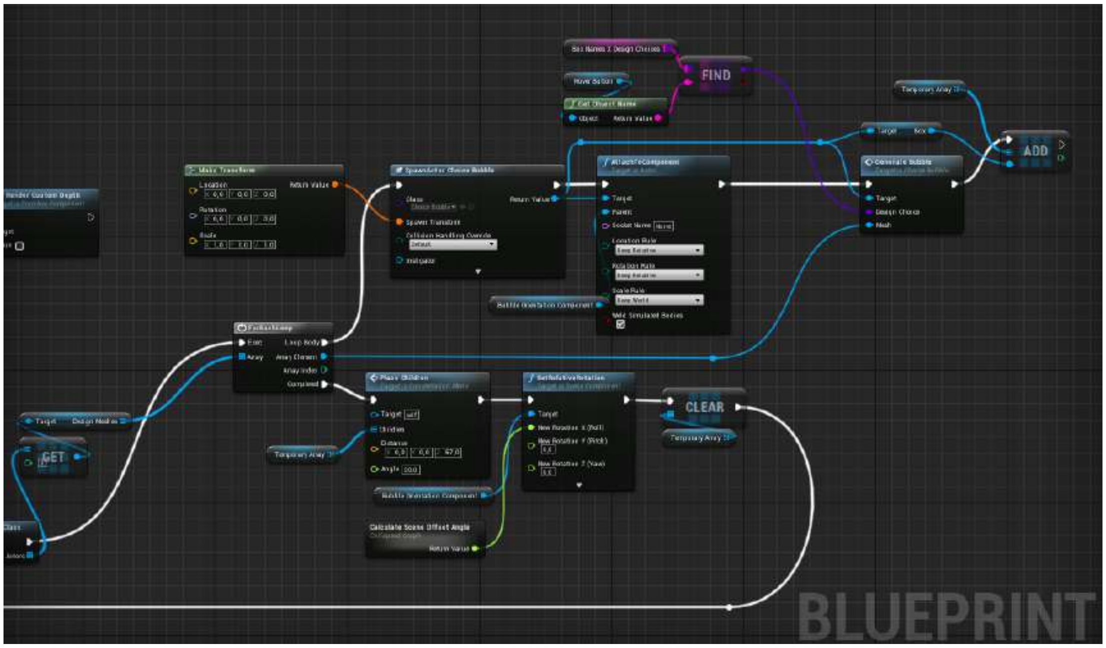

Figure 2: Unreal Engine node based visual scripting. Adapted from [16].

2.3.1 Datasmith

Unreal Engine supports importing of 3D models in specific formats, for example ".fbx" which is a 3D asset exchange format owned by autodesk that facilitates higher-fidelity data exchange between different software [24]. Importing large FBX files can be a tedious process where the developers might have to deconstruct large scenes into chunks and re-import them into unreal engine and assemble the scene inside the engine. Another issue with importing FBX models to UE4 is that the model's hierarchy structure of how it was in its 3D program is not preserved. However, by using datasmith, a plugin to Unreal Engine developed by Epic Games, it is possible to bypass most of these issues. Datasmith is developed for real time rendering and visualizations - in industries including architecture, engineering, construction, manufacturing, live training, and more [25]. Its long-time purpose is to reduce, or eliminate, the need for extra work, related to adjusting imported content. Datasmith uses a ".udatasmith" format which is supported by a large variety of sources, including Autodesk 3ds Max, Trimble Sketchup and Dassault Systèmes SolidWorks. Instead of having to assemble the 3D model pieces together manually, datasmith does this automatically, creating a bundled scene asset for the imported 3D model. Datasmith will also maintain the hierarchy levels and layers for all the objects and will auto generate names based on how objects were named in the 3D program during creation.

2.4 Related work

This chapter discuss related research studies dealing with user and consumer experiences when VR is being used. In addition, programs with similar purpose to that of the prototype made in this study are described as well. These programs are commercial program used by architects to review house designs using VR. Catalogues and software used by customers to make personal design choices are also presented.

2.4.1 VR in architecture

Today, VR is being used by architects in many different ways. The ability to interact with a 3D-model of a building design through the perspective of being in that same space makes VR an especially valuable tool in architecture, as is shown by the number and variety of applications which can be used to experience house models through VR. The five different tools that we list here are those we find to be the most prominent, but more programs which could serve as alternatives or compliments to these also exist.

The difference between these applications and the prototype made in this project is that they are targeted towards users familiar with using VR. The interfaces of the applications listed below we believe to be more complex than what should be built for a user inexperienced in both VR and architecture. The features of the programs are also generally focused around the creation and visualization of new buildings through VR, rather than comparing design alternatives in already existing house models.

Fuzor [26]- Fuzor is a collection of 3D and VR tools which are all targeted towards architecture, engineering and construction for expert users. The tools are sorted by their functional areas: design, construction and analysis. Their uses vary from populating areas of a 3D-model with plant life to comparing build processes and their schedules. When using Fuzor in VR, users are able to create models of buildings and their interiors with more or less the same features as in Fuzor's 3D-editing mode.

eyecad VR [27]- eyecad VR is a software which market itself as being a real-time rendering software in which the user can import models, create a realistic looking VR setting, and render those models. The user is able to change materials, create interactions, set up lighting, and furnish the model inside of VR using eyecad VR.

Prospect [28]- Provided by the company IrisVR, Prospect is a VR tool that features functionality which can be used for reviewing models of houses in VR. The main functionality which are advertised at the softwares homepage are the user being able to take notes, display different layers of the model, inspect building information properties, write reports, take measurements, and make sun studies, all in VR.

Twin Motion [29]- Similar to eyecad VR, Twin Motion is a real-time rendering software focused on architectural visualizations which has support for showing those visualizations in VR. The program features tools for editing a scene outside of VR into which a 3D-model can be imported, the editing tools are differentiated from those of eyecad VR by the ability of not only being able to change light and materials but also seasons. The user is also able to animate pedestrians and traffic moving along set paths.

Enscape [30]- Enscape is another real-time rendering software focusing on rendering architectural models. In Enscape editing is done using a screen based interface outside of VR. The program's VR functionality is only focused on visualizing an imported model, neither editing nor interacting with it.

2.4.2 VR Graphical User Interface

Every VR application generally have some sort of user interface (UI), and from the moment the user puts on the VR headset they are interacting with it. However, most of the existing UI's are not designed for new users which mean that they can have high complexity. The user is usually required to learn from exploring the interface. This does not impose a substantial issue right now as VR is still new and in an exploratory stage of development which encourages users to explore the medium. However, with the technology becoming more familiar, the demand of a UI that is simpler will become greater. Some of the existing VR UI's today which meets this criterion are the starting areas of Oculus Rift and HTC VIVE, which are called Oculus Home, and Viveport respectively. They are the first interfaces a user of these systems will interact with and see; therefore, they have to be simplified and easy to use by non-expert users.

Oculus Home/Dash [31]- is the default virtual environment shown if no other application is running when using an Oculus HMD. The platform contains all virtual reality games owned by the user, a profile that is customizable, all the user's friends also using oculus, navigation to use desktop functionality, and a store to purchase virtual reality content. It is possible to create a personalized space with imported 3D models, customized background and invite friends to Oculus Home [32]. The platform's GUI is based on floating menus which contains all information, these menus are displayed in a hemispherical motion. Owned games, and game suggestions are located in the middle of the hemisphere, a panel of friends on the right side, profile information to the left and navigation scrollbar which gives access to desktop apps at the bottom (see figure 3).

Figure 3: Oculus Home application. Adapted from [33].

Viveport [34]- is the official store for VR applications in HTC VIVE. Like Oculus Home, it contains all virtual reality applications owned by the user, a store with new or upcoming applications, application suggestions for the user, videos to watch and integration to desktop files. Viveport uses a floating menu which is perceived as being 3D due to depth usage for hovering and selection of an item (see figure 6). Instead of using a broad interface with a horizontal layout as Oculus do, Viveport utilizes verticality in its GUI.

2.4.3 Visualizing design choices in housing

When a housing company provides personal design choices to their customers, they also require some way of displaying those choices. This is mainly done in two different ways, through catalogues and interactive housing design applications. Recently, one Swedish house retailer has also started providing customers with the alternative to view personal design choices through VR [11].

Housing companies generally display the different models of houses that they sell through a catalogue, the personal customer choices available for those house models are then often featured in a separate catalogue. Götene hus displays their house models online [35] in a separate catalogue from the personal design choices the customer can make for those houses [36]. Catalogues showcasing personal choices in this way can be extensive, Eksjöhus provides an 85 pages long catalogue [9] (see figure 4) in which customers can read about, and look at images of, thirty different categories such as roof tiles, floors, and doors each having up to eight different alternatives to their design. When using a catalogue to make personal choices the customer will need to imagine how the alternatives available in the catalogue would look in their future home when deciding which ones to buy.

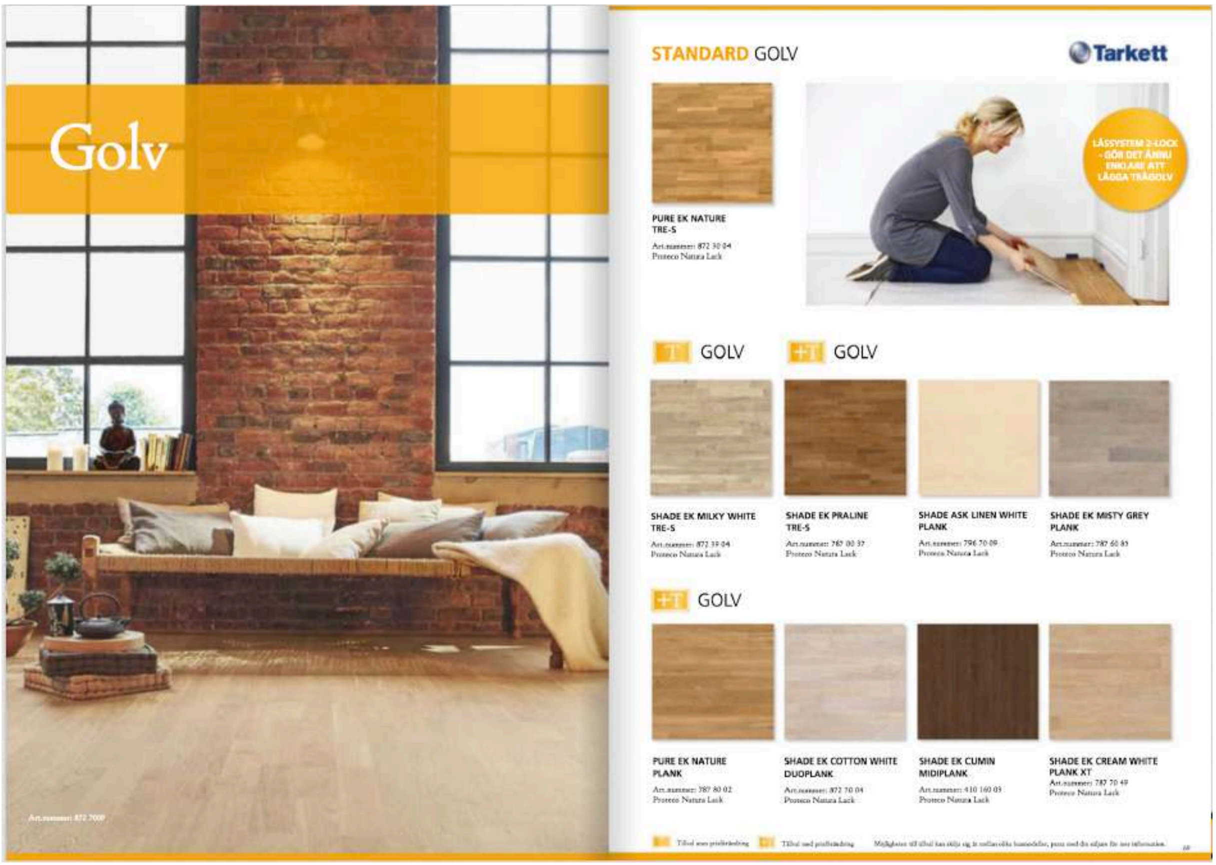

Figure 4: Eksjöhus digital catalogue. Courtesy of Eksjöhus, www.eksjohus.se

An alternative to catalogues, which are provided by some housing companies, are interactive house design applications. Programs such as a-hus house builder [10] allows the customer to render a 2D-image of the house model they intend to buy with some of the personal design choices they have made displayed in the image (see figure 5). This is done by altering properties of an image depending on choices made in a catalogue style interface, when a choice is made the image updates in real time. Unlike when using a catalogue, a customer using a house builder tool like this does not need to only envision the changes their design choices will make but can also see them and quickly switch between different alternatives.

Figure 5: a-hus online interactive design application. Courtesy of a-hus, husbyggaren.a-hus.se

2.4.4 Customer experience in using digital advertisement

There are studies showing how customer experience may potentially change based on how products are visualized and by which medium they are presented. A study carried out by Li, Daugherty, and Biocca [37] shows that 3D advertising when compared to 2D images is able to influence not only customer product knowledge but also their attitude towards the brand of the product and their purchasing intentions. They report that people during tests felt more present and engaged when having a 3D based purchasing experience rather than 2D. They argue that customers using 3D advertisement tools have more control in the way that they are able to inspect the product more thoroughly, which improve customer decision quality and knowledge. It may be the case that customers have an additional level of control in VR compared to a 3D based screen application. This could imply that a VR based advertisement tool would increase customers sense of presence and engagement even more than that of a 3D screen visualization. Kerrebroeck, Brengman and Willems [7] claim that this is true when customers are shown an advertisement in VR rather than on a 2D screen. In their study they show that using VR as a medium can influence how products and brands are perceived, just like Li, Daugherty and Biocca did for 3D advertisement. While Kerrebroeck, Brengman and Willems findings are close to answering part of the question asked about experiences in VR in this study, they base their findings on research which claim that the feeling of presence in VR is the cause of users' experiences being different in VR compared to SB. Their source on this, Cheng, Chieng and Chieng [38], claim that only a fourth of the presence experienced in VR is caused by interaction while the rest is caused by visualization. Therefore, users in Kerrebroeck, Brengman and Willems tests were unable to interact with the environment they were presented with in VR. This study takes a different approach in that interaction is a key element of the study and hence may find complementary or contradictory results to Kerrebroeck, Brengman and Willems study.

How customer behave and interact with an environment is not affected by if that environment is real or experienced through VR. Siegrist et al [12] showed that during a shopping session the customer will follow the same procedures in VR, and take as much time performing set tasks, as if they were doing it in real life. This could have implications for our project in that customers can be expected to behave and react in the same way to a visualized model of a house experienced in VR as if they were to visit that house in a real setting. If this is true it could mean that VR is an especially useful tool for visualizing design decisions in architecture in particular, as all design decisions when building a house have to be made before the process of constructing that house has started and the house cannot be visited for real.

3

Theory

Most of the decisions taken during the study regarding the prototypes design are based on theory written by experts on interface design as well as established concepts of design. Design principles and guidelines have been followed when making the 2D elements of the interface and some of these principles have been useful to refer to when designing 3D VR elements as well. Such principles, guidelines, as well as frameworks for VR design which has been considered in the making of this study, are presented below.

3.1 2D Interface design principles

Although an environment in VR is inherently three-dimensional, interface elements still follow many of the same design principles that are used for 2D interfaces. Often, interfaces in VR are designed to simulate screen based interaction within the otherwise three dimensional space, as is the case with Oculus Home [31] and Viveport [34]. Explicit guidelines on how to design for such interfaces are not well established but Cooper *et al* present principles for designers to follow when designing for similar interfaces encountered in the real world [39].

3.1.1 Device-Embedded Interfaces

In design, due to its three-dimensional nature, it is possible to treat VR as an alternative version of the real world, in which the user is interacting with a series of different device-embedded systems. Following such a view makes it appropriate to apply guidelines describing how to design for device-embedded interfaces, such as kiosks, cameras or microwaves, when designing for VR. Cooper *et al* [39, p. 555-560] lists seven guidelines to consider when designing for device-embedded interfaces. The guidelines a designer should follow when designing for device-embedded interfaces are the following:

- *Do not think of your product as a computer*
- *Integrate your hardware and software design*
- *Let context drive the design*
- *Use modes judiciously*
- *Limit the scope*

- *Balance navigation with display density*
- *Minimize input complexity*.

3.1.2 Posture

The posture of a product may, at an initial presentation, both describe the way it is used and also enable that way of using the product [39, p. 206-218]. The most prominent postures found in desktop applications relevant to this study are sovereign and transient. Each of these postures are used for different types of software with unique goals. A sovereign posture is used by programs which users use for longer periods of time, they have many features and claim a lot of screen space. Software with a transient posture are focused on fulfilling on clear user need and are generally limited to only a single window or view. Full description of these postures and additional postures are found in About Face by Cooper *et al*. [39]. An application's posture is driven by the goals users expect to achieve when using it in addition to the system on which that application is running. VR is a system which inherently features sovereign posture applications, because of its ability to immerse users, and claim all of the user's attention. However, the interfaces within sovereign application, used to complete tasks are often of transient nature. The screens used to navigate in Viveport [34] is an example of a transient feature inside a sovereign VR system (see figure 6).

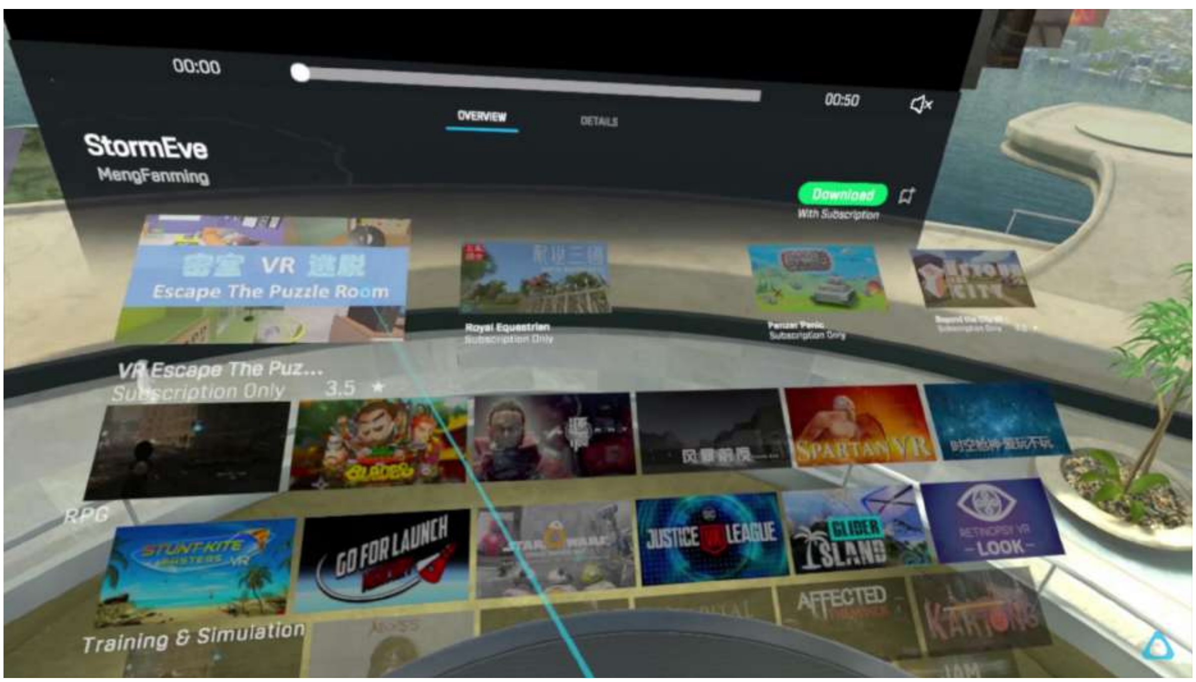

Figure 6: Transient navigation panels in Viveport. Adapted from [40].

3.1.3 Kiosks

Cooper *et al* [39, p. 561-564] describe kiosks as interactive systems located at a specific location unique to that system and available to the public. Similarly, to the prototype designed in this study, the interface of a kiosks is meant to be usable for first time users, possibly only ever using the system once, with an explorative goal. Cooper *et al* does not provide extensive guidelines on how to design for kiosk interfaces but they do provide with some general advice:

- *When designing for kiosks, consider giving the interface a sovereign posture while still using interactions found in applications using transient postures*
- *Take into consideration the environment and situation in which the kiosk will be used, designing for a noisy environment is much different from a library*
- *When the kiosk apply a touchscreen interface apply the same principles as regular touchscreens but avoid using drag and drop interactions*

These advices could be applied to VR design in addition to kiosks. The touchscreen advice is not applicable to this study as handheld controllers are being used as input device. However, guidelines for touchscreen interface design could be useful when designing kiosk like interfaces for VR when using hand tracking technology such as Leap Motion [41] as input rather than controllers.

3.1.4 Gestalt Laws

Gestalt laws are principles of design which help designers understand user perception of visual information [42]. The laws are used to communicate relationships between visual elements of a scene. There are several collections and versions of these set of laws, but they were first introduced in general gestalt psychology by Wertheimer, Kohler, and Koffka [43]. The list of the laws that they suggest consisting of: The law of- *proximity, similarity, continuation, closure, common fate, good continuation,* and *pragnäz*. A full description of these laws can be found in the paper "Laws of Organization in Perceptual Forms" [44]. In design for VR interfaces, Jerald [1, p. 230-231] states that:

"Gestalt psychology is even more important for VR as compared to pictures alone as the best VR applications bring together all the senses into a cohesive experience that could not be obtained by one sensory modality alone."

3.1.5 Skeuomorphism

Skeuomorphism is the concept of having an interface component which mimics real world counterparts [45]. Classic examples include the desktop trash bin, which allows users to discard unwanted material, and the floppy disk saving icon. The benefits of skeuomorphism, and why it is used in interface design, is that a skeuomorphic element does not have to be learned from scratch [46]. Users can make use of previous knowledge and pre-established mental models to navigate and use an interface with skeuomorphic design. Just like skeuomorphism was used extensively in early desktop and smartphone design, only to be abandoned once abstract interfaces had started to become conventional, it could serve VR interfaces as a way of lowering their learning curve [1, p. 227].

3.2 Frameworks for VR design

The creation of sophisticated UI's in VR is a relatively new area, which means a lot of different UI's exist but are not as refined as 2D interfaces might be. However, some research on how to create a more usability friendly UI in VR has been conducted by Google IO, Intel, Jason Jerald, and Mike Alger. These parties have started to try to generalize VR interfaces with guidelines and frameworks for developers to follow. The frameworks described in this chapter focuses on achieving immersivity (see chapter 3.2.2) and general knowledge when designing UI in VR in terms of comfort zones, content zones, input, icons, text, environment, and more.

3.2.1 Google Daydream

Google's research is based mostly on 2D interfaces in a 3D environment. Google uses a template they call "Daydream Sticker Sheet" [15], which is a complement to a video by Chris McKenzie and Adam Glazier in which they talk about "Designing Screen Interfaces for VR" [47]. The sticker sheet contains general knowledge which can be used when designing for a 3D interface (see figure 7).

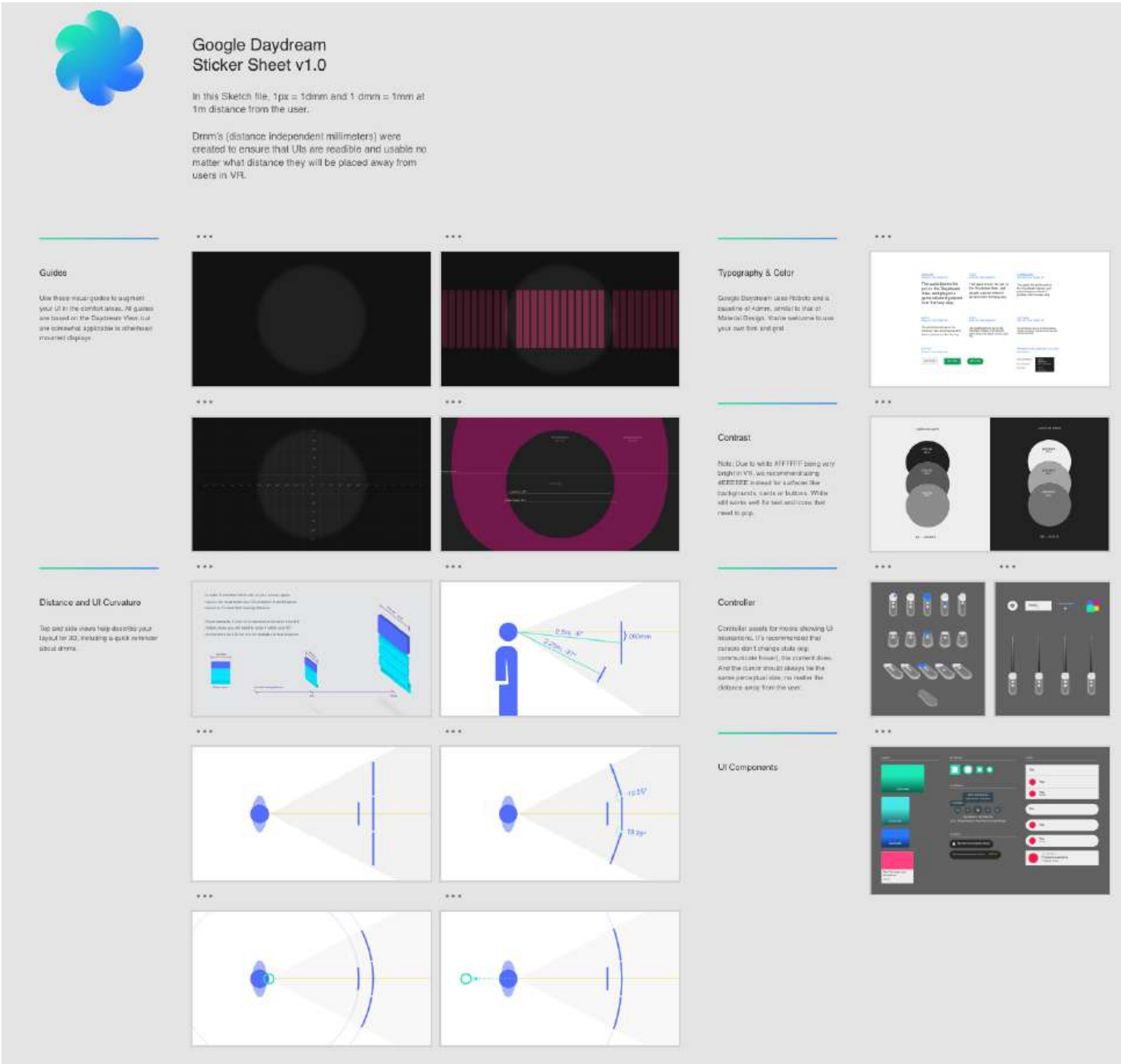

Figure 7: A few of the guidelines presented in Daydream sticker sheet. Adapted from [15].

The prototype created in this study has a UI designed for VR. Most of the UI elements in a general 2D based interface should in some form exist in a 3D version as well, such as colors, text size and fonts. Furthermore, in designing a UI having one additional axis that creates depth, complications are caused in how the layout of interface elements should be distributed. Therefore, the most useful information in Google Daydream "Daydream Sticker Sheet" for this study is the use of typography, colors, contrasts, comfort zones, field of vision, primary UI zones, distance, UI curvature, and cursor size. These guidelines from Google address some of the existing problems when creating a UI for VR.

3.2.2 Intel

By making full use of VR, by creating a virtual environment that is believable and credible, Intel claims it is possible to make the user feel a heightened sense of realism, as if they are in a different environment [14].

Immersive systems are displays that fully immerse the senses of a human by using a computer-generated stimulus. The HMD is a distinctive feature of one such system [48]. Being fully immersed in VR gives the user a heightened sense of realism and can possibly provide them with a different perception of reality and also change the credibility of the digital environment. Immersion is very easy to break by making the outside world influence the digital through things like physical contact, unsuitable graphics, sound and interactions [14]. For this reason, Intel has created a set of guidelines on how to retain immersion in VR. These guidelines are presented in a video series by Seth Schneider, Senior Technical Program Manager at NVIDIA [49]. The guidelines are based on three different topics: physical foundation, basic realism and beyond novelty [14].

Physical foundation- Physical foundation focuses on keeping the user safe from injury caused by poor ergonomics, collision with real life objects and also keeping the user free from motion sickness. The topic also addresses social safety, giving the user control over their own appearance in VR, as well as their name in interactions with others.

Basic Realism- Basic Realism address how everything in VR is perceived, with realistic sounds, graphics and system responses to user interactions in the virtual world.

Beyond Novelty- Beyond Novelty keeps the user immersed during longer periods by enabling interactions with nearly everything in the VR environment that the user would expect to be able to interact with in a similar real-world setting. The topic also addresses gameplay and content aspects.

3.2.3 Mike Alger

Mike Alger is an VR Designer, a Google employee who has conducted his own research focusing on “How can the two-dimensional paradigm of operating systems be most ergonomically redesigned for head mounted displays?” [13]. Same reasons as described in 3.2.1 Google Daydream, frameworks and guidelines that address how to design for a 3D UI in general are relevant for this thesis. Therefore, the used information from this research are how input, environment, icons, buttons and content zones are being considered in Alger’s report.

3.3 Design for different levels of expertise

Designing for different levels of expertise is the concept of designing a product to be suited for users of different levels of experience [39, p. 243-247]. These levels consist of beginner, intermediate and expert users. Design for each of these user experience levels requires the designer to use different design principles. The prototype created in this study is meant to be usable by anyone, regardless of prior experience with VR and architecture. It is designed to be used in short periods of time, within the scope of 30 minutes. This means that most of our users will start using the prototype as beginners and hopefully transition into intermediates after only short use. No user is ever expected to reach expert levels of interaction due to the nature of the house purchasing process. The customer will only need to consider design choices a few times during this process, thus only using the system once or twice in their life. Therefore, guidelines and recommendations for how to design interfaces for beginners and intermediate users are of particular interest to this study.

3.3.1 Beginner users

When using a product, beginners will try to accomplish a task but can be expected to have almost no experience in how to do so. Therefore, unless the product is designed to meet their needs, beginners will have a more difficult time completing the tasks than users of other levels of expertise. Beginners are exploratory, meaning that they learn by testing, playing around, observing, and doing mistakes [50]. Being a beginner is not something a user aspire to be, Cooper *et al* [39] argue that an ideal design should minimize the time spent as a beginner without bringing attention to it. Further they define being a beginner as never being an objective, but a rite of passage everyone must experience. Beginners are usually not patient and being overwhelmed by an over complex interface can discourage the user from proceeding to use the design.

The guidelines to use when designing for beginners as described by Cooper *et al* [39] can be summarized as follows: The concept and scope of the design must be clear and easy to grasp. Otherwise the beginner user will lose interest in the system and they might even abandon it. It is also important to make designs for beginners follow established mental models as this makes beginners able to understand some of the designs fundamental interactions without needing to have prior experience. Beginners will also need direct help from the design in order to transition to intermediates, however this help should not be fixed to the interface, it needs to be hidden as soon as it is no longer needed.

3.3.2 Intermediate users

Intermediate users include everyone between expertise level of beginner and expert; thus it is the most common group for a user to be in [51]. According to Cooper *et al* [39] the expertise level among users of an interface follows a gaussian curve (see figure 8). The intermediate users make up the vast majority of the curve, the middle area between the two outlier cases beginner and expert. Users generally transition from beginner to intermediate after only having apprehended a few basic concepts and features of a design [51].

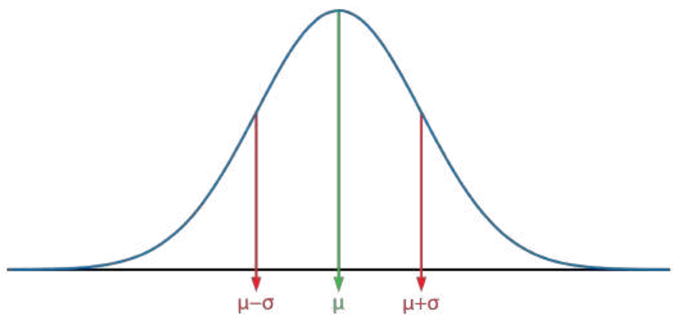

Figure 8: Gaussian curve. Adapted from [52].

Cooper *et al*'s [39] guidelines on how to design for intermediates are somewhat sparser than those given for beginners: Intermediates should be given quick access to their most commonly used tools, allowing a workflow in which the users favorite tools are the most prominently displayed in the interface. Having tooltips is a feature that is appreciated by intermediates, giving them information about what can be achieved using the tools without reminding them about scope and purpose. Intermediates usually already know the underlying meaning of a feature, and want a simple reminder of what it does, and where to find it if it exists.

4

Methodology

This study uses design process and its results as a method for research and finding answers to its research questions. This design process is made up of a design framework in addition to several methods which are presented in this chapter.

4.1 Design as research method

This study bases its methodology on experimental research principles formulated by Lazar, Feng and Hochheiser in the book “Research Methods in Human Computer Interaction” [8, 25-44]. Two different research methods described in their book are, descriptive research and experimental research. Experimental research is based on finding answers to research questions through comparison of different actions or states. By doing so researchers are able to find what Lazar, Feng and Hochheiser call a *causal effect*, which is the reason behind the differences, if a difference exists. Generalized, this process can be described as having two versions of the same system which are different only in the *independent variables* that researchers are interested in studying. During tests, testers are randomly assigned to each of the two versions and differences in set *dependent variables* during interaction with the two system versions serve as results for the study. The independent variable of this study is which type of system the user may use to make personal design choices, VR and SB. In order to have access to a VR system appropriate for tests in this study that system will need to be developed and designed as part of the study.

That system will be a prototype designed to explore the answer to a research question, a process Bredies describe as a step in the methodology of research *through* design [53, p. 12-16]. Following this methodology prototypes may be designed and created as means to bridging gaps in causality between different evolutionary development stages in design [53, p. 70-76].

To make the two systems used for experimental research in this study as alike, and as representative as possible, descriptive research is conducted in addition to experimental research. In descriptive research a behavior or state is observed during use of a system. These observations can then be used as arguments for change in the system, or support in reasoning for what elements and interactions functions well or which has to be reworked.

4.2 Wicked problems

Rittel and Weber [54, p. 155-169] identify problems as either being tame or wicked by nature. A tame problem as they describe it, can be formulated in such a way that it can be solved based only on the information given by its formulation, it has a definitive solution. Wicked problems on the other hand are redefined over time, their formulation being biased by the one making them [55, p. 5-17]. Hence, they have no definitive answer, as context and time will change the validity of the answer. Research questions in design are inherently wicked problems. There is no test which can be done to find a true answer to the questions of design, any suggested answer is always contextual [55]. Studies such as the one described in this report, which seek to answer wicked problems, can find no true or false answer, instead answers will need to be given in the form of good, bad, better, or good enough [56, p.31]

4.3 Iterative processes

Development of this study's prototype is done following a design process including iterative stages. Design processes are described slightly different by most practitioners [57, p. 28-33] [58, p. 6-7] [59], following the wicked nature of the questions of design it is natural that each process will also be contextual and slightly different from case to case. Common for most described design processes is that they include an iterative cycle. User interface design is a subset of design in which process Nielsen claim that "...user interfaces should be designed iteratively in almost all cases because it is virtually impossible to design a user interface that has no usability problems from the start" [60]. That iterative design is described in most design processes indicate that this is true for other elements of design as well. This study follows four main stages: *definition, ideation, prototyping* and *testing* (see figure 9), where after each test the process loops back to definition and ideation. Several quick and informal tests are held in addition to one well planned and more extensive usability test. This helps in refining the prototype based on previous iterations, each time creating a version which has higher usability and more refined scope than the previous [61].

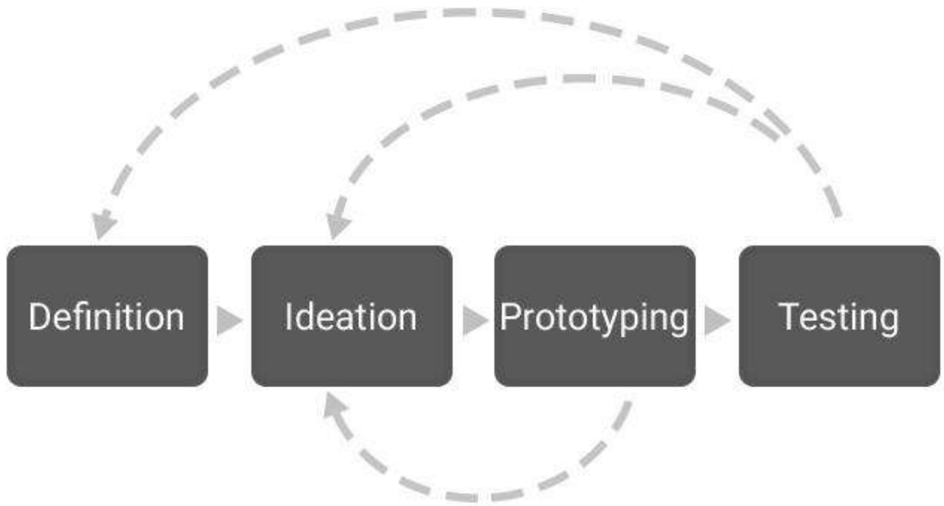

Figure 9: The iterative process of the study. Authors own image.

4.4 Research methods

Methods used to gain knowledge in order to develop the prototype through design, and conclude findings are described in this chapter.

4.4.1 Semi-structured interview

Semi-structured interviews are an interview method in which the interviewer sets up a baseline structure of the interview by determining in advance the goal of the interview and a guideline of questions to ask [62]. The person being interviewed has a lot of freedom in what to talk about. McCammon [63] highlights that one of the strengths of semi-structured interviews is how balanced they are. The method offers balance between the flexibility of an open-ended interview, and the focus of a more structured interview. Therefore, any predetermined questions can be easily replaced or changed depending on the respondent's answer.

4.4.2 Questionnaire

Similar to interviews, questionnaires are used in this study both when gathering material to answer the research question as well as when evaluating the prototype. Questionnaires in this study were constructed as recommended by Hanington and Martin [58]. They suggest using open ended questions to receive qualitative answers, and close-ended questions to receive quantitative answers. A questionnaire can follow certain frameworks which measures specific aspects of a system or product. This study made use of a framework called User Experience Questionnaire (UEQ), which has its focus on usability. UEQ measures six different scales [64, p. 2]:

- Attractiveness, which is the overall impression of the product.
- Perspicuity, how easily the product is to get familiar with.
- Efficiency, if the users can solve their tasks without unnecessary effort.
- Dependability, if the user feels in control of the interaction.
- Stimulation, how exciting and motivating the product is.
- Novelty, if the product is interesting and innovative.

The questionnaire is formed with a specific set of questions (see appendix I) to answer how well each of these scales apply to the prototype.

4.4.3 Cognitive Walkthrough

Cognitive walkthrough is a method in which the evaluators simulate a series of tasks required for the user to perform in order to complete a goal and asks a set of questions for each of these tasks. These questions focus on the perspective of the user and mean to create an understanding of the system's learnability for beginner or infrequent users [65], [66]. The questions could differ but are usually similar. One set of such questions [67] that are suggested to be used during a cognitive walkthrough are the following:

- Will users want to produce whatever effect the action has?
- Will users see the control (button, menu label, etc.) for the action?
- Once users find the control, will they recognize that it will produce the effect that they want?
- After the action is taken, will users understand the feedback they get, so they can confidently continue on to the next action?

After answering the questions, it is possible to determine most common errors being made by the users in the system.

4.4.4 Significance through frequency analysis

Significance through frequency analysis (SFA) is an undocumented method that was used in the study as a way of sorting qualitative data gained from observations during a usability test. Requisite for the analysis is that the qualitative data have been collected through a task model, where all testers are asked to complete the same set of tasks given a starting condition. During the test, task specific observations are recorded. In the SFA it is noted if each individual tester completed the task with or without any errors. If they completed the task with at least one error, the error is marked and categorized. The number of errors for each task, as well as the frequency of each error category then tells which parts of the system causes the most errors and is in most need of improvement. Apart from being categorized, errors may also be graded, this will help identify severe problems even if they are not as frequent. An example of this process can be seen in appendix II.

4.4.5 Think-aloud protocol

Think-aloud protocol is a method in which participants are asked to say out loud any thoughts in their mind during the completion of a task [68]. This is a cheap and effective way of gathering qualitative data and is often used in conjunction with user testing in a controlled environment [66]. Whatever the tester says while completing the task is noted down for future analysis. Meanwhile the user's actions may be recorded through film or screen capturing software, this can be used for connecting written notes to test situations.

4.4.6 Affinity Diagram

Affinity diagram is a method used to bundle large amount of data together, which helps the designers to name, rank, and understand relations between groups of information [69], [70]. The information is visualized using sticky notes, which are categorized in ways that helps sorting data into themes. The category or theme with the greatest number of sticky notes is the area of the design which may be in most need of being revisited and changed. This method can be used after receiving a lot of feedback and mixed information from testers during user tests. By categorizing the data, it is possible to externalize and find meaningful cluster observations and insights from the recorded information [58].

4.4.7 Content Analysis

Content analysis is a method used for transforming a large amount of text based qualitative data into a more organized format in the form of a concise summary of key results [71]. This is done by condensing verbal statements into meaning units, giving those units a code and sorting the codes into categories. The nature of the codes and the sizes of the categories then works as a summary of the larger data set and can be handled in a more efficient way.

4.4.8 Literature review

The purpose of literature reviews as is described by Hanington and Martin [58] is to capture the essence of previous projects in a way that is beneficial to one's own. In this study, this is done by searching for related research and existing products through internet resources, like the university library. In addition, as VR is fairly new and belongs to fields which are changing rapidly, less academic medias like YouTube will be used for research. When using sources like YouTube, extra care has to be taken into consideration when evaluating their reliability. There are frameworks and guidelines, like those described by Booth [72] in the book “The craft of research”, which helps in evaluating the reliability of a source, and doing so methodically.

4.4.9 Mann-Whitney U-test

A Mann-Whitney u-test is used for calculating if a statistically significant difference between two independent groups exists [73]. It is a non-parametric test, which means that it is not assumed that the data measured is normally distributed. Its purpose is to investigate whether to reject or accept the null hypothesis (H_0) and the alternative hypothesis (H_1). In this case, accepting H_0 generally means that the distributions of both populations are equal. On the other hand, accepting the alternative hypothesis H_1 means that the distributions are not equal. According to N. R. Smalheiser [74, p. 157 - 167] the Mann-Whitney u-test “...gives the most accurate estimates of significance, especially when sample sizes are small and/or when the data do not approximate a normal distribution”

When analyzing data with mann whitney u-test, a few assumptions has to be made in order for the test to be valid [73]. These assumptions are as follows:

Assumption 1: Your dependent variable should be measured at the ordinal or continuous level.
Assumption 2: Your independent variable should consist of two categorical, independent groups.
Assumption 3: You should have independence of observations, which means that there is no relationship between the observations in each group or between the groups themselves.
Assumption 4: A Mann-Whitney U test can be used when your two variables are not normally distributed.

4.5 Development methods

Methods used to ideate concepts, find functionality, test for readiness, and to make the findings from research methods into a design, are described in this chapter.

4.5.1 Brainstorming

Traditionally, brainstorming is focused on quantitative generation of ideas, and used to generate ideas and concepts in a specific area by utilizing the creativity found in a group. Brainstorming share similarities to regular conversation on how to find solutions to a problem but is differentiated by having specific rules for discussion. The rules of brainstorming say that ideas suggested during the session should not be criticized or judged. Odd ideas should be encouraged and be used as a complement to further generate ideas. Osborn [75] imply that it is common to build off one another's ideas during a brainstorm session to create new ones. Brainstorming has also been used for elaborating designers thinking process and their "fluency of thinking" [76].

4.5.2 Sketching

Images made through sketching are used by designers to discuss, exchange and critique ideas [77]. Sketches are different from other forms of drawn images in that they should be able to be drawn quickly in the time at which the need for the sketch arises. A sketch should also clearly visualize only one concept at a time. Using sketches allow designers to archive ideas for later, create abundant ideas without worrying about their quality, and think more openly and creatively about their ideas [78]. It is a quick process, only requiring pen and paper, which can be done simultaneously as, or as a complement to, other methods.

4.5.3 Hierarchical task analysis

A hierarchical task analysis (HTA) is a structured analysis which creates an understanding of tasks users need to perform in order to achieve their goal [79]. In this study, it was used to identify what functions the prototype needed to have. These functions stemmed from what primary goals the users would have, and the steps the users had to perform to accomplish those goals. In this study, goals with subtasks were visualized using post-it notes, which were put in a top-down hierarchical order.

4.5.4 Sketchstorming

Sketchstorming is an idea generation method which uses ambiguity to create additional value from an original idea. The method is described by Turner [80] in seven steps: have a group of two to seven people to which you present a design challenge or question. Then, let each person sketch their idea of a solution to that question for ten to fifteen minutes. Turner highlights that symbols and text should not be used in sketches, and participants should refrain from talking to each other. When the time is up, each sketch is presented in turn by the person who drew it. The sketch is presented without an explanation to what is drawn, it is up to the other participants to guess what the sketch portraits. It is during the guessing that new and novel ideas may be generated.

4.5.5 Prototyping

Prototyping is a core way of exploring and expressing designs [81, p.367]. By making a prototype concepts spawned from idea generation can be shared and evaluated. Prototyping can be done using a range of different methods, for which the common nominator is that the results of the methods in some way envision and mediate a part of the final product. Sketching, storyboarding, paper interfaces, role-playing, and physical models are all examples of prototyping methods [82]. A prototype can be of either high or low fidelity. This term describes how well the prototype resemble a real product [83, p.185-187]. In this study, a single prototype is made. The prototype is first made with low fidelity properties but in iteration, as it becomes more and more defined, it is finally created with as high fidelity as possible.

A low fidelity prototype is a prototype which does not resemble a finished product in look and feel, instead it is often made using pen, paper and hand drawn sketches [84]. This makes low fidelity well suited for quick visualization of alternative design solutions, which can help in finding improvement in a design or spark new ideas. Low fidelity prototypes are fast and cheap to make, which makes them suitable for quick iterations early in the design process.

A high-fidelity prototype is close to the intended final product in look, feel and functionality. Benyon, Turner and Turner [85] describes some of the benefits of making such a model as it being well suited for usability testing in addition to evaluation of its main design elements, e.g. visuals, interactivity and functionality.

4.5.6 Bodystorming

Kachur & Jones [86] describes bodystorming as a tool which can be used for rapid communication between people and quick generation of ideas. They describe bodystorming as a highly structured process in which up to eight people all participate in an act which uses props, a narrator and have a well-defined scenario. However, Hanington & Martin [58] presents the method differently. They present bodystorming as a more spontaneous process during which design ideation, concept generation, and evaluation of ideas happen in parallel. In this project we follow how Hanington & Martin describe this method.

4.5.7 Pilot test

When a test or questionnaire has been formulated it is a product made only by a few people. It is therefore impossible to say if the desired results will be achieved if the plan for the test is followed [87]. Therefore, a pre-study (pilot test) has to be made where errors in the testing protocol can be identified and the type of data that the test will produce can be evaluated. A pilot test is conducted as a small test run, identical to how the final test is intended to be done [66].

5

Design Process

The process of the study has been divided into four major phases: two iterative development phases and two user tests. Pre-studies consisted of planning the study, defining its scope and researching material related to the domain. During the iterative phases most of the development of the prototype was done. In descriptive and exploratory user tests data for answering the research questions was collected and analyzed.

5.1 Workflow

From the beginning, the plan for finding material for answering the research question was to compare a SB system used for making design choices with a VR system of the same functionality. Following the research methodology presented by Lazar, Feng and Hochheiser [8, 25-44] (see chapter 4.1) differences in user experience was planned to be found through an explorative test, where the only independent variable were the compared systems medium. Rather than using an existing VR system for comparison, designing one as part of the study was planned for two reasons: Firstly, no VR system with functionality similar to a SB system allowing for making design choices was available to the study. Secondly, designing a VR system within the study allowed for making it as similar as possible in functionality compared to the SB system, making it more likely for the systems medium to be the independent variable affecting results in the explorative test which was planned.

The major part of the study was conducted over a 16-week period (see table 1). The process, and what should be done in each of these 16 weeks, was planned at the start of the project. The process was divided into four major phases in addition to pre-studies, the phases consisted of iterative development of the prototype and testing (see figure 10). During the weeks of pre-studies, the domain and what has been done previously in relation to the study's research question was researched through literature studies. This research covered reading papers and books about the domain, finding software and programs similar to the prototype planned to be made and search the internet for sources containing more general information.

During the iterative development phases, material for answering the research questions were collected. The first step in this process was building the prototype which were to be used for both descriptive and exploratory research tests. The initial implementation of the prototype was based on researched material of the pre-study phase, it was then contextualized using rapid prototyping such as sketching and digital mockups.

After the descriptive research test, the prototype was iterated based on results of the descriptive research test in the second iterative development phase. The prototype was then used as part of the exploratory research test. During this test, users were observed both using an SB interface and an VR interface when making decisions for a prefabricated house.

Table 1. The timeplan of the project.

Week.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Pre-studies																
Iteration 1																
Desc. Plan																
Desc. Test																
Iteration 2																
Expl. Plan																
Expl. Test																
Analysis																
Report																

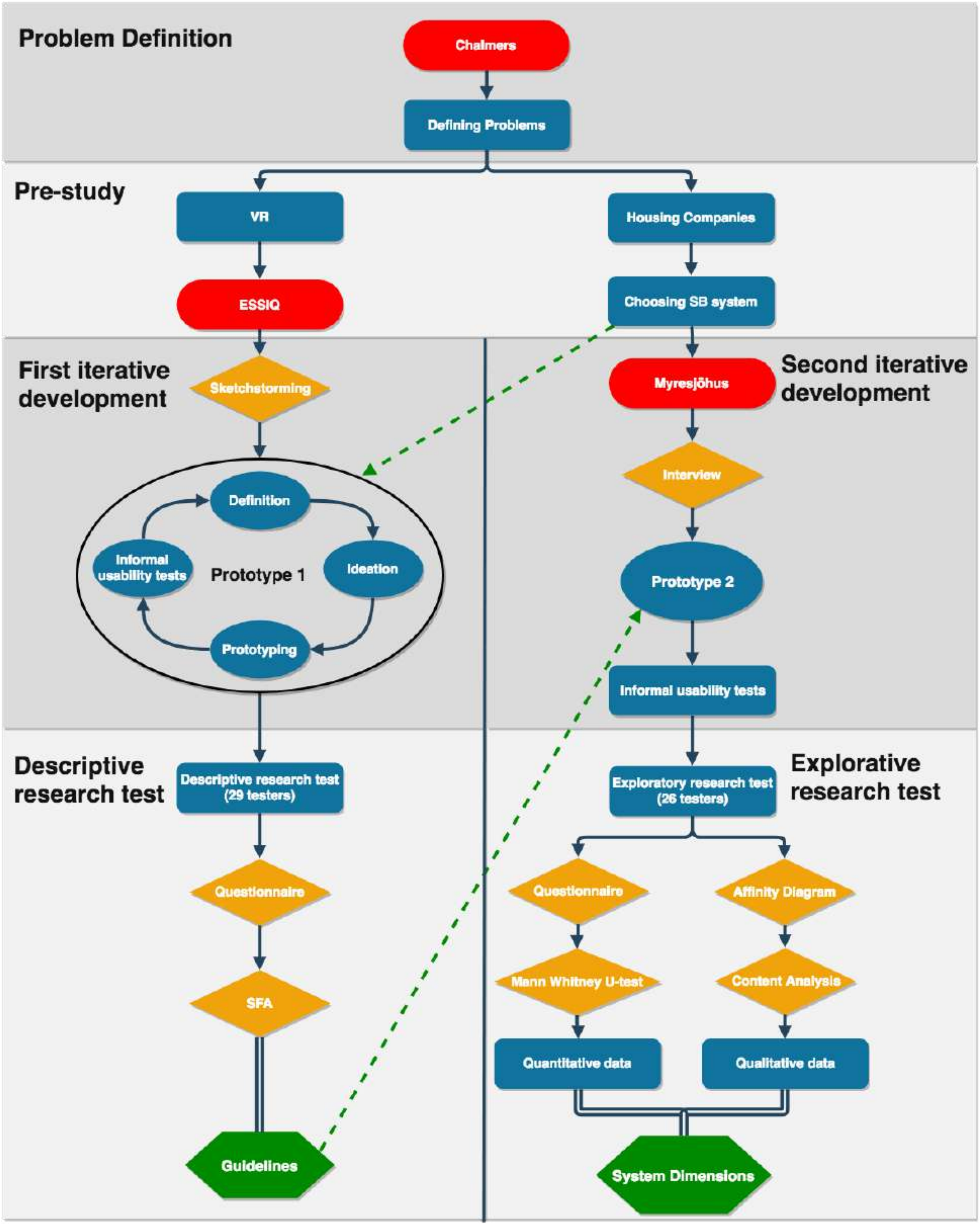

Figure 10. Process diagram which shows the overall workflow of the study.

5.2 Initial concept

The first step in the design process was to consider if the prototype we planned to make as part of the study was possible to realize and within scope of the study. The original concept from the start was to create a program or plugin which would import any model of a house, and set up an generalized environment for that model in which design choices could be viewed and made. No additional third party softwares would then be required, since the program would be standalone or integrated into an already existing software.

The first concept version of this idea was to create a plugin for the program Sketchup. The prototype would allow users to create models and design choices directly in Sketchup. With the help of the prototype, which would act as a plugin to Sketchup, it would be possible to see created designs in a VR environment and make design choices for that model.

The second concept was to create a standalone application to which users could import any external model, which could then be seen in VR with the possibility to change design choices. When considering the two concepts it was decided that they were both out of scope. The first concept being technically challenging, and the second too time consuming. It was decided that the idea had to be simplified and revised.

5.2.1 Concept revision

After having realized that the prototype had to be simplified, we researched different 3D-asset import pipelines for UE4 and found datasmith [25]. It was decided that a prototype using this pipeline were to be made which would work only for one VR environment, thus discarding making a generative environment. Having a generative environment was not expected to contribute to the study's goal of answering the research questions. After the revision of the concept prototype, it was defined as a program which would visualize how one arbitrary house model would look like in one arbitrary VR environment, where specific design choices for that house could be made.

5.3 Pre-study

In order to start shaping an explorative study which would yield material for answering the research question a pre-study containing literature studies, market research, and contact with companies was made. During the process, the pre-study was also summarized in a planning report. In the pre-study, information about related research made on user experience in relation to VR and digital advertisement was mainly found through Chalmers library's online resources and Google

Scholar. Technical material such as VR frameworks provided by companies, related software, and UE4 documentation was found through Google and YouTube.

5.3.1 Market Research

Market research included learning about the process of buying a prefabricated house, as well as learning how personal choices are made during that process. Catalogues for making design choices were ordered from several different companies, in addition online services for making design choices were tested and evaluated. Several SB interfaces were investigated and among these, a-hus's online house planning software [10] was chosen as the best software suited to be used as the SB interface in the exploratory research test. The software was mainly chosen because of its simplicity and focus. It was experienced as the most understandable and intuitive in a usability perspective for beginner users among the software tested. It also did not feature much excess functionality compared to other online services; it was mostly focused on making design choices. It was also deemed to be within the study's scope, considering that the functionality of the SB interface was also to be featured in the VR prototype and were to be implemented within the study's timeframe. In addition, VR applications used by the housing and architecture industry were evaluated based on function and interface design. None of these softwares were considered having a similar purpose to a-hus's online house planner and interface elements had vastly different functionality than what the study's prototype was planned to have. Hence, the interface of those VR software was not considered an important source for inspiration or learning for this study.

5.3.2 Company contact

During the pre-study six swedish housing companies providing prefabricated house services were contacted through email. In these email conversations ten specific questions were asked, shaping an open-ended questionnaire (appendix III), in addition permission to use the company's images as part of this report was also requested. Eventually, a few companies gave permission to use imagery but only one contact responded to the questions asked. The contact with this company would prove valuable for both getting to meet with a professional house retailer and gaining access to a professionally made model of a house later in the study.

5.4 First iterative development phase

The development of the VR prototype followed an iterative process consisting of four stages: definition, ideation, prototyping and testing (see figure 9). In the first development phase focus of development was mainly on giving the system and its functions a clear definition. This definition and structure could then be refined during the second development phase.

5.4.1 Defining the prototype

By analyzing the features of a-hus's online house planner [10] a set of requirements of what interactions the prototype must allow was made. A list of which design choices should be available for the user to change was also written, the list stating the number of alternatives each design choice should have and the nature of those choices. During this process it was decided to further limit the scope of the prototype to only feature a few of the choices which are available to customers of prefabricated houses. Adding more design choices would not contribute much to the study's results, since the results from the chosen design choices are applicable on design choices in general. Therefore, it was decided that only design choices which were available inside the house would be part of the study. This removed the need for the prototype to feature an outside environment.

The features of the SB interface, the online house planner, was mapped using an HTA. By making an HTA it was possible to define what needs of the user the prototype had to fulfill rather than what its exact features should be. This difference was important to make as the interface were to be translated to VR, a different system than SB, in which needs of the user could be fulfilled in a fundamentally different way than they are currently. The mapping of the HTA was done by going through the needs of a user of the SB system while writing the steps that users would need to take in order to reach their goals on sticky notes stuck to a wall (see figure 11). Five main goals of the user, with varying number of steps to be achieved, was found.

Figure 11. Mapping of user needs and system features. Authors own image.

5.4.2 Ideation

Having defined the needs of the user, the next step of the process was to ideate on features of the VR interface which would be able to fulfill those needs. Conducting the study at ESSIQ, many practitioners from different fields of engineering willing to help the study were available. It was decided that ideation was a good time for utilizing this resource. Generating ideas using more people could yield more concepts and those concepts had the potential of giving insights in what beginner VR users mental model looks like, as the practitioners available for idea generation were generally unexperienced with VR. A sketch storming session was therefore held, the method has a game like structure [80] making it possible to turn into an enjoyable group activity. The sketchstorming had six participants, two were students from Chalmers, whom also conducted a study at ESSIQ, and the remaining four were young engineers 25-30 years old employed at ESSIQ. The expertise of the engineers included machine technology and UX design.

During the sketch storming session two different features which were considered challenging to design were presented to the participants. Following the process of sketch storming (see chapter 4.5.4) time was given to sketch solutions to the different problems (see figure 12) and the sketches were presented to the group without an explanation as to what the sketch were supposed to illustrate. Guesses on what solution each sketch suggested were recorded as well as the original idea behind the sketch.

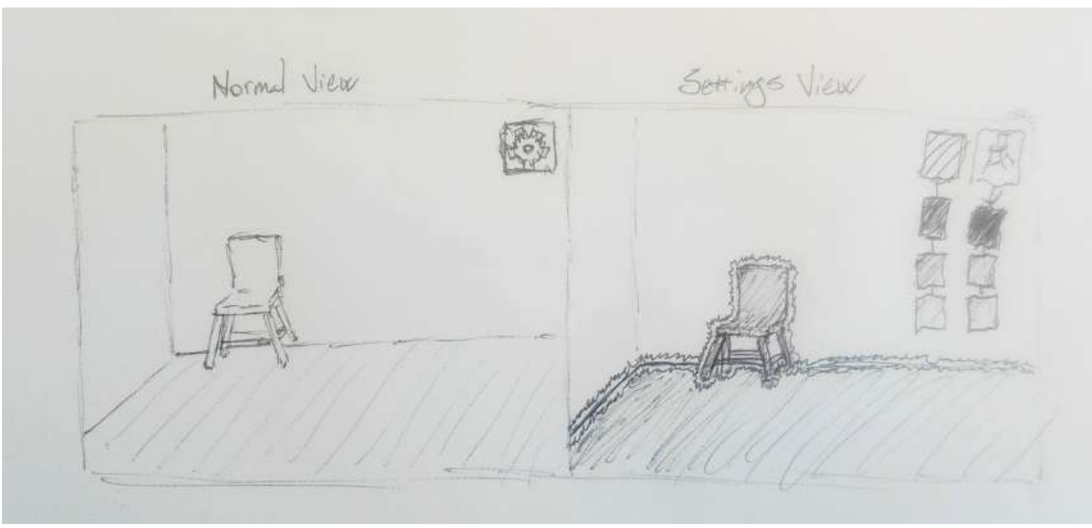

Figure 12. A sketch from the sketch storming session. Authors own image.

The material received from sketchstorming was not possible to make into features of the prototype directly. The challenges presented during the sketchstorming process each focused on a single feature, therefore suggested solutions did not relate to the prototypes' other features and requirements. Instead of being used as features directly the material was used as a base, and a source of inspiration, during brainstorming not including practitioners from ESSIQ. As a complement to brainstorming, bodystorming was used and concepts ideas were sketched on paper (see figure 13). Props used for bodystorming consisted of catalogues, VR controllers, pens, papers, and sticky notes (see figure 14). This process gave finalized feature concepts ready to be prototyped using UE4 and VR.

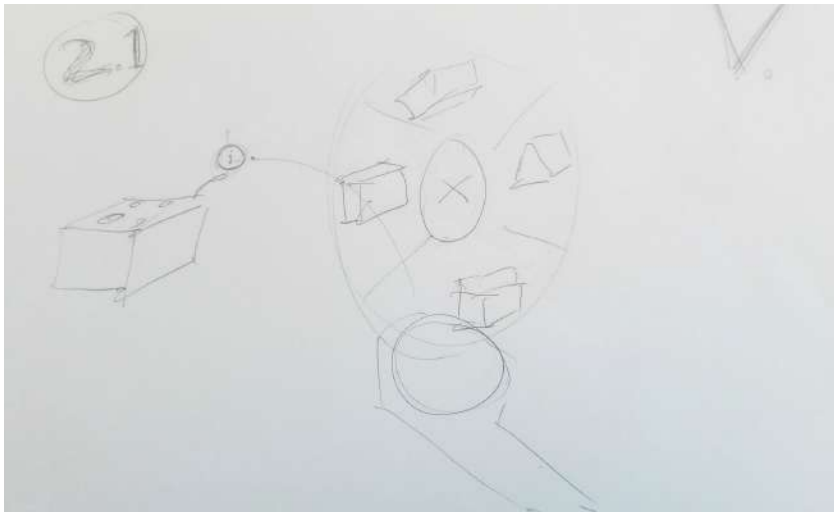

Figure 13. Sketch of idea for a circle based menu used for making choices. Authors own image.

Figure 14. Bodystorming a VR menu interface using a catalogue, sticky notes, and a VR controller. Authors own image.

5.4.3 Low fidelity prototype

A low fidelity prototype was made using UE4. Authors' experience in working with the game engine made the process of creating an interactive digital prototype quick. In this stage, the time to make the prototype and its level of fidelity was comparable to that of a paper or foam board prototype. The underlying data structure was created first and it was the only part of the prototype which was made finalized enough not to have to be changed over the course of the study. This allowed for different ways of interacting with the data to be prototyped quickly, without having to change underlying functionality. In the low fidelity prototype basic shapes were used as replacements for design choices and placeholder images for icons were used (see figure 15). Focus of the prototype in this stage was to allow a rapid process consisting of quick implementation, test of concepts, and many iterations. During this development online documentation was used extensively to solve unexpected problems in implementation and some research on how to use specific features of UE4 was required to be done.

Figure 15. Screenshot of the low fidelity prototype when tested in VR. Authors own image.

5.4.4 Informal usability tests

If practitioners from ESSIQ were available and willing to assist in the study, they were asked to act as testers for the low fidelity prototype. Having others test even the most basic concepts of the prototype allowed for discovery of fundamental flaws otherwise overlooked in its design. The tests were spontaneous and informal in that they followed only a rough protocol where the participant was asked to try a specific system feature and to think aloud. After each test a list of bugs to fix, errors to correct, and concepts to rework or discard was made. The tests were conducted at ESSIQ's main office using an HTC VIVE. During the first development phase, three informal test sessions were held, testing with a total of five different users.

5.5 Descriptive research test

The descriptive research test was the final test of the first iterative development phase. Its purpose was to evaluate the usability of the interface. The test was planned to gather both qualitative and quantitative data. There were two tests conducted at Chalmers and ESSIQ with a total of 29 test users.

5.5.1 Test design

The test process mainly consisted of having users complete a set of given assignments while also following a think aloud protocol (see chapter 4.4.5). These assignments were based on the functionality of the prototype as well as areas of the system which could potentially evoke errors in interaction.

A cognitive walkthrough was used to identify potential problematic areas of interaction which assignments could later be based on. First, tasks covering the core functionality of the system were defined as well as actions required to complete those tasks. For every action, we determined if there was a potential problem in completing that action or not. Once the problem areas and interactions had been identified the assignments to use during the test were defined. The goal of the assignments was to cover as many system features and potential problem areas as possible. Six assignments were used to cover all features and problem areas: Change the design of the doors, find the kitchen in the floor plan, change the design of every possible choice in the kitchen, find the price of the house, find information about the building area and finish the process.

The test was based on these assignments in order to make it possible to conduct an SFA (see chapter 4.4.4) which would help find error patterns of usability. However, there were also other observatorial needs which were not directly related to any of the assignments. As the point of the descriptive research test was to test the usability of the prototype focused on beginners, the users first action and button press were important to record. Therefore, a list of observational points was integrated into the SFA, which focused on first actions, first button press, and if there was some kind of confusion during certain kinds of actions.

To make the assignments in the test seem less obligated, and to make the user feel like they were in the process of buying a house, a scenario was written. During the test, the scenario was read to the test user one assignment at a time. In addition to the scenario a script for test facilitators to follow was also written. The script described what should be done and said at each stage of the test.

To collect quantitative data, and a good representation of the prototype's usability, a five-scale questionnaire following the UEQ framework [64] was made for participants to answer after interaction with the prototype. It was deemed that a scale of five answer options, rather than the original seven of the UEQ framework. If seven answer options were to be used results were expected to be more scattered and more difficult draw a conclusion from, due to the relatively low amount of questionnaire answers. In addition to the questions of the UEQ framework the questionnaire also had a few VR specific questions regarding experience from previous VR usage and interaction, motion sickness, disorientation, and clarity of the display and text. To measure the time the test would take, and to know if anything should be changed in the test script, a pilot test was conducted.

5.5.2 Testing at Chalmers

A room scale VR setup was brought to Chalmers and set up in a bookable study room. This setup was similar to the VIVE setup at ESSIQ used in informal user tests, in that the user could move freely due to the large space. Notes were placed at various locations on campus, advertising the test session to Chalmers students. The notes attracted students to the test location by offering free coffee and the opportunity to try VR. Coffee and candy were placed on a table outside the room in which the test was conducted to attract even more bypassing students. This process managed to attract 18 spontaneous test participants in five to six hours. They were all students roughly 18-25 years old. The test at Chalmers were focused on having as many testers as possible, therefore each tester was asked to complete only three of the prepared six assignments, making the test shorter. This focus was based on that recurring errors can either originate from general VR behaviour or from how the prototype is designed. More people and more data were to help in analysis in order to determine if the errors found were general for VR design or if they were more specific based on the prototype's design.

In order to conduct the test, two different roles had to be filled. One test facilitator recruited people for testing, by giving information about the test to bypassers of the room and serve them coffee. The other test facilitator performed the test with participants and took notes on each of the assignments, defined observation points and information gained through think aloud.

5.5.3 Testing at ESSIQ

Most of the people available at ESSIQ’s headquarter office were asked to participate in the test. A thread was also started on ESSIQ’s intranet, asking if more consultants, not at the headquarters, were able to participate in testing. A total of 11 participants were available for testing. They were all hired consultants of ESSIQ, roughly aged between 20 - 45, with a higher than average interest in technology. Each participant was given their own time slot of 20 minutes. Testing at ESSIQ was planned to be more qualitative than at Chalmers, with more time dedicated for each individual tester and with a more elaborated questionnaire. Therefore, testers at ESSIQ did all six of the assignments, and three qualitative and open-ended questions was added to the questionnaire.

The test process at ESSIQ were similar to the one at Chalmers but with a change to the roles of the test facilitators. At ESSIQ, one introduced and conducted the test, while the other took notes. It was decided to split the roles like this to allow more elaborate note taking.

5.5.4 Analyzing results and defining changes

From the descriptive research test three different types of data to be analyzed had been collected: UEQ questionnaire answers, assignment and observational points, and open-ended questionnaire answers. Results of the analysis of this material is presented in chapter 6.2.

Answers to the UEQ questionnaire were summarized in a quantitative data table displaying all numerical values of the data set in addition to each question mean and median value. The table showed mean and median values both for tests conducted at Chalmers and ESSIQ respectively as well as a total given from all answers. By comparing the mean values of the answers to the questions it was possible to determine how testers experienced their interaction with the interface. The five most prominent questions with the worst mean value were considered to reflect the greatest flaws of the system and changes to the prototype aimed at addressing these flaws were planned.

Observations were analysed following the process of an SFA (see chapter 4.4.4). The most frequent and vital errors were added to the list of flaws of the system along with suggestions on improvements. The open-ended questionnaire questions mainly addressed features of the system users thought were missing or that they wanted to add. These features were discussed one by one, being added to the list of changes if they were deemed to be an improvement to the system and within the study’s scope.

Once the collected data from the descriptive test had been summarized it was used to try to answer the second research question of the study. This process consisted of finding features and parts of the VR system which had either particularly high usability or irregularly low. Then, these features were analysed and discussed based on literature and personal assessment. Based on this analysis six guidelines for design was found (see chapter 6.3).

5.6 Second iterative development phase

A second development period was initiated following the descriptive research test. During this phase iterative development of the prototype continued and it was made to be of higher fidelity. Contact with housing companies from pre-studies was also continued, leading to an interview with a professional house retailer and permission to use a professional model of a house as part of the prototype.

5.6.1 Interview with real estate salesman

Through email conversation with Myrsejöhus the opportunity was given to meet and interview a real estate salesman. The interview was conducted at Myresjöhus's office in Gothenburg and it was held in an unstructured manner, meaning that general goals of the conversation were prioritized and only a few specific questions were prepared beforehand (see chapter 4.4.1). The method was chosen because relatively little was known about the subject of the interview prior to the meeting, the interviews purpose being to fill that gap. It was therefore decided to use an exploratory and highly qualitative method.

The interview helped in gaining increased knowledge about the domain of purchasing and selling prefabricated houses and making personal design choices for those houses. This knowledge was mainly used for planning and design of the exploratory research test.

5.6.2 Receiving a professional model

During the interview with a retailer from Myresjö, contact information to a developer whom had created a VR software for showcasing personal design decisions for Smålandsvillan was received. Contact with this developer allowed us to gain information about the software developed for Smålandsvillan, which had been finished a few weeks before. In the VR software there was a very well made, professional 3D model of a house. Following Intel's guidelines [14] on the principles of basic realism it was deemed favorable for the validity of the results of this study to make use of a digital environment which was as realistic and well-made as possible. Permission to use the model used in Smålandsvillan's software was therefore requested. After having signed an agreement not to use the model outside of this study, permission to use the model was granted. As part of this agreement we are obliged to note that anything displayed using this model is not representative to houses which may be bought from Myresjöhus or design choices which may be made to such houses. After the model had been received it had to be adjusted to fit the study's prototype. Part of this process consisted of adding textures to all surfaces of the model and implementing design choices available to the user.

5.6.3 High fidelity prototype

The prototype was changed based on analysis of the results of the descriptive research test. After changes had been made informal user tests were held once more and the prototype was further iterated upon. When permission to use the model from Smålandsvillan had been received the prototype was made to be of a higher fidelity. Making it so included fine tuning aesthetics of both the environment, interface, menu placement, and adding highly detailed materials to surfaces and design choices. The materials were made using a plugin for UE4 called Substance [88] which allowed for making and editing highly detailed textures (see figure 16). Having a prototype of high fidelity in both functionality and looks, representative for commercial VR software, to be used for the explorative research test was considered to be important for the validity of the tests results.

Figure 16. Detailed surface materials made using Substance. Authors own image.

5.7 Explorative research test

To gather data to be used for answering the study's research question an explorative research test was held. The test itself consisted of letting a user make personal design choices for a house using either an SB or VR interface. During interaction, a think-aloud protocol was used and afterwards testers were asked to answer a questionnaire with questions based on six hypotheses. The quantitative results were analyzed numerically, supported by a Mann-Whitney U-test, and the qualitative results by using an affinity diagram together with a content analysis.

5.7.1 Test design

The second test was designed based on the collection of data which would answer the hypotheses defined in chapter 4.1. In the test, the user was asked to complete a set of assignments. These assignments were formed based on the questionnaire questions, which was applicable to both the SB and VR systems. The assignments participants were asked to fulfill were to: Consider each available design choice, keep within a specified budget, have knowledge of the build area of the house, and have knowledge of the energy class of the house's fridge.

The test's questionnaire consisted of a total of 20 questions (see appendix IV). The questions of the questionnaire were mainly designed to gather quantitative data, but it also featured one open ended question. The questions were formed to answer six hypotheses. These hypotheses were formulated by following Lazar, Feng and Hochheiser's [8, p.25-44] process of experimental research. They consist of one null-hypothesis (H_0), stating that there is no difference between the different examined states of the system, and one hypothesis (H_1) stating that there is a difference. The hypothesis used for formulating the questions of the questionnaire in this test were:

$H_1$1: *Design choices are perceived differently when experienced using a VR interface compared to an SB interface.*

$H_1$2: *A customer will have a better understanding of how a house will look when finished when using VR to make personal design choices compared to SB.*

$H_1$3: *There is a difference in how confident customers are in their design choices when choosing them using VR compared to SB.*

$H_1$4: *There is a difference in the basis on which customers make design decisions when doing so in VR compared to SB.*

$H_1$5: *There is a difference in how customers perceive facts about their design choices and the house when that information is mediated through VR compared to SB.*

$H_1$6: *There is a difference in the amount of money spent using VR compared to SB when selecting design choices.*

Similar to the first test, to measure the time the test would take and to know if anything should be changed in the test script, two pilot tests were conducted: one for VR and one for SB. The pilot tests were performed according to script, to represent a real testing scenario.

5.7.2 Test execution

Tests were held both at ESSIQ and Chalmers, using the same VR setup at ESSIQ as for the previous test, and borrowing Chalmers' equipment and space. Personal computers were used to run the SB interface. Test subjects were found by contacting most of the people working at ESSIQ headquarters and contacting acquaintances, in total there were 26 test participants roughly between 23-50 years old.

During the test, one test facilitator followed the test script and interacted with the test subject. The other test facilitator took notes on what the user said during the test and their actions when completing the assignments. The collected data from those notes were later used for analyzing the test results. The script of the test followed a seven-step process which was adapted from the book Research Methods in Human Computer Interaction [8]. Summarized, the seven-step process consisted of resetting the test and greeting the test subject, randomizing which interface to use, have the user interact with that interface, and then let them fill out the questionnaire. During interaction the test subject was asked both to fulfill all given assignments and to think aloud. The tests were recorded using a screen capturing software.

The SB system used in the test had more available design choices than the VR system. In order to get a representative comparison between the two systems users of the SB interface were restricted to only making specific choices found in the interior and kitchen category of the program.

5.7.3 Analyzing test results

Two types of data were collected from the exploratory research test, qualitative data from observations and quantitative data consisting of questionnaire answers. The results found through analysis of this data were intended to answer the first research question through confirming or rejecting of the hypothesis presented in chapter 4.1. The full results of the analysis are presented in chapter 6.4 and 7.1.

The quantitative data of the exploratory test was analyzed similarly to that of the descriptive test. A table was made summarizing the numerical answer to each question of the questionnaire, each question mean answer, and the contrast between mean value of answer between the SB and VR interface. This contrast was what was of the most interest in the resulting data. It would tell if there was a difference in how users experience the SB and VR interfaces and such a difference would be able to confirm stated hypothesis, otherwise the null-hypothesis would be confirmed.

To assure that the difference between each pair of mean values were statistically significant a Mann-Whitney U-test was made (see chapter 4.4.9). If the result were significant between two mean values of high contrast it showed that it was valid to use as results. A lack of significance in low contrast pairs instead confirmed that there was no difference in the experience between the two interfaces related to that question. Any results in between these two alternatives could also not be considered to be true differences.

The qualitative data was analysed using content analysis in combination with an affinity diagram. Notes recorded during testing through a think aloud protocol were used as the material for the affinity diagram. Expressions and quotes said by testers were recorded on individual sticky notes and posted on a wall. One diagram was made for comments made about the SB interface and one was made for the VR interface. The sticky notes were then grouped into categories based on the similarity and topic of the comments. The categories of the affinity diagram were then used as codes in the content analysis. Using these codes larger categories were identified, letting the total number of quotes in each category determine its importance and significance. The categories and their grades were then compared and used to validate, or invalidate, differences found in the analysis of the quantitative data. Additional differences were also found in comparing the results of the content analysis.

6
Results

The results of the study include all material produced in order to help answer the research question. This includes the prototype, analyzed data from both user tests, as well as the design guidelines and differences in system dimensions found from the analysis.

6.1 Final prototype

The final version of the prototype is made to function as a VR alternative to a-hus online housebuilder tool [10]. The prototype's purpose is not to introduce new features and functionality: the user should be able to achieve the same goals using the prototype as when using the online housebuilder. The prototype is designed to fulfill the same user needs as the housebuilder but using VR as a medium rather than SB. All images in the following subchapter are owned by the authors.

6.1.1 Tutorial

When the user starts using the prototype, they are introduced to a tutorial explaining the ways in which they will be able to interact with the virtual environment. The tutorial is displayed on a curved screen in a white environment, the screen not being completely white. The tutorial consists of two different images, the first (see figure 17) shows button interactions of the controller through an orange highlight and text, and the second (see figure 18) displays the two ways in which the user can choose between design choices. Progression through the tutorial is done by pressing both interactive controller buttons at the same time. The user is given feedback if any of these buttons is pressed through a corresponding icon turning orange in the screen's bottom right corner (see figure 18).

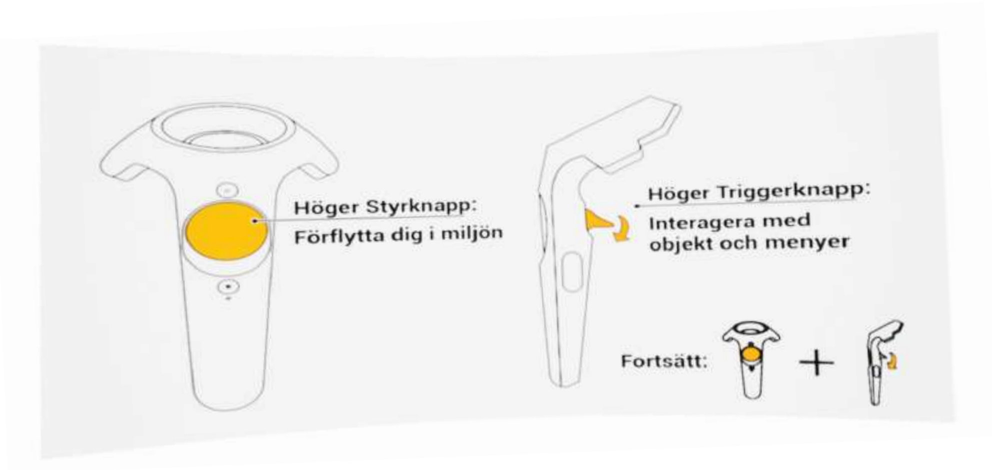

Figure 17. The first screen of the tutorial.

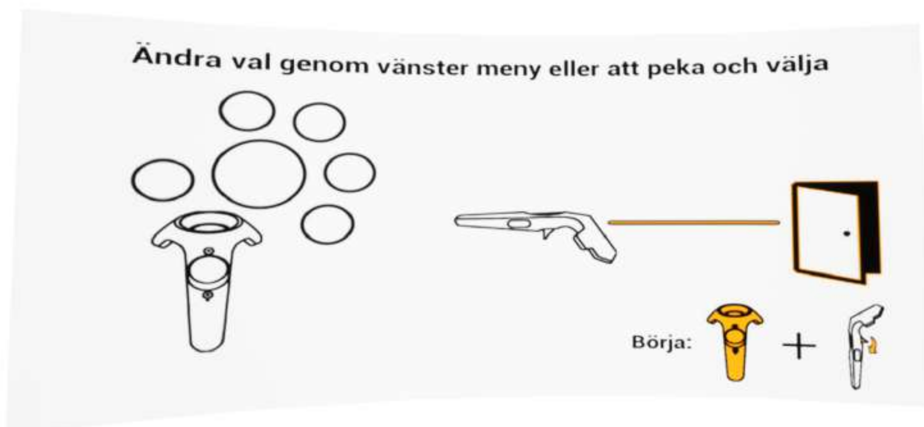

Figure 18. The second screen of the tutorial, one controller button currently being pressed.

6.1.2 Point laser

A blue laser emanates from the user's right controller at all times (see figure 19). This laser is used as a way for the user to interact with elements of the environment. When pressing the interaction button on the controller, it is the element which the laser is pointing at which will respond to the interaction. The laser can also be used to highlight interactable elements of the environment. When an interactable element is being pointed at with the laser the laser turns yellow and the element pointed at will provide feedback to the user, showing that it is being highlighted (see figure 20). When pointing at an element close to the user the laser becomes thinner. A spherical shape at the end of the laser mediates that it hit an element that it is unable to pass through.

Figure 19. A laser emanates from the user's right controller at all times.

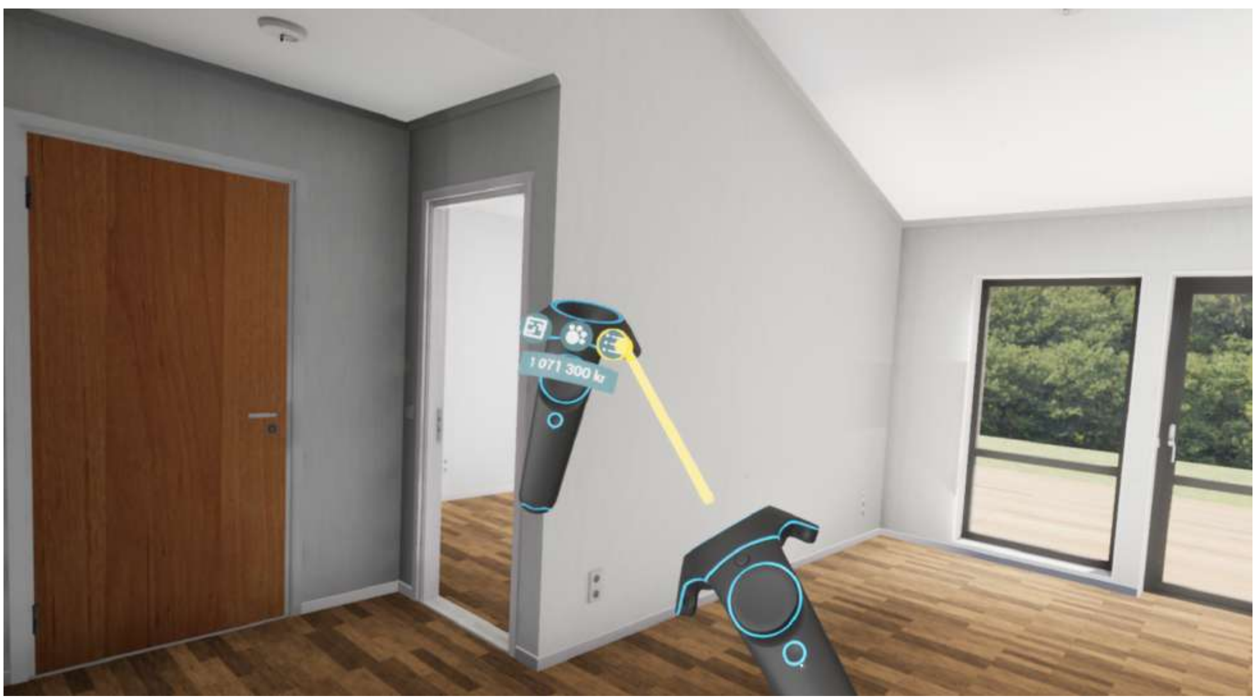

Figure 20. An interactable element is being highlighted by the point laser.

6.1.3 Design choices

The prototype features 52 different choices which can be made for different interiors across 11 different categories, the categories being sorted by "interior" and "kitchen" choices. The different categories from which design choices can be made is: Appliances, kitchen fan, kitchen drawer handles, kitchen drawers, kitchen tap, ceiling, floor, doors, door handles, and baseboard. When a choice is made within a category, all visual elements of the environment of that category changes their visual appearance.

When an element of the environment which can be changed is pointed at with the point laser the laser turns yellow and all elements of the pointed at element's category displays a yellow highlight visible through geometry (see figure 21 and 22).

Figure 21. Kitchen drawer handles pointed at, all handles showing a highlight.

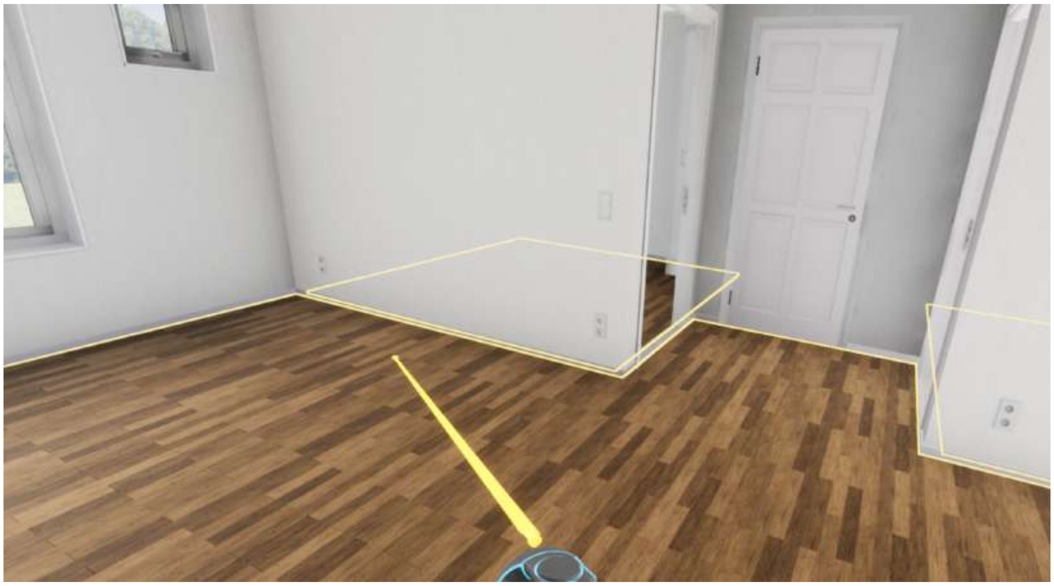

Figure 22. The floor pointed at with the point laser, highlight visible through geometry.

6.1.4 Choice menus

Design choices can be changed visually through interaction with two different menus. Within the study, these different menus are called the *constellation menu* and the *circle menu*. The name of the constellation menu originates from Google's Daydream Elements [89], which features a similar menu from which it was inspired.

The constellation menu is always available through the menu at the users left controller. It features all categories of design choices in the environment, making it possible to change any design choice regardless of the user's location. The menu consists of circular navigation elements and *choice bubbles* (see figure 23). When a navigation element is pointed at with the laser it displays elements directly above and below it in the menu hierarchy while also minimizing all other menu elements. However, navigation will only happen if the user moves the laser slow enough, otherwise the system will register the user pointing at the menu as unintentional. The menu hierarchy has a tree like structure with the two main categories, interior and kitchen, as roots, each design choice category as branches, and design choices as leaves. Design choices are displayed through individual choice bubbles.

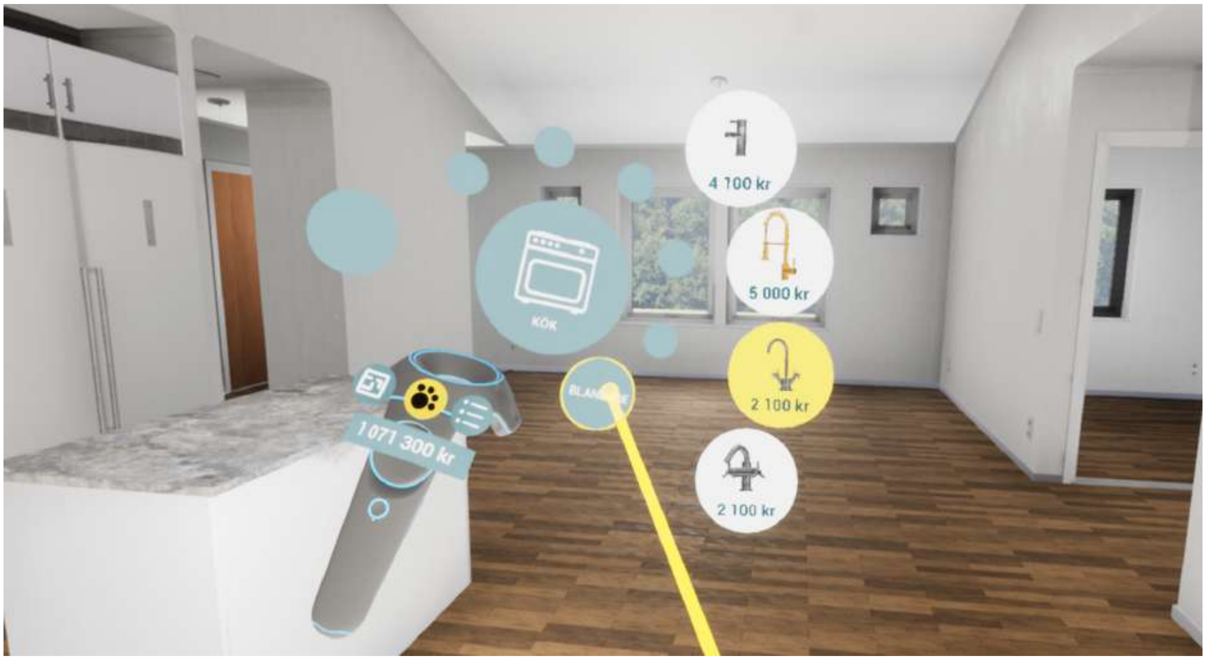

Figure 23. The constellation menu.

A choice bubble displays a 3D model of the choice's visual characteristics in a white circular space along with its price below the model (see figure 24). If a choice only changes a model's material properties, the displayed 3D model in the menu is a square like slab (see figure 25). If a choice is the currently selected choice the space inside the bubble is yellow rather than white. When a choice bubble is pointed at, all elements of the bubble's choice category in the environment is changed to match the visual characteristics of the pointed at choice. When interacted with, the choice of the bubble becomes the currently selected choice for that category.

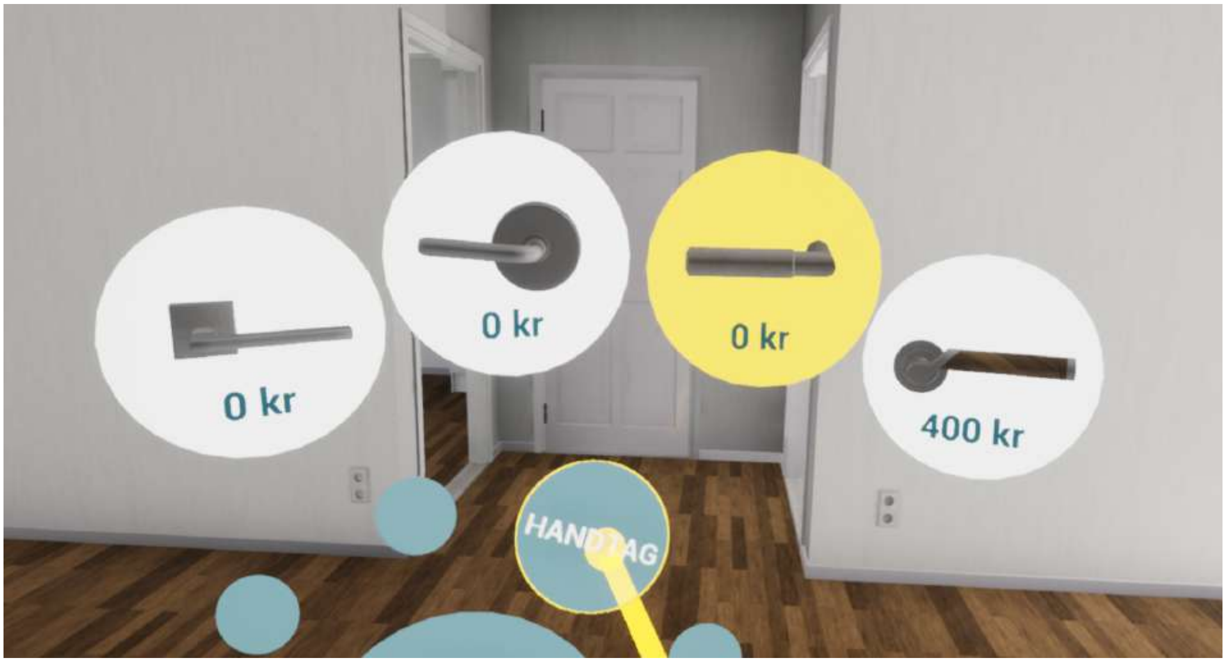

Figure 24. Close up of choice bubbles in the door handle category.

The circle menu is accessed by interacting with an element of the environment which can be changed. The menu appears at a set distance relative to the world location at which the laser was pointed and the user. The menu is always rotated to face the user and it adjusts its rotation if they move. The size of the menu is also changed continuously, the menu keeping the same relative size from the user's perspective. It becomes larger when further away from the user and smaller when it is close. The menu changes size until it reaches a set limit where it would be impractical to use due to it being too small or big. The menu is closed when the user teleports, interacts with the constellation menu, or opens another circle menu. Accessing the circle menu also collapses the constellation menu, displaying its two root elements.

The circle menu consists of either eight, four, or two choice bubbles depending on the number of available choices for the currently accessed category. The choice bubbles in the circle menu functions the same way as the ones in the constellation menu (see figure 25). In the centre of the menu there is an interactable button with an information icon. This button allows the user to access more information about the currently selected choice (see chapter 6.1.6).

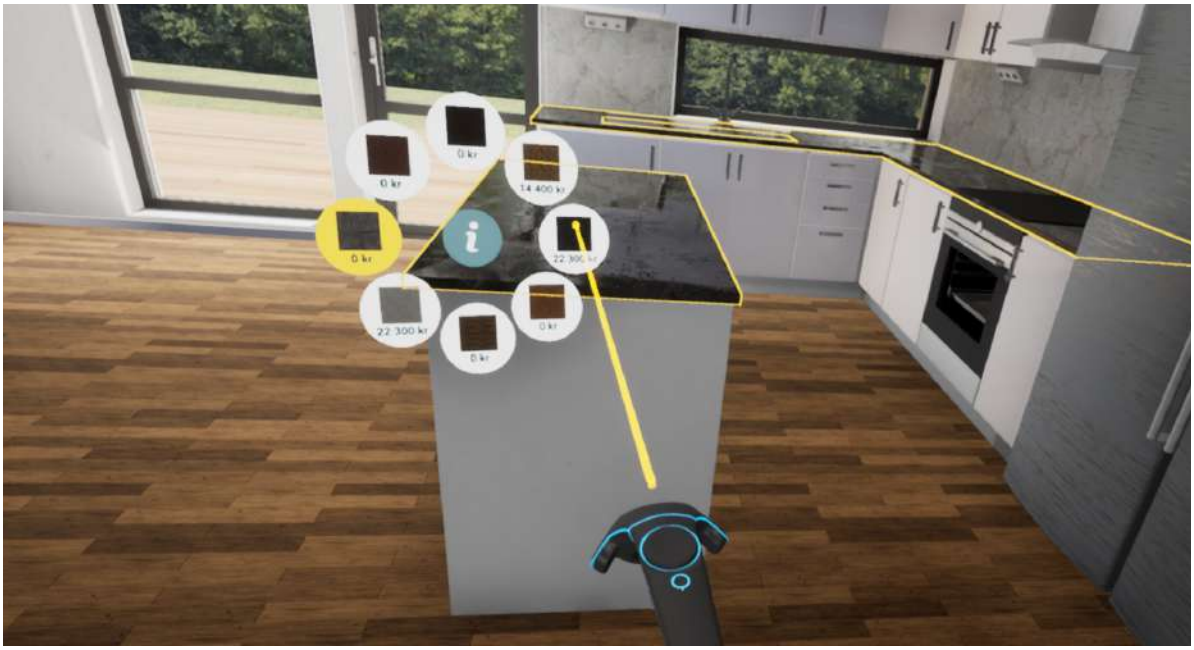

Figure 25. The circle menu displaying eight choice bubbles.

6.1.5 Controller menu

The left controller features three different options: Floor plan, constellation menu, and information menu. Each option changes the appearance and function of the left controller. Changing which mode is active is done through interaction with one of three buttons located below the changing element (see figure 20). The button representing the currently selected option has a different color scheme than the other buttons. Interaction with the active button deselects the currently selected option.

The floor plan option consists of a smaller and more simplified 3D model of the house making up the virtual environment (see figure 26).

Figure 26. The floor plan of the environment.

6.1.6 Text based information

When interacting with the information button in the circle menu the user is presented with a flat screen displaying information about the currently chosen design choice (see figure 27). If another choice bubble is hovered while the information screen is active the screen's text will update to display that choice's information instead. The screen follows the same behavior for re-scaling and rotating as the circle menu. The menu is closed either by interacting with the information button again, interacting with the screen, or closing the circle menu.

Figure 27. The screen displaying information about the selected design choice.

The information menu of the left controller consists of three different pages. The menu pages are navigated through interaction with tabs connected to the pages. The three pages displays a summary of the price of the house, information about the house, and contact information to real estate salesmen respectively (see figure 28). The price tab displays a summary of the price of all design choices chosen by the user as well as the summary for each of the main categories, interior and kitchen (see figure 29). The price summary can also be viewed and accessed from the left controller at all times.

Figure 28. The information menu in the tab displaying house information.

Figure 29. A summary of the price is displayed in the information menu and on the controller.

6.1.8 Teleportation

Like in any VR environment the user can move in the virtual environment by moving in the real world. The user is also able to use teleportation for movement, this can be used for short re-location or for travel over long distances. When holding down the teleportation button on the controller an arc displaying the user's new position (see figure 30), as well as the boundaries for their real-life space is shown. Similarly, to the point laser, this arc can be directed using the controller. When releasing the button, the user's location changes. This feature is inherent to any VR project created with UE4 and is active by default. Changes made to the original teleportation feature provided by the game engine is the color of the navigation elements, and removal of teleport rotation.

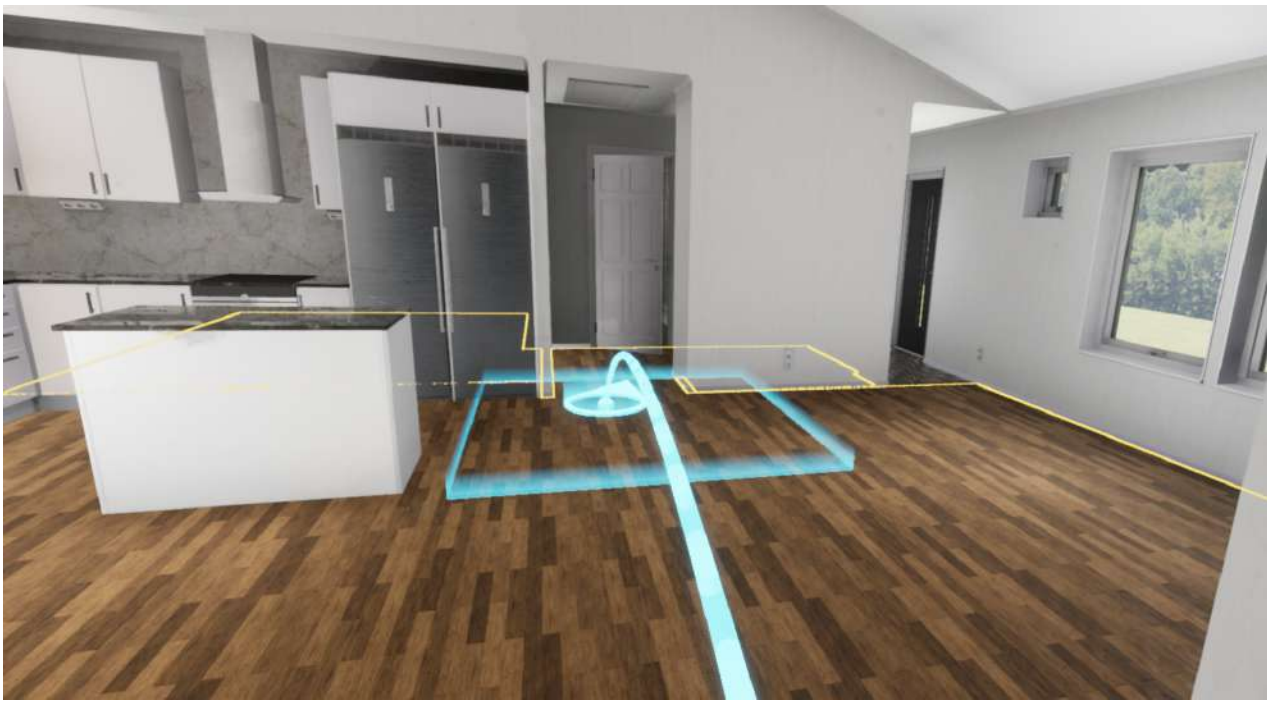

Figure 30. Visual elements of teleportation used to navigate the environment.

6.1.9 Environment

The environment in which design choices are made mainly consists of a house model provided by, and used with permission from, Myresjöhus (see figure 31). However, the house model, its materials, and any design choices that can be made in the prototype is not representative of any real-life products by Myresjöhus. The model and its materials are highly detailed, contributing to the high fidelity of the prototype (see figure 32). The environment outside of the house consists of a simple porch, a flat grass textured surface, and a backdrop image of a tree line (see figure 33).

Figure 31. One part of the environment in which the user can make design decisions.

Figure 32. Details of the model and materials.

Figure 33. The tree line backdrop as seen through a window.

6.2 Results from descriptive research test

Results gained from the usability test of the VR system, which consists of data from UEQ and SFA are presented in this chapter. These results do not represent the current version of the prototype presented in chapter 6.1, but rather the low fidelity version used at the time of the test.

6.2.1 UEQ

With data collected from UEQ a data table was constructed, which displays a user's score for each of the questionnaire questions (see appendix V). A mean value was taken from all test users for each question, which is presented in chart 1.

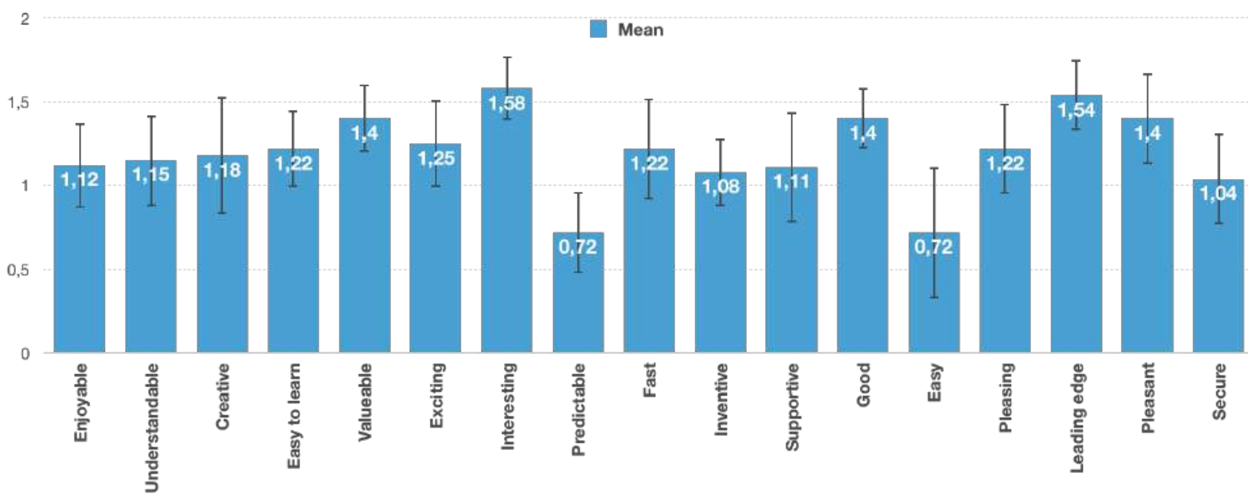

Chart 1: Graph of mean values of the UEQ with a 95% confidence error interval. Authors own image

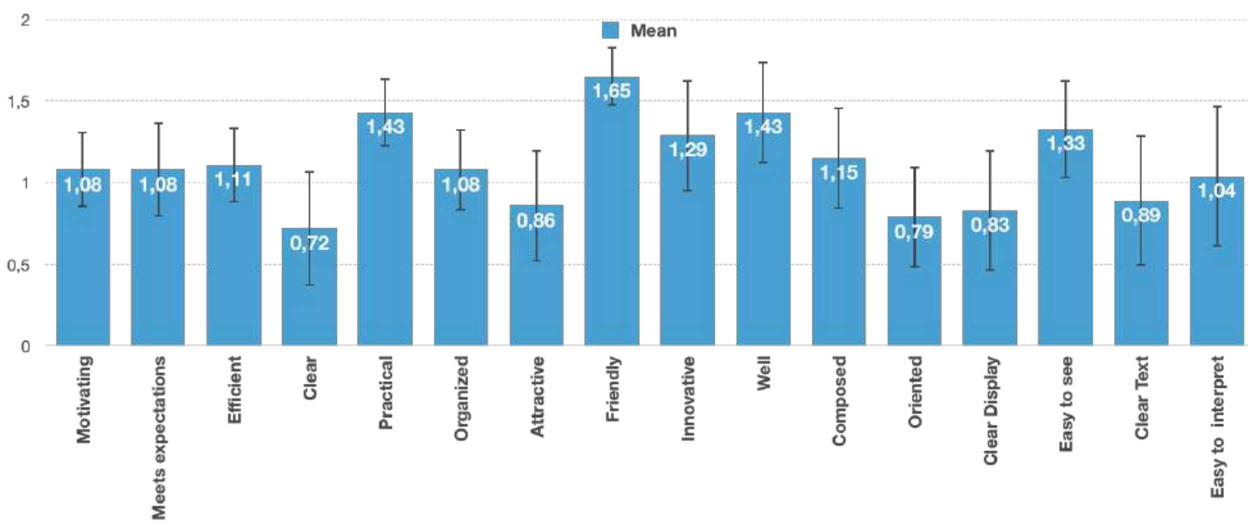

Chart 1 continued.

The numbers in the graph are set in a range from a possible score of negative two to positive two, however since every question got a score over zero, the lower range is not visualized in the chart. If a question in the UEQ score above 0,8 for a seven answer Likert scale, it got a positive evaluation [64]. Corresponding to a five answer Likert scale, which was used in this study, the value is 0,57, thus every asked question got a mean value representing a positive score. The error bars in the graph represent the 95% confidence intervals of the scale mean, this means that the antonyms of the questionnaire which are likely to be positive with a 95% probability are: enjoyable, understandable, creative, easy to learn, valuable, exciting, interesting, fast, inventive, supportive, good, pleasing, leading edge, pleasant, secure, motivating, meets expectations, efficient, practical, organized, friendly, and innovative. Categories of the UEQ that do not have a high probability to achieve a score over 0,57 can be categorized as being neutral.

Not a part of the original UEQ, as described in the UEQ handbook [64], were questions added by the author focusing on VR specific aspects. These were also analyzed in the same manner as the UEQ questions. With a 95% probability, using the VR system users felt: well, composed, and like they could easily interpret graphics and text. Categories that can be categorized into the neutral area are that users might feel disorientated, and that the display and text are slightly blurry.

From these results it is possible to determine in which areas of the UEQ scale structure (see figure 34) the system is lacking, and in which area it performs better. The results from table 2 lists how many items for each scale value is positive. Results show that the hedonic qualities of the interface are positive for all the scale items while some of the pragmatic qualities could be improved.

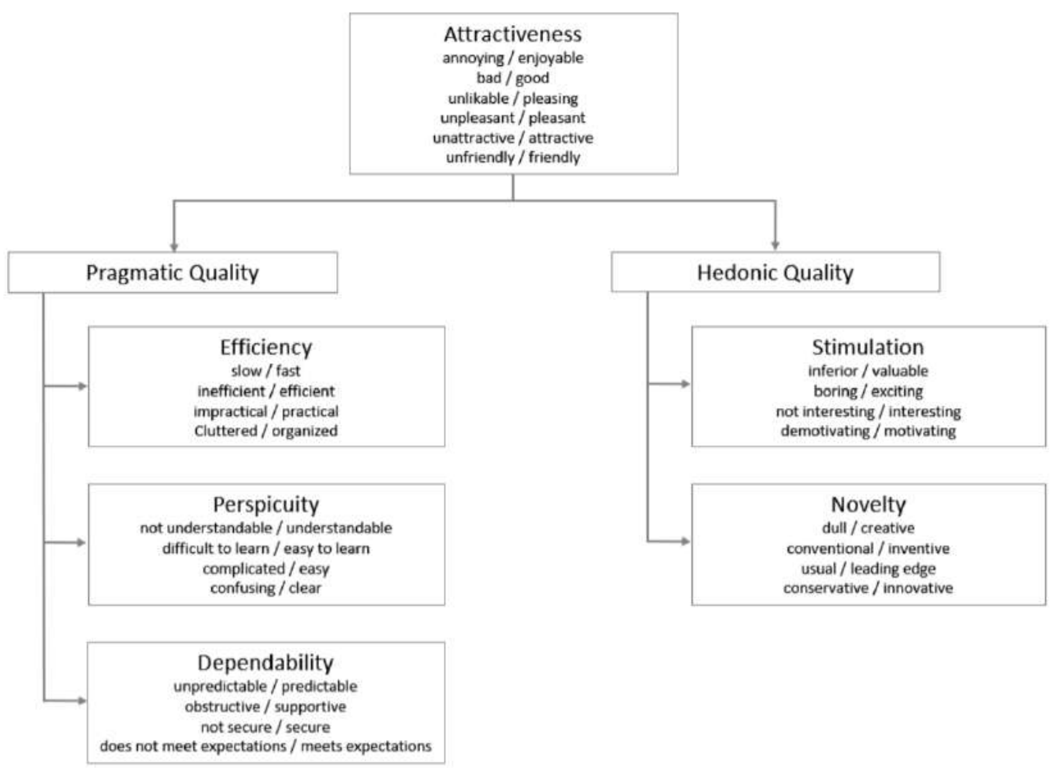

Figure 34: UEQ scale structure. Adapted from [64]

Table 2. The score for each scale value.

Scale	Max items	Positive items
Attractiveness	5	4

Efficiency	4	4
Perspicuity	4	2
Dependability	4	3
Stimulation	4	4
Novelty	4	4

6.2.2 Severity through frequency analysis

The data visualized through an SFA based on observations showed that there were some recurring problems in interaction with the system. Table 3 lists the problems, their frequency among all 29 users and how many of those were beginner users. A * indicating that the frequency of the problems was not documented, however through observations this problem occurred frequent enough to be relevant.

Table 3. Problems found in the SFA analysis along with their frequency.

#	Problem	Frequency	Beginners
1	The user finds an object in the environment they want to interact with, but they have a hard time understanding how to initiate interaction with it.	7	6
2	User did not understand how to initiate interaction with the constellation menu, some users searched for a physical button on the controller to use for interaction.	6	5
3	It is hard to look at a choice while at the same time interacting with the constellation menu, sometimes the users accidently hovers the wrong item while navigating through the menu.	*	
4	The user does not understand that choices can be made through two different menus.	*	
5	Text in the interface is blurry and hard to read.	*	
6	The main menu buttons are difficult to interact with.	*	
7	Users do not understand that the teleport functionality exists.	3	3

8	User understands that a design choice has been changed, but they are unsure about if other choices of the same category also changed.	6	5
9	Knows the system controls, but uses the wrong button anyway.	4	2

During the test, it was also observed which button the user pressed first, and what their intention with that button press was. Table 4 lists the four different combinations of button press and intentions. Blue represents a match between a user's button press and intention, while red implies a mismatch.

Table 4. Users first button press and intention

#	Button	Intention	Frequency	Beginners
1	Interact	Interact	8	8
2	Interact	Teleport	5	1
3	Teleport	Teleport	3	2
4	Teleport	Interact	9	9

6.3 Guidelines for beginner experiences in VR

Six guidelines on how to design VR interfaces for beginners are presented below. These guidelines are based on the authors own interpretation of the analysis from the descriptive research test in addition to observations made during the test. They are compiled from the quantitative results of the UEQ and the qualitative results of the SFA. Examples in the guideline descriptions are taken from the state in which the prototype was at that time.

Given the wicked nature of design these guidelines should be considered to be suggestions, each design and its process is created in its own context, were some of these guidelines may be applicable while others may not. Some of the guidelines presented are not beginner specific but general for VR. These guidelines are listed as well given that an overall improved design for all users will contribute to improve beginners experience as well.

Presented below is a summary of each of the six guidelines, following these are sub chapters describing each guideline further.

1. *Find and follow the few conventions for mapping VR controllers that already exist.*

2. *Consider teaching the user of the VR system what interactions are available and how they are made.*

3. *Acknowledge the visual difficulties imposed on a user of VR, consider ways to compensate.*

4. *Stabilize system elements attached to a controller or hand which the user has to read or carefully observe.*

5. *Provide rich and instant feedback that the user can not miss, never leave the user guessing.*

6. *Consider the advantages of skeuomorphism for interfaces and interactable elements.*

6.3.1 Follow mapping conventions

> **Guideline:** *Find and follow the few conventions for mapping VR controllers that already exist.*

In the prototype used at the descriptive research test the user were able to interact with elements of the environment using the pad button at the top of the HTC VIVE controller (see figure 35). They were also able to use the trigger button at the back of controller to navigate the environment through teleportation.

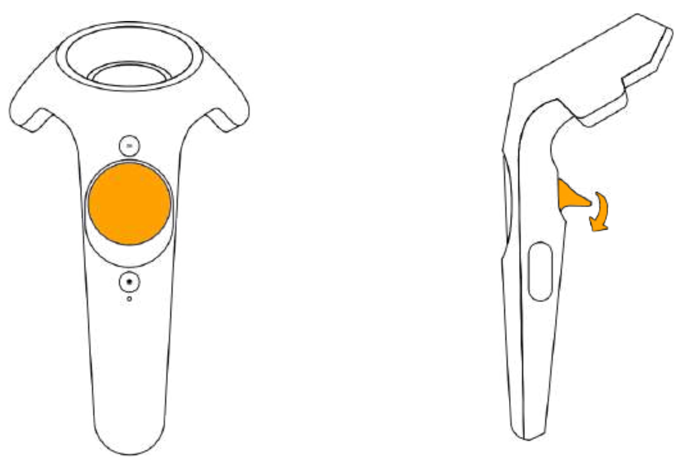

Figure 35. The pad and trigger buttons of the HTC VIVE controller. Authors own image.

The SFA shows that when wanting to interact half of the beginner users intuitively used the pad button while the other half used the trigger button (see table 4 #1 and #4). More experienced users on the other hand most often intended to teleport but used the systems interaction button instead (see table 4 #2).

This shows that given no instructions, beginners are equally likely to try either button for teleportation and interaction, but intermediates and experts will most often use the pad button for teleportation and the trigger button for interaction. A convention of how the buttons should be mapped has started to form, which can be seen in several examples, a few being Skyrim VR [90], The lab by Valve [91], and UE4's default mapping of controllers for VR projects.

Given that no mapping is favored by beginner users, in the test nearly an equal amount of users tried to teleport using the trigger as the pad, designers should consider helping their users in interaction with future VR systems by following the few mapping conventions of the controllers that does exist. In doing so they will have an easier time using other VR software, as they have learned "the right way" to interact with VR, the way it is used by most software, already from the start.

6.3.2 Teach interactions

> **Guideline:** *Consider teaching the user of the VR system what interactions are available and how they are made.*

When users of the VR prototype found an object in the environment, they wanted to interact with they often had a difficult time understanding how to initiate that interaction. Some user also did not understand how to initiate interaction with the constellation menu, searching for a physical button on the controller to use for interaction. This implies that given a new situation in VR a beginner user has no previous knowledge of how VR interactions with basic parts of the system works. In the test, some users explored the different options available to them in the normal fashion of beginner users [50], but others were observed requesting help immediately when presented with the virtual environment. These users initiated no actions themselves as they had just started using the software. It was also common for users to understand that an interaction was available, but not which button on the controller that would allow for that interaction, or if a button on the controller should be used at all.

Given these findings, designers of beginner VR experiences should consider including elements of their system which teaches the user what interactions are available and how they are made. The system must help the user by filling out the blanks of their understanding of how general interaction in VR systems works. Given VR interaction's relation to gaming, game tutorials can be used as a good example of how a system may teach a user how it is used at the same time as they are engaging with it.

6.3.3 Linewidth and text size

> **Guideline***: Acknowledge the visual difficulties imposed on a user of VR, consider ways to compensate.*

In the prototype used at the descriptive research test the user had to read text and interpret icons in order to complete assignments. A common problem for users was that the text in the interface was blurry and hard to read. Other observations note how icons with fine detail were unclear and hard to interpret.

The early prototype did not follow this guideline, making it hard to see the details of icons when using VR (see figure 36). The finalized prototype following this guideline, shows all icons and text being big and bold (see figure 28 and 36).

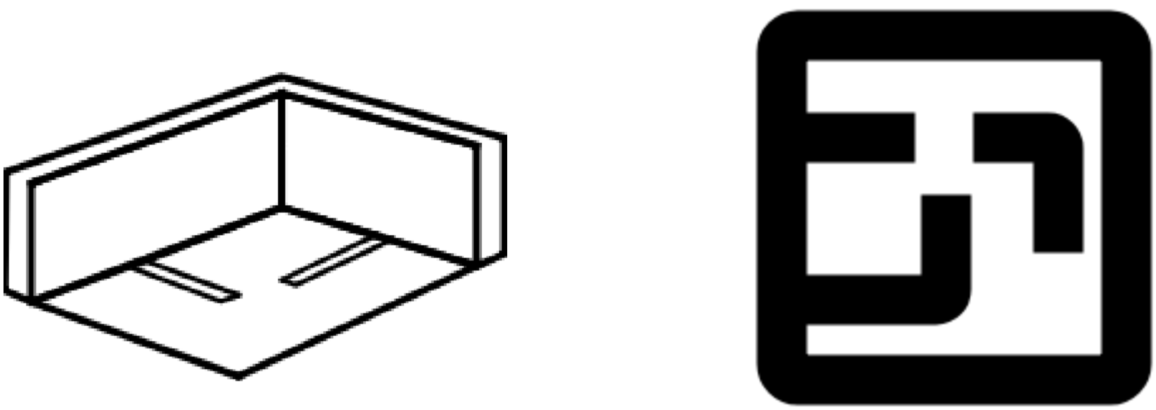

Figure 36. Two versions of the floor plan icon, using different linewidth. Authors own image.

In VR, text and small details are hard to perceive. It is important to make sure typography, and linewidth of icons and symbols are thick and of greater size than they usually are in screen based systems. Google developers mention that text should have a baseline of four dmms [47]. A dmm is a measurement created by google which represents the size of one millimeter to one-meter distance.

6.3.4 Stabilization

> **Guideline:** *Stabilize system elements attached to a controller or hand which the user has to read or carefully observe.*

Observations from the descriptive research test notes how elements attached to the user's controllers are sensitive and respond to every instance of movement they do. This creates an effect which makes the held element appear shaky. This were observed in the prototype where reading from information menu, a virtual piece of paper, or observing the floor plan could be difficult for the user.

Creating a restriction to ignore registration of minor movement and having a threshold when the element should move with the hand is one way to stabilize it being held. It is important not to overdo it by making the threshold too high, making the element detach from the controllers unexpectedly. Alger [13], [92], introduces the same concept but with laser pointers. He observed that it can be difficult to interact with a target from a distance when using a laser pointer due to shaky hand movement. A border cone was suggested as means for stabilization in this case. The cone making it so that if the laser is moved within the borders of that cone, the laser movements do not register.

6.3.5 Feedback

> **Guideline:** *Provide rich and instant feedback that the user can not miss, never leave the user guessing.*

During the descriptive user test, system interactions that were easy for the user to understand were those which provided instant and rich feedback. Examples of such an interaction was pointing at a choice bubble, which instantly changed the design choice the user often had in front of them. Interactions giving no feedback were harder for the user to understand. Example of an interaction lacking in providing feedback in the prototype was changing a design choice, which did not mediate that all other choices of the same type were also changed. Given no feedback the user has to either know or guess the consequences of an action, which is especially difficult in a VR system given beginner users do not have an underlying understanding of how the system can be expected to work.

6.3.6 Skeuomorphism

> **Guideline:** *Consider the advantages of skeuomorphism for interfaces and interactable elements.*

One way to compensate for users' limited knowledge when they start interacting with a VR system is to use skeuomorphic interfaces and interactive elements. The information menu consisting of papers with separate tabs was shown to be one of the easiest parts to understand of the prototype during the descriptive research test. No user interacted with the menu in an incorrect way. Given that a new user to VR has a lot to learn, skeuomorphic system elements is a way to lower that learning curve [1, p. 227]. Other than making interactions easier to understand, skeuomorphism also contributes to the system's basic realism, an important factor for keeping users immersed [14].

When system elements look and interact similar to what users would expect from real world representation of those elements the interaction becomes easy to understand and it can also feel more natural.

6.4 Results from exploratory research test

The data collected from the questionnaire of the exploratory research test were analyzed numerically by utilizing a data table, calculating mean differences, confidence intervals and significance values, and then comparing the values. The qualitative data was condensed using an affinity diagram and a content analysis. After the analysis of the different data a final collection of differences in user experiences between VR and SB found in the study are presented.

6.4.1 Questionnaire

With data collected from the questionnaire a data table was constructed (see appendix VI), which displays a user's answering score for each of the questions of the test's questionnaire (see appendix IV). A mean value was taken from all test users for each question, which is presented in chart 2.

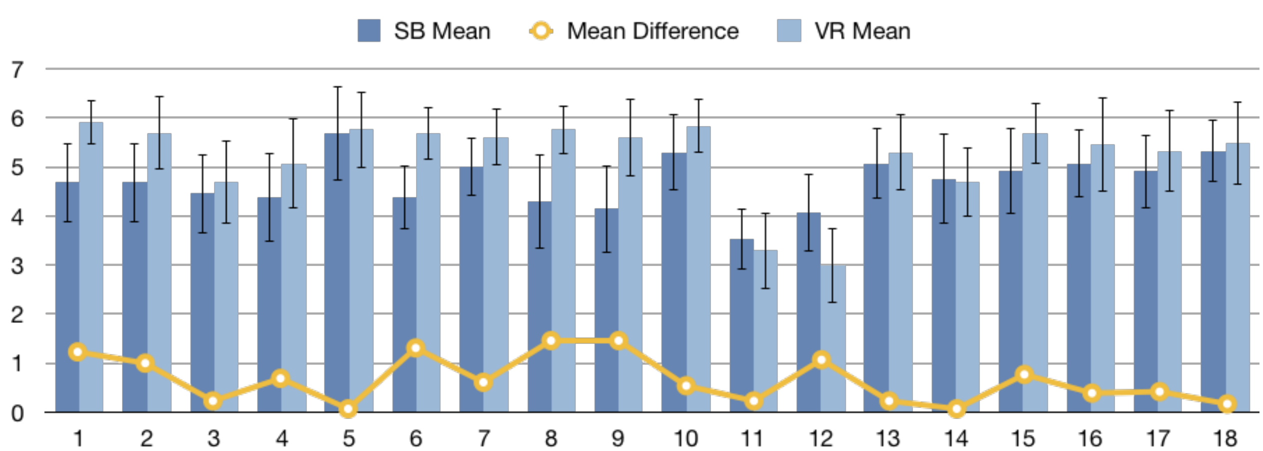

Chart 2: Graph of mean values and their difference of the questionnaire with a 95% confidence error interval. Authors own image

The numbers in the graph's y-axis are set in a range from a possible answer score of zero to seven. The questionnaire used a seven Likert scale where one is the lowest score, representing disagreement or negativity, and seven is the highest score representing agreement or positivity. The graph's x-axis represents each question in the questionnaire showing its corresponding number in the questionnaire. The error bars in the diagram represent the 95% confidence intervals of the scale mean, if the same test were conducted again there would be a 95% probability for the true mean of the answers to be within these error bars. The orange line in the diagram represents the difference in mean value score between VR and SB.

A Mann-Whitney U-test were conducted with a 95% significance level, to find if each of the questions had a significance difference in answering score between VR and SB. Each question had two hypotheses being:

H_0 : The distribution of both populations are equal
H_1 : The distribution of both populations are not equal

The U-test showed that there was a significant difference between the two systems in questions one, six, eight and nine. Thus, H_1 is accepted for those questions, which suggests that there is indeed a significant difference (see table 5). For the remaining questions H_1 is rejected.

Table 5. H_1 accepted questions

#	Question
1	The program I used today allows for customizing design choices to fit my liking (Disagree - Agree)
6	The visual differences between design choices within each category was (Unclear - Clear)
8	When using the program, my understanding of how the choices I made fit aesthetically in the house was (Poor - Good)
9	When choosing design choices the most important aspect was the aesthetics of the choice (Disagree - Agree)

Interesting findings for the study are whenever the difference in answering score between VR and SB for a question is either high or very low to none. For a more exact measurement questions with a difference that is neither high nor low are deemed as noise. Therefore, questions which had a very low difference are being distinguished. Every question having a mean value score difference of 0,23 or less are deemed as having a low difference. Questions with a difference of 0,23 or lower were three, five, eleven, thirteen, fourteen, and eighteen (see table 6).

Table 6. Questions which have a mean difference of 0,23 or lower and H_0 accepted.

#	Question
3	When using the program, I was confident in what the choices I made would look

	like in real life (Disagree - Agree)
5	The visualizations of choices that I saw in the program related to real life products (Not at all - Very well)
11	When making design choices the most important aspect was the pricing of the choice (Disagree - Agree)
13	When using the program, reading information about the house was (Difficult - Easy)
14	When using the program, reading information about the design choices was (Difficult - Easy)
18	After having used the program my knowledge of the information about the fridge is (Poor - Good)

6.4.2 Affinity diagram and content analysis

The results of the affinity diagrams and content analysis consists of categories of different codes. The codes are collections of condensations and the relevance of each category is determined by the number of condensations making up that category. Condensations in this context are comments and statements made by users during tests summarized into short sentences. Codes used in categories were the results of making two separate affinity diagrams, one for SB and one for VR (see figure 37 and 38), where condensations were written on the sticky notes of the diagram before sortation. From 157 condensations 16 codes were found for the SB interface and 12 were found for VR. A full list of these condensations can be seen in appendix VII.

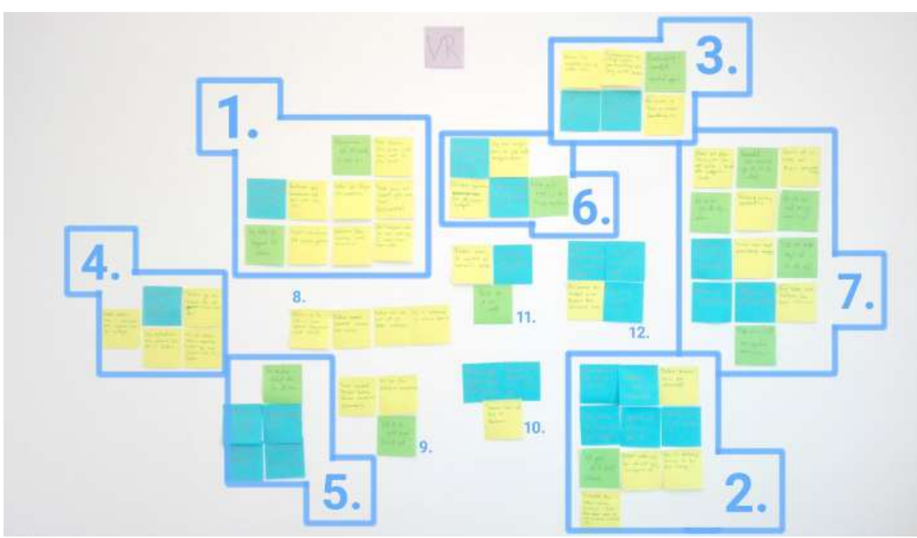

Figure 37. The VR affinity diagram with codes numbered. Authors own image.

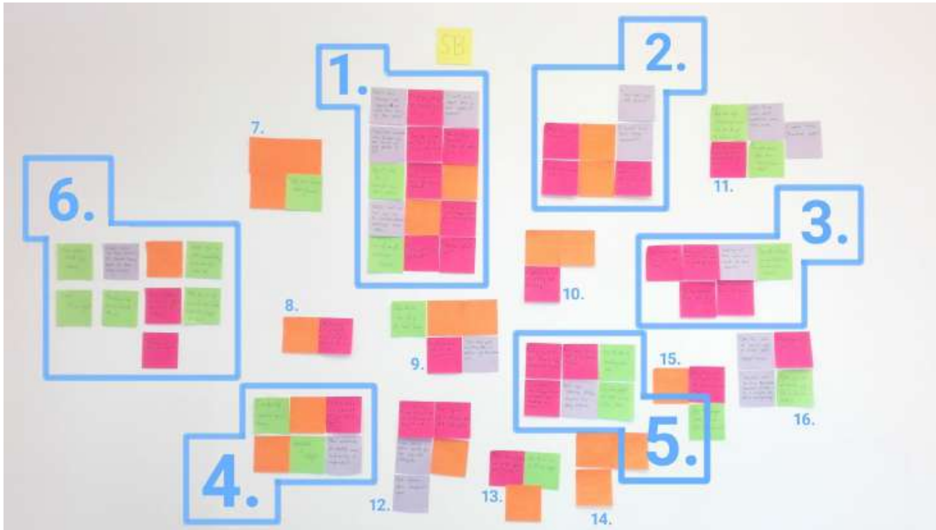

Figure 38. The SB affinity diagram with codes numbered. Authors own image.

A total of 70 condensations were found for the VR interface and 87 for the SB interface. In order to compare the number of condensations between the two interfaces, condensation numbers for each VR code were increased by 20%. This makes each condensation in a code for VR have equal weight as a condensation in SB. The codes found for the VR and SB interfaces through affinity diagrams as seen in figure 37 and 38 are presented below (see table 7). The number in parenthesis indicates the number of condensations in that code, increased by 20% for the VR interface.

Table 7. Codes for each interface found through the affinity diagram.

#	**Virtual Reality codes**	**Screen Based codes**
1	Choices are considered in relation to each other (12)	Visual insecurity (15)
2	Choices based on looks (12)	Desire to view from different angles (7)
3	Practicality (7)	Willingness to read about choices (6)
4	Navigates environment to see choices (10)	Desire for quality (6)
5	Bad vision (6)	Desired choices missing (6)
6	Desire to use all money (6)	Unique Codes split into 6.1 - 6.7 (9)
7	Unique codes split into 7.1 - 7.11 (13)	Products are expensive (4)
8	(Merged with 4 and 7.11) (-)	Practicality (2)

9	Products are expensive (4)	Choices are considered in relation to each other (5)
10	Consideration of environmental aspects (4)	Choice made based on material (3)
11	Disregarding money and price (4)	Not sufficient information (5)
12	Taking the budget into consideration (5)	Makes the cheapest choice (4)
13		Choosing whatever looks good (3)
14		Budget consideration (5)
15		Desire to use all money (3)
16		Uncertainty of the menu images (4)

From these codes, seven categories on how users experience the interface were found for SB and nine for VR (see table 8).

Table 8. Categories of codes.

VR CATEGORIES

1. *Product aesthetics affect choices made*
(25) VR codes: 1, 2, 7.11

2. *Using the digital environment as a tool for decision making*
(14) VR codes: 4, 10

3. *Poor visual information*
(12) VR codes: 5, 7.3, 7.5, 7.6, 7.9 & 7.10

4. *The total budget affect choices made*
(11) VR codes: 6, 12

5. *Product ergonomic features affect choices made*
(7) VR code: 3

6. *Noise*
(5) VR codes: 7.1, 7.4, 7.7, 7.8

7. *The price affect choices made*
(4) VR codes: 9

8. *Not thinking about money and costs*
(4) VR code: 11

9. *Desired choices missing*
(2) VR code: 7.2

SB CATEGORIES

1. *Difficulty in understanding visual representations*
(28) SB codes: 1, 2, 6.2, 16, 6.5

2. *Product technical features affect choices made*
(22) SB codes: 3, 4, 8, 10, 11

3. *The price affect choices made*
(10) SB codes: 7, 12, 6.4, 6.7

4. *Product aesthetics affect choices made*
(8) SB codes: 9, 13

5. *The total budget affect choices made*
(8) SB codes: 14, 15

6. *Desired choices missing*
(6) SB code: 5

7. *Noise*
(3) SB codes: 6.1, 6.3, 6.6

6.4.3 System differences in user experiences comparing VR and SB

Using both questionnaire answer scores and categories from the content analysis the most prominent differences between the VR and SB interfaces were identified, then scores and categories were grouped based on similarity. In most cases, this meant that a difference found in questionnaire answers were confirmed by a category found in qualitative analysis. From these groups, six system dimensions in which there can be said to be a difference between VR and SB systems were defined.

In figure 39, the system dimensions are listed, and each system is placed on a scale visualizing the systems allowance for that dimension. Allowance describe how well a system inherently allows for designing for a dimension based on how users experience it. E.g. spatial understanding has higher allowance for VR than SB, as the study has shown that users are more inclined to take ergonomic features and surrounding objects into consideration when making design choices in VR. On the scales of the figure, the underlying quantitative value for each system is visualized. When applicable, this value is taken from the questionnaire question on which the system dimension is based, giving the scale an index value of one to seven. In the cases in which there are no quantitative data to support the differences in the dimension each systems value is visualized as being 3.5. Arrows of the figure shows in which ways the qualitative data supports the quantitative values in the form of content analysis categories. The numbers above each arrow indicates the number of condensations the category on which the arrow is based on consists of.

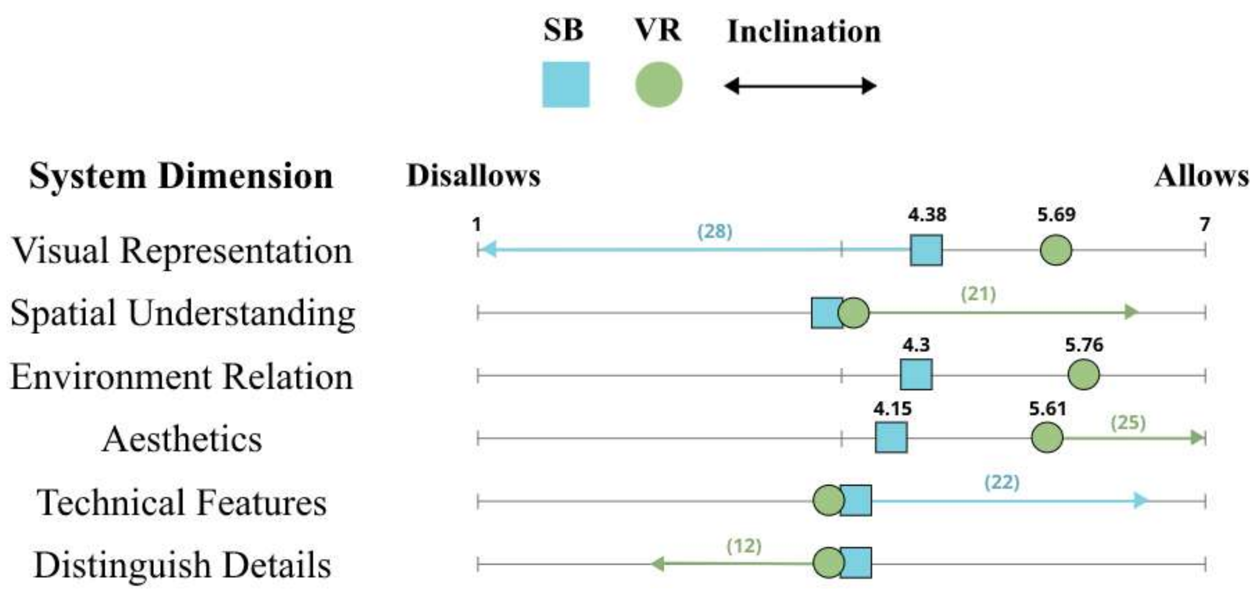

Figure 39. The six system dimensions users experience differently comparing VR and SB. Authors own image.

VISUAL REPRESENTATION

The visual representation system dimension is defined as the user experiencing that they are able to determine what a visualization depicts using the system. Users of a VR system have a better general understanding and experience of visual representations and visualizations of design choices than users of a SB system. Questionnaire answers show that users of a VR experience that they have a greater understanding of the visual differences between design choices that they can make compared to SB users (see table 5 #6). Using an SB interface, users also express that they experience difficulty in understanding visualizations using the system (see table 8 SB#1) which is not seen among VR users.

SPATIAL UNDERSTANDING

Spatial understanding tells how well users are able to experience and understand a three-dimensional space using a system. Users of VR experience that choices they make are part of a greater three-dimensional environment to a greater extent than SB users (see table 5 #8). VR users also use the spatial freedom allowed by being able to move in all direction using the system to view choices from different angles and distances (see table 8 VR#2). Users also experience that the ergonomic features of a choice are of importance when using a VR system (see table 8 VR#5), an attribute that is much less regarded by SB users. Users were observed to consider both how objects would feel like to grab and how objects would fit the space they inhabit when using VR.

ENVIRONMENT RELATION

The system dimension of environmental relation describes how well a system allows for the user to experience that objects relate to not only each other but also the environment they reside in. A user experiencing a design choice using VR have a greater understanding of a choice's relation to its environment than a user of a SB system (see table 5 #8). A VR user also experience that an object's environment is of greater importance when making choices than an SB user.

AESTHETICS

A systems aesthetic dimension tells how much users experience that the looks of a choice matter when taking decisions. Users of a VR system experience that the aesthetics of their design choice is of more importance (see table 8, VR #1) than users of an SB system (see table 8, SB #4). Table 5, #9 show how there is a significant difference in this dimension, further confirming that VR systems allow more for this dimension.

TECHNICAL FEATURES

Technical features refer to how much users of a system consider technical features when making design choices. Users using a SB system experience that their choices' technical features are of greater importance than users of VR. Content analysis data of the SB system shows that technical features affect choices made when using that system (see table 8, SB #2), while such considerations are non-existent for VR users. VR therefore is neutral in this dimension while SB allows for it to a greater extent.

DISTINGUISHING DETAILS

This dimension reflects how well users experience that symbol details can be well perceived and that a system provides a clear vision. It describes how well users see and read text, but not how hard it is to understand information. SB allows more for this dimension than VR, it is easier to experience details and read text using an SB system. It is common for users of VR to experience visual information and symbols poorly (see table 8, VR #3). Since no quantitative and qualitative data reflects this dimension for SB, it has a neutral position for the dimension.

7
Discussion

In this chapter, discussions regarding how valid presented results are, ethical considerations, and how the results can be used for further development are described.

7.1 Methodology

The method chosen for research in this study has been based on Lazar, Feng and Hochheiser's [8, 25-44] description of research through design and explorative tests. This methodology is based on the assumption that when comparing two systems or scenarios any differences in interaction or experience that exist between the systems are caused by the differences that exist between the two systems, their independent variables. In this study, the goal has been to investigate the differences that exist in user experience comparing VR and SB, therefore it has been desirable for the difference in medium to be the only independent variable in testing. To achieve this, the VR system was designed to match the SB system as closely as possible in functionality not inherent to the system's medium. This is to say that each system should not allow the user to make actions unavailable using the other system, unless that action is inherent to interactions in that system. If this is achieved, differences found in user experiences in the study should be caused by the tested systems medium as this were the test's only independent variable.

Following this approach, it has to be defined what is considered to be an inherent functionality of a medium and what is not. In this study, non-inherent functionality has been defined as features which allows for the user to interact with the virtual environment e.g. changing object's location by picking them up or changing element's appearances. As the VR prototype was designed following this definition, the differences in user experience that were found between VR and SB interactions in this study can be said to have been caused by each system's inherent properties. If a different definition had been used, the VR prototype would have needed to be designed according to that definition, which would have given results different than those presented in this study.

7.2 Results

The results of the study are not definitive. Both the research question and design process of the study are wicked in nature and the results of a similar study will therefore always be different depending on the study's context. The factors which potentially affected the results of this study the most are presented in this chapter.

7.2.1 The prototype

Interactions with the prototype is the basis of more than half of this study's results. How that prototype is designed will have affected the outcome of both the descriptive and exploratory user tests. If the study were to be conducted again, the design of the prototype would most certainly be different. Although the results of the study are well grounded in test data and statistics, a different design of the prototype probably would have led to finding different or complimentary results to the ones presented.

An essential part of the prototype, which have possibly affected the results of the study the most, is its high fidelity. The fidelity level of the prototype is what has allowed for users to experience a basic level of realism [14], which is important as this is likely to have affected the answer to several of the questions of the questionnaire regarding realism. Having both the compared VR and SB system be of similar fidelity therefore helps in increasing the validity of the study's results. That the prototype is of roughly equal fidelity to the SB interface could also be confirmed in the study as it could be compared to a system by Smålandsvillan, which was released during the time of the study and accessed through contacts at Myresjöhus. The fidelity of the prototype and Smålandsvillans's system for mediating design choices through VR are deemed to be equal and hence the prototype can be considered to be representative of a commercial system.

It is also possible that if a prototype of even higher fidelity than the one designed had been used, answers regarding realism from questionnaires would have received higher scores.

7.2.2 Tutorial design

The design of the tutorial (see chapter 6.1.1) does not follow the guidelines for designing for beginners as presented by Cooper [39] in that it was indiscreet, it brought attention to the users inexperience with the system, and it halted the experience of the impatient first time user. A more appropriate approach on how to design tutorials can be found in game design, where there are numerous unfamiliar mechanics and concepts needed to be thought to the user. The principle of using an "invisible tutorial", in which the user learns by playing the game while complex mechanics are introduced bit by bit through dynamic interactions [93], is common practice in game design. A similar approach could also have been used when designing the tutorial for the prototype.

The tutorial is also the only feature which exists only in the VR system and not in the SB counterpart. It is possible that in teaching the user how to interact with the VR system frustrating moments from trial and error in learning were prevented. This could have created differences in user experience between the systems not related to their inherent qualities. If this difference were great, it could have given the study faulty results.

7.2.3 Recruitment of test users

For both tests of the study, the testers have been recruited from a homogenous group of users. Testers were chosen from a convenience sample [94] rather than a probability sample suitable for the study. This has sped up the process of the study at the cost of validity of its results. Optimally, to receive the most valid results, users in the process of purchasing a prefabricated house should have been observed over a longer period of time where either the VR or SB interface were part of their purchasing process.

A potential error in test results were also observed when analyzing tests conducted at Chalmers and ESSIQ respectively. It was found that test users at ESSIQ generally gave a more positive response to the prototype in the questionnaire (see chart 3). That the majority of tests were conducted at ESSIQ could therefore have skewed the results of the study in favor of the VR interface where applicable. This is probably due to the authors closer relationship to testers at ESSIQ than Chalmers but could also have been caused by the differences in test set-up and location.

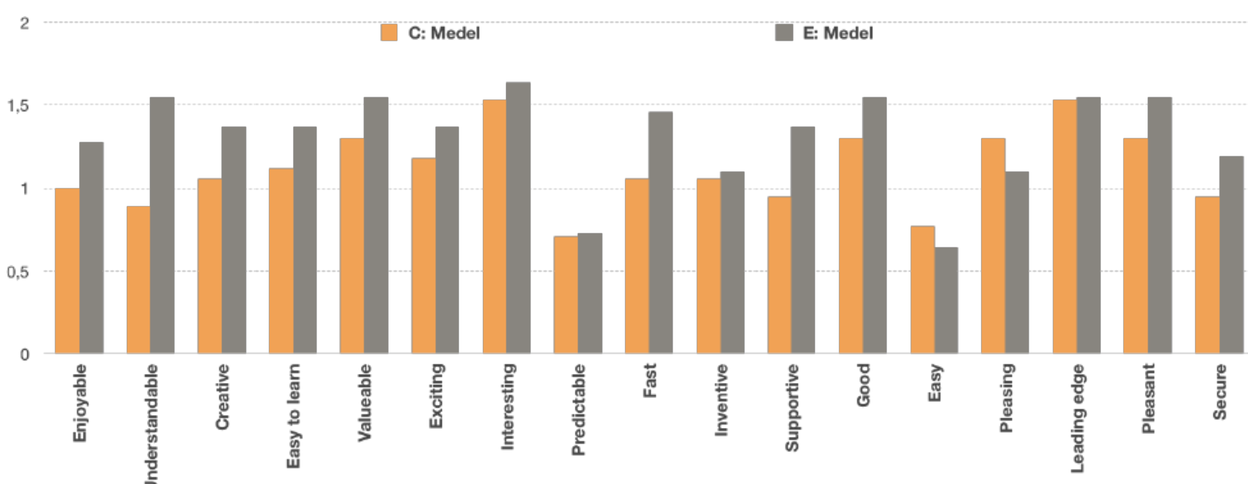

Chart 3. Questionnaire answers from ESSIQ (gray bars) generally favored the prototype. Authors own image.

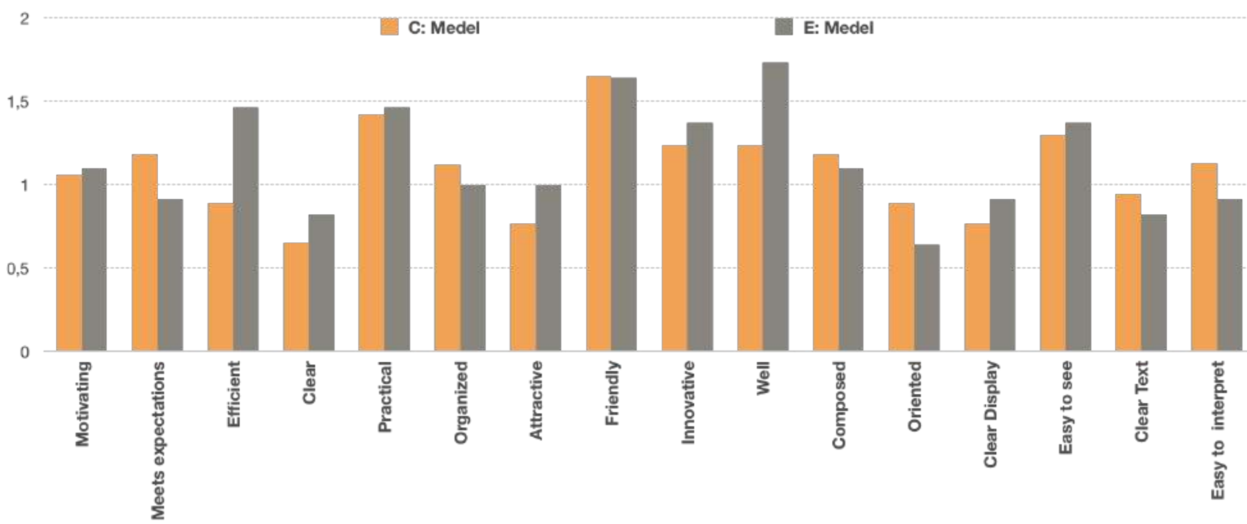

Chart 3 continued.

7.2.4 Test results

System dimensions, as well as categories from the content analysis, were formed based on data collected from the user tests. However, the defining of codes and categories in the content analysis is somewhat subjective, meaning that if others were to conduct the same analysis with the same data, they might analyze it differently, thus giving other results. The same principle applies to how the system dimensions were defined. Since a system dimension is a collective word for how VR and SB differ in a specific area, other words could have been chosen to represent the same or different system dimensions. Further, the scale in figure 39 is the authors interpretation of the analyzed material and might not represent how others would interpret the data, affecting how big the difference for each system would be on the scale.

A factor which have influenced the results of the study is which SB interface was chosen to compare. An SB interface with a poor user experience overall might be less appealing than its VR counterpart, even if that VR system have fundamental flaws. However, an SB interface which has an amazing user experience might instead be more appealing than the compared VR system. Since the chosen SB system is a released system from a well-known company, the VR prototype created in the study might not be of equal high fidelity as the SB interface. The SB interface being of higher fidelity could therefore have favored it in questionnaire answers. Additionally, choosing a different SB interface for comparison in the study could have led to the VR prototype having different features than the ones tested. This could have changed the guidelines found from the descriptive research test.

In the exploratory test no difference in how users spent or related to their budget was found. How users relate to money is a question which could be of high interest to the housing industry, but compared to other parameters of the study, it was more difficult to test accurately. In tests, there were no consequences for the user related to how much of their budget they spent, as there would have been in a real-life scenario. In order to collect accurate data on how users relate to money in this kind of setting, one would need to impose a consequence on the user for using their budget. Ideally, this consequence should impact the user in a way that is relatable to the amount of money being spent, which is difficult to achieve unless a user is observed in real life scenario in which they are spending real money. It is possible that observing how users relate to money in this kind of setting would have provided with results different to the ones found in the study.

7.2.5 Significance through frequency analysis

Not having any references to how to best conduct the SFA during tests, the method suffered from some faults in execution. During tests at Chalmers, the same person was assigned as both test facilitator and note taker of the SFA. This led to test notes being incomplete and insufficient. There was a clear difference in the quality of the notes when two people held the test, one dedicated to taking notes and one leading the test, compared to the same person doing both.

Note quality was also affected by the notetaker of the SFA, who had to simultaneously write notes and sort those notes into tasks and categories. This led to much information during tests being missed. An alternative way of conducting the method would have been to note everything said and done during tests and then sort that information during analysis. Similarly, to how a content analysis focuses on compiling information after, not during, tests.

The analysis was also only focused on which parts of the interface did not work. Any system features not subject to an error were simply marked as good or functioning, but how users interacted with that feature was not noted. Having information on the positive interactions of the interface as well as the negative could have helped when identifying guidelines for what to do when designing a VR interface for beginners.

7.2.6 Guidelines and dimensions

The guidelines presented could be helpful for designers in that they are able to tell which type of system is best suited for a particular design. If there is a dimension in which a designer wants their product to focus on or excel in, and there is a difference in how that dimension is experienced, one can use the results of the study as base for decision making in the early planning phases of a design process. The guidelines are better suited to be used during ideation, after VR has been chosen to use as a system. Most development will benefit from considering the guidelines presented, as it is rare to be developing a program which will not need to take beginner users into consideration, especially so for VR programs. In such a process the guidelines can be seen only as a good advice to consider, or they could be tested in early prototyping, where the applicability of each guideline for the design being developed could be evaluated.

There is a risk that both the guidelines and system dimensions presented will be outdated or obsolete in the near future. VR is an expanding field; the technology is getting more and more advanced each year and some of the guidelines and dimensions derive from hardware and software limitations which may become less prominent in the future. E.g. the user's ability to distinguish details was found to be poor when using a VR system compared to SB. Therefore, as hardware becomes better at producing imagery of higher resolution in VR, it is possible that this dimension will become increasingly inaccurate. Considering this, most of the presented results' relevance should be seen in relation to the time passed since this study was conducted. It is possible that in the coming years, it would be necessary to repeat a similar study with the purpose of updating these results.

The guidelines presented in this study are solely based on the descriptive research test. Therefore, it is likely that during design of the prototype other guidelines could have been found which were not possible to find in the descriptive research test. This means that additional results could have been discovered during the process of making the prototype. As the focus of this study has been on presenting results based of tests, the design might have been overshadowed, even though valid results could have been discovered from its process.

7.3 Ethical considerations

This study has shown that there are ways in which users experience visualizations of design choices differently when using an interface in VR rather than SB. Change in user experience could in turn also change users' emotion and consequently also their behavior [95]. Being able to affect user behavior by visualizing design choices using different systems could have both negative and positive implications. For example, combined with customers not considering technical aspects of choices when using VR, it could be used to sell products of lesser quality but higher visual appeal more expensively. However, if visualized in an informative way, users focus on visual features in VR could be used to highlight positive aspects, such as which choice has the least environmental impact.

It should also be noted that this study shows that among beginner users, VR is still regarded as a novel, interesting, and cutting-edge technology (see chart 1). It is possible that companies could make customers have a positive attitude towards the company and its products solely based on having those products be presented using VR. Kerrebroeck, Brengman and Willems' study [6] also support this as they show that VR visualizations positively affect attitude towards advertisement. This could be used to positively affect companies' standings among users on faulty grounds.

Like for any visualization, advertisers and retailers using VR will have a responsibility to visualize their products in a way that is representative to reality. Business may utilize VR as a way to visualize products in different or more visually appealing ways which are not true to reality. If an increasing number of retailers would need to visualize products in a virtual environment, due to VR advertisement becoming more established, problems could arise if there are not enough expertise on how to make 3D visualizations. Customers could become victims of incorrect visualizations and companies may be required to invest in visualizations to a greater extent than previously, thus increasing costs.

VR also has an inherent problem in that it currently is not possible to give the user accurate haptic feedback using the system. If users were to rely more on making decisions based on visualizations presented in VR this could pose two different problems. Firstly, although users care about ergonomic aspects and have a higher spatial understanding in VR compared to SB, they have no way of actually feeling objects meant to be touched such as handles and faucets. Secondly, users of VR are unable to feel the texture and temperature of materials. Users may become unhappy with choices made in VR if for example they choose a floor based on its aesthetics, but later find out that it is unpleasantly cold to walk and stand on. Until more advanced technology capable of mediating this is available, it is advisable to not only rely on computer-based visualizations when making design choices, but also visit retailers to experience them in real life, as is part of the housing process today.

7.4 Future work

Based on the results presented, further complementary work to this study could be considered. This work includes both expanding upon the prototype by adding more functionality and finalizing its design, as well as exploring potential areas for further research based on the presented guidelines and system dimensions.

7.4.1 Future development of the prototype

To correctly simulate how an SB system of the type investigated in this study is often used, implementing a VR prototype allowing for multi user experience should be considered. Applying the same type of experience to a VR system could allow for discovery of more or different findings. A multi user experience can either be designed for letting several users use the same computer or having each user use one computer each. In VR, it is more difficult to prototype how several users would use the same system, since every user would need their own HMD and space to move. When two users both interact with an SB system of this kind, only one user can control what is seen and manipulate what happens on the screen. When simulating the same kind of experience in VR one could provide more functionality, such as allowing for every user to manipulate the system all at once. In this way VR and SB systems are inherently different and there is a high probability that differences could be found in multi user experiences.

VR and SB differ in their underlying technology and features, which provides VR with unique functionality that is not possible to implement in an SB system and vice versa. The existing VR prototype could be improved by introducing additional functionality such as changing the appearance of the floor plan model when changing design choices, allow for placement of furniture, change of the time of day or season, and interaction with objects in the environment similar to what is possible in the real world.

Currently the prototype is only made for the purpose of testing differences in user perception, understanding and confidence between a VR and SB system. However, one of the major flaws in this prototype is its availability. The prototype does not support use by consumers as it is required to have an expert of the program import models and design choices. As a continuation of the study, it would therefore be interesting to build a program which would be based on the prototype but have support for the consumer to import their own external model and design choices. This idea is somewhat similar to the second concept of the initial idea described in chapter 5.2.

7.4.2 Future research

A possible future work would be to conduct the same kind of study but with a different SB system. This would result in the making of a different VR prototype, as it should correspond with the same functionality as the chosen SB system. By comparing those two systems through the same means as in this study, it could be possible to see if there are other differences in user perception, understanding and confidence to distinguish in interaction, or if the results would be the same as for this study. Different or complimentary results could also be found from making the same type of study again, but with test users who are actual clients of housing companies, as discussed in chapter 7.1.3.

Both guidelines and dimensions presented in the study could also be expanded upon. Each guideline could potentially serve as the starting point for a study in which the extent and aspects of the guideline is explored. E.g. one could investigate the exact ways in which skeuomorphism affects users, in which scenarios it is preferable to use, and compare a skeuomorphic based interface with one using another design principle. Similarly, the system dimensions in which VR and SB differ could be expanded upon. It would be of interest to investigate if it is possible to form a VR design framework, based on the presented dimensions, which could be used for evaluation or comparison of different VR and SB systems.

8
Conclusion

The purpose of this study has been to investigate which factors of design users experience differently when a VR interface is used to make design decisions compared to an SB interface. The investigation has been focused on finding results able to answer the research question:

"What factors in interaction are experienced differently when making design choices in terms of perception, understanding, and confidence when using a virtual reality interface compared to a screen based interface?"

Results were found based on analysis of data from an exploratory research test where two systems, one screen based and the other in VR, with similar functionality were compared. These results consist of six system dimensions in which VR systems differ from SB. The dimensions favored by VR are VISUAL REPRESENTATION, SPATIAL UNDERSTANDING, ENVIRONMENT RELATION, and AESTHETICS while the dimensions favored by SB are TECHNICAL FEATURES and DISTINGUISHING DETAILS. All but one of these dimensions are perception based, which indicates that there is a difference in how users experience visualizations between VR and SB system when making design choices. The study shows that users of VR experience visualizations as being part of a contextual environment to a greater extent than users of SB. They also consider objects spatial and aesthetic properties to a greater extent. Users of SB on the other hand experience that the technical properties of a visualized design choice is of higher importance than a user of VR. Hardware limitations also made it more difficult for users of VR to experience visual details than SB users. The study did not find any supporting evidence showing that there is a difference in how users experience understanding or confidence between the two compared systems.

Due to not having access to an appropriate VR system at the beginning of the study, the VR system used in the test were designed as part of the study's process. As VR is a relatively new area of design, guidelines for how to design a system and interface providing a good user experience are sparse. Therefore, in the design of the VR system, the study also intends to answer a second research question:

"Which guidelines should be considered when designing virtual reality interactions for inexperienced users?"

Through evaluation of the VR system midway through the study's process, guidelines for how to design VR interaction for beginners could be established. The evaluation was based on results of a descriptive research test in which users were observed while they performed a set of tasks using the program. Six guidelines for design focused on beginners were established:

1. *Find and follow the few conventions for mapping VR controllers that already exists.*

2. *Consider teaching the user of the VR system what interactions are available and how they are made.*

3. *Acknowledge the visual difficulties imposed on a user of VR, consider ways to compensate.*

4. *Stabilize system elements attached to a controller or hand which the user has to read or carefully observe.*

5. *Provide rich and instant feedback that the user can not miss, never leave the user guessing.*

6. *Consider the advantages of skeuomorphism for interfaces and interactable elements.*

These guidelines are contextual to the study in that their discovery is solely based on the interactions and features available in the tested VR system. A system not designed for finding as many or complete guidelines as possible, but for being a proper comparison to an SB system which allows for making design choices. Additional guidelines therefore surely exist, and there may be situations in which the ones stated do not apply.

Our hopes are that the differences in experiences found in this study will help guide designers when they are to choose which system to use for their designs. We hope our findings show that VR and SB are systems capable of giving users different experiences and they can be used for different purposes. Each designer should put the guidelines presented into the context of their own design, as VR is a field in rapid development and constant change. We also hope that the dimensions presented will spark interest in expanding upon the field of VR design. The dimensions could be used as a base for developing a VR design framework, or each dimension could be investigated in more detail within its own study. Any such study could help designers who are developing for VR gain a deeper understanding of the medium, resulting in better VR designs for the future.

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Appendix I

Questionnaire test 1, UEQ and additional questions

Vid hur många tillfällen har du använt VR?

Inga	☐
En gång	☐
Två till Fyra	☐
Fler än Fyra	☐

Om du har använt VR, använde du dig då också utav handkontroller?

Ja	☐
Nej	☐

Under användandet av VR prototypen idag så kände jag mig:

Illamående				Välmående
☐	☐	☐	☐	☐
Förvirrad				Samlad
☐	☐	☐	☐	☐
Disorienterad				Orienterad
☐	☐	☐	☐	☐

Bilden jag såg under användandet av VR prototypen idag var:

Suddig				Klar
☐	☐	☐	☐	☐
Svår att se				Enkel att se
☐	☐	☐	☐	☐

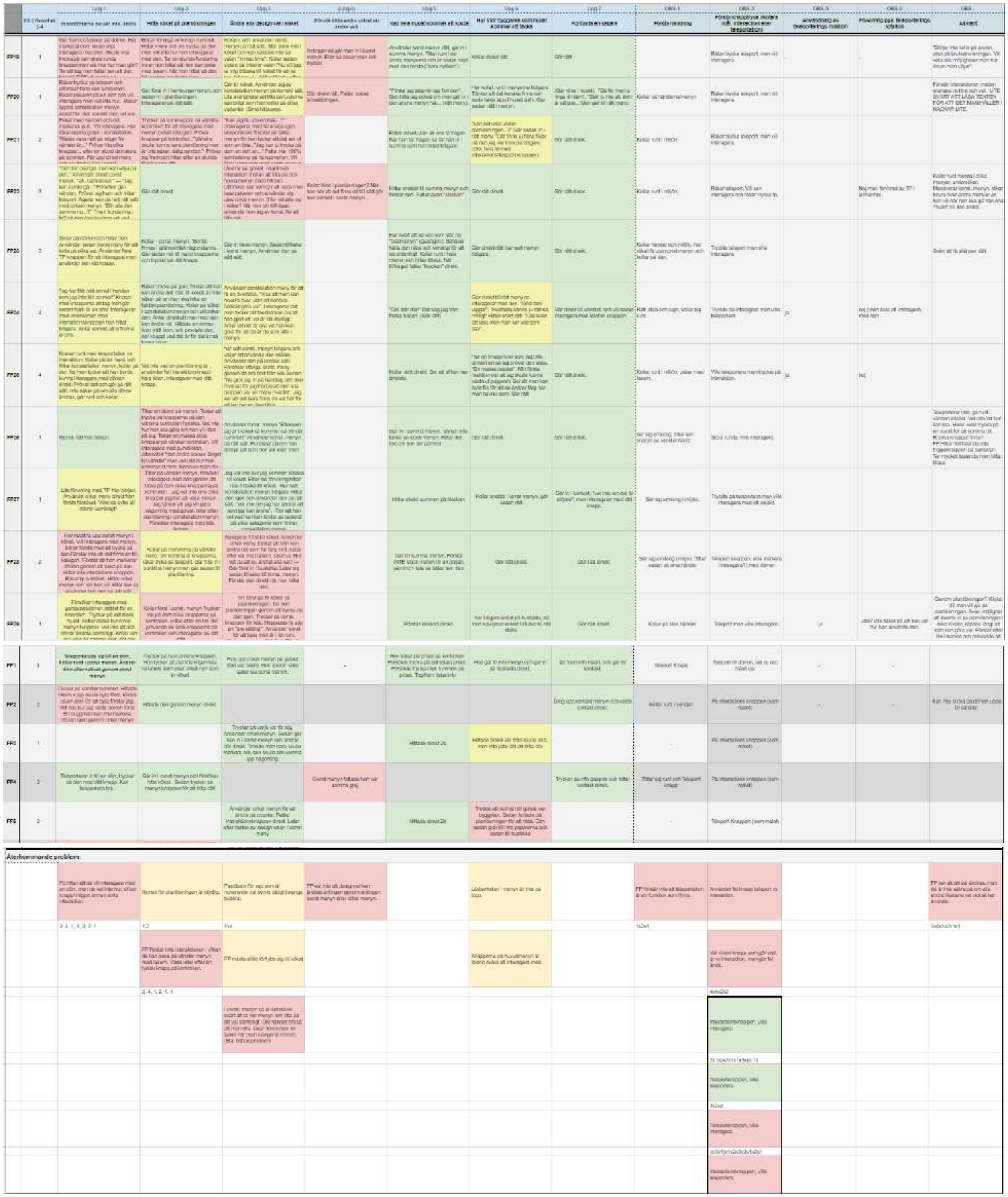
Bilden jag såg under användandet av VR prototypen idag var:

Suddig				Klar
☐	☐	☐	☐	☐
Svår att tyda				Enkel att tyda
☐	☐	☐	☐	☐

	1	2	3	4	5	
Irriterande	☐	☐	☐	☐	☐	Njutbar
Obegriplig	☐	☐	☐	☐	☐	Begriplig
Kreativ	☐	☐	☐	☐	☐	Tråkig
Lätt att lära	☐	☐	☐	☐	☐	Svår att lära
Värdefull	☐	☐	☐	☐	☐	Värdelös
Tråkig	☐	☐	☐	☐	☐	Spännande
Ointressant	☐	☐	☐	☐	☐	Intressant
Oförutsägbar	☐	☐	☐	☐	☐	Förutsägbar
Snabb	☐	☐	☐	☐	☐	Långsam
Uppfinningsrik	☐	☐	☐	☐	☐	Fantasilös
Hindrande	☐	☐	☐	☐	☐	Stödjande
Bra	☐	☐	☐	☐	☐	Dålig
Komplicerad	☐	☐	☐	☐	☐	Enkel
Möter inte behov	☐	☐	☐	☐	☐	Möter behov
Bakåtsträvande	☐	☐	☐	☐	☐	I framkant
Inte tilltalande	☐	☐	☐	☐	☐	Tilltalande
Säker	☐	☐	☐	☐	☐	Inte säker
Motiverande	☐	☐	☐	☐	☐	Omotiverande
Möter förväntningar	☐	☐	☐	☐	☐	Möter inte förväntningar
Ineffektiv	☐	☐	☐	☐	☐	Effektiv
Tydlig	☐	☐	☐	☐	☐	Förvirrande
Opraktisk	☐	☐	☐	☐	☐	Praktisk
Strukturerad	☐	☐	☐	☐	☐	Rörig
Estetisk	☐	☐	☐	☐	☐	Oestetisk
Användbar	☐	☐	☐	☐	☐	Inte användbar
Konservativ	☐	☐	☐	☐	☐	Innovativ

Appendix II

Part of the significance through frequency analysis



Appendix III

Open ended questionnaire sent to housing company contacts

1. I vilka steg i en köpprocess hos er har en köpare möjlighet att göra tillval eller personliga val?

2. Hur brukar det gå till när en köpare väljer tillval hos er?

3. Brukar pris, utseende och ekologisk påverkan påverka vilka tillval eller personliga val en köpare gör?

4. Om ja, vilket är det som påverkar mest?

5. Finns det några andra faktorer som brukar påverka vilka tillval som köpare väljer?

6. Vilka tillval eller personliga val är det vanligast att köpare gör?

7. Vilka tillval eller personliga val är det mindre vanligt att köpare gör?

8. Skulle det vara möjligt att tillgå exakt statistik på hur ofta varje tillval väljs?

9. Hur många tillval som höjer priset väljs generellt?

10. Hur mycket spenderar en kund generellt på tillval och personliga val?

Appendix IV

Questionnaire test 2

The program I used today allows for customizing design choices to fit my liking:

Agree O O O O O O O Disagree

When using the program, I was confident in the design choices I made:

Agree O O O O O O O Disagree

When using the program, I was confident in what the choices I made would look like in real life:

Agree O O O O O O O Disagree

When using the program, I was confident in that the visualizations was a true representation of reality:

Agree O O O O O O O Disagree

The visualizations of choices that I saw in the program related to real life products:

Very well O O O O O O O Not at all

The visual differences between design choices within each category was:

Clear O O O O O O O Unclear

When using the program, my understanding of how the choices I made fit aesthetically together was:

Good O O O O O O Poor

When using the program, my understanding of how the choices I made fit aesthetically in the house was:

Good O O O O O O O Poor

When choosing design choices the most important aspect was the aesthetics of the choice

Agree O O O O O O O Disagree

When making design choices the most important aspect was how all choices looked aesthetically together:

Agree O O O O O O O Disagree

When making design choices the most important aspect was the pricing of the choice:

Agree O O O O O O O Disagree

When making design choices the most important aspect was to consider the total budget:

Agree O O O O O O O Disagree

Was there another aspect which was important in deciding on which design choice to make?

____

When using the program, reading information about the house was:

Easy O O O O O O O Difficult

When using the program, reading information about the design choices was:

Easy O O O O O O O Difficult

When using the program, understanding information about the house was:

Easy O O O O O O O Difficult

When using the program, understanding information about the design choices was:

Easy O O O O O O O Difficult

After having used the program my knowledge of the information about the house is:

Good O O O O O O O Poor

After having used the program my knowledge of the information about the fridge is:

Good O O O O O O O Poor

Appendix V

Datatable questionnaire 1

FP Nr:	Irriteranc	Obegripl	Kreativ -	Lätt att l	Värdeful	Tråkig -	Ointress	Oförutsä	Snabb -	Uppfinni	Hindranc	Bra-Dåli	Komplic	Möter in	Bakåtstr	Inte tillta	Säker - l	l Motivera	Möter fö	Ineffekti	Tydlig - l	Opraktis	Struktur	Estetisk	Användt	Konserv	Illamåer	Förvirrac	Disorien	Suddig -	Svår att	Suddig -	Svår att
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	5	4	5	3	2	4	5	4	2	2	5	2	5	5	5	5	1	1	1	4	2	5	2	2	1	5	5	4	4	5	5	5	5
3	4	4	5	2	2	4	4	4	2	2	4	2	4	4	4	5	1	1	1	4	1	5	2	2	2	4	5	4	4	5	5	-	-
4	4	4	3	2	3	5	5	2	2	2	4	2	4	5	4	4	3	3	2	3	3	4	2	2	1	5	4	4	4	3	4	3	4
5	4	4	4	1	2	4	5	4	2	1	5	2	5	4	5	3	2	2	1	4	1	4	1	1	1	1	3	4	5	4	5	5	4
6	4	4	5	1	2	5	4	3	1	1	3	2	4	4	5	5	3	2	2	4	2	4	2	2	1	5	5	5	4	4	4	3	5
7	4	4	5	1	1	5	5	3	3	2	5	1	4	4	5	5	3	2	2	5	2	4	2	4	2	4	3	2	2	3	4	4	5
8	5	5	4	1	1	4	5	4	1	2	5	1	5	4	5	4	2	1	1	4	1	4	1	2	1	2	5	5	4	4	5	5	5
9	3	3	3	2	2	3	4	4	3	3	4	2	4	4	5	4	2	2	2	4	4	5	2	3	1	5	3	4	2	4	3	3	3
10	4	3	4	3	2	3	4	4	1	2	4	2	2	4	4	4	1	2	2	4	3	4	2	2	1	4	5	5	4	4	4	4	5
11	3	4	4	2	2	4	4	3	4	3	4	2	3	3	4	4	2	3	4	3	2	4	3	3	2	4	4	4	3	2	2	3	4
12	5	4	5	2	2	5	5	4	2	1	2	1	3	4	5	5	2	2	2	4	2	4	1	1	2	5	5	5	4	2	4	4	3
13	3	5	4	2	2	4	4	4	2	2	4	2	5	4	4	2	2	3	2	4	2	4	2	4	2	4	2	5	5	2	3	3	3
14	4	4	5	1	1	5	5	4	1	2	5	1	4	5	5	4	2	2	2	4	3	5	2	1	1	4	5	5	5	4	5	5	5
15	4	4	4	2	1	4	5	3	3	2	2	2	4	5	3	5	3	2	2	4	2	5	3	2	1	5	4	4	3	4	5	2	3
16	3	4	1	2	2	4	4	4	2	2	4	2	2	4	4	4	3	2	2	3	4	4	2	2	2	5	4	4	4	5	5	4	2
17	-	2	5	3	1	5	5	4	1	2	3	2	1	5	5	5	1	1	1	5	4	5	1	3	1	5	5	2	4	4	5	5	5
18	5	4	4	2	1	3	4	5	1	2	4	1	5	5	5	5	2	2	2	3	2	5	2	2	1	5	5	5	5	5	5	5	5
19	5	5	5	1	1	5	5	5	1	1	5	1	4	5	5	5	1	1	1	5	1	5	1	1	1	5	5	5	3	5	5	3	5
20	4	4	3	2	2	4	4	3	2	2	4	2	3	3	5	4	3	2	3	4	3	4	3	3	2	5	4	4	4	2	3	3	2
21	4	4	3	2	2	4	4	3	1	3	4	2	4	3	4	4	2	2	3	4	2	4	2	3	2	4	5	4	4	3	4	5	5
22	5	5	5	2	1	5	5	4	1	1	5	1	2	5	5	5	1	1	1	5	2	5	1	1	1	5	5	4	4	5	5	5	5
23	4	5	4	1	1	4	5	4	1	2	5	1	5	4	4	4	2	2	2	5	1	5	2	2	1	4	4	5	5	4	5	2	2
24	4	5	5	2	1	4	5	4	2	2	5	1	4	5	4	5	2	2	1	5	2	5	1	2	1	4	5	4	3	4	5	3	3
25	4	5	4	1	1	3	4	4	3	2	5	1	5	5	5	5	2	3	1	5	4	5	2	2	1	4	5	5	4	4	4	5	5
26	4	3	5	2	2	5	5	3	2	2	3	2	3	3	5	5	2	2	3	4	3	4	3	2	1	4	5	3	3	3	4	4	4
27	3	4	4	2	2	4	4	3	2	2	4	2	4	4	4	4	1	2	2	4	2	3	3	4	2	4	4	3	3	5	4	2	2
28	5	5	5	2	2	5	5	4	1	2	4	2	4	3	5	4	3	2	3	4	2	4	2	1	2	4	5	4	3	4	4	5	5
29	5	5	5	1	1	5	5	4	1	2	4	1	2	5	4	5	1	2	3	4	2	5	2	1	1	5	5	4	4	4	5	5	5
Medel	1.12	1.15	1.22	1.22	1.4	1.25	1.58	0.72	1.22	1.08	1.11	1.4	0.72	1.22	1.54	1.4	1.04	1.08	1.08	1.11	0.72	1.43	1.08	0.86	1.65	1.29	1.43	1.15	0.79	0.83	1.33	0.89	1.04
Median	4	4	4	2	2	4	5	4	2	2	4	2	4	4	5	4.5	2	2	2	4	2	4	2	2	1	4	5	4	4	4	4.5	4	5
Std	0.68	0.74	0.95	0.62	0.56	0.69	0.5	0.66	0.82	0.54	0.88	0.49	1.07	0.73	0.57	0.73	0.73	0.61	0.79	0.63	0.94	0.57	0.67	0.91	0.49	0.93	0.83	0.85	0.84	0.99	0.81	1.07	1.15
C: Med	1	0.89	1.12	1.12	1.3	1.18	1.53	0.71	1.06	1.06	0.95	1.3	0.77	1.3	1.53	1.3	0.95	1.06	1.18	0.89	0.65	1.42	1.12	0.77	1.65	1.24	1.24	1.18	0.89	0.77	1.3	0.94	1.13
C: Med	4	4	4	2	2	4	5	4	2	2	4	2	4	4	5	4	2	2	2	4	2	4	2	2	1	5	5	4	4	4	5	4	4.5
E: Med	1.28	1.55	1.37	1.37	1.55	1.37	1.64	0.73	1.46	1.1	1.37	1.55	0.64	1.1	1.55	1.55	1.19	1.1	0.91	1.46	0.82	1.46	1	1	1.64	1.37	1.73	1.1	0.64	0.91	1.37	0.82	0.91
E: Med	4	5	5	2	1	4	5	4	1	2	4	1	4	4	5	5	2	2	2	4	2	5	2	2	1	4	5	4	4	4	4	4	5

Appendix VI

Datatable questionnaire 2

FP Nr:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Tid	Kr
19 SB	5	3	3	6	1	4	2	5	6	2	7	7	1	1	2	1	4	2	13.54	121
2 SB	3	3	5	4	3	5	5	4	2	1	5	3	4	6	5	4	6	4	7	116
3 SB	4	4	4	4	4	4	5	3	3	3	3	3	3	3	3	3	3	3	-	109
16 SB	3	6	7	7	5	5	6	5	6	3	5	6	5	3	3	3	3	4	6.58	89
14 SB	3	4	4	4	2	5	2	5	4	3	6	5	5	4	5	3	4	4	16.33	118
6 SB	1	3	4	3	2	3	1	4	3	2	5	4	2	4	2	3	2	2	8.53	128
7 SB	2	1	1	1	2	3	2	2	5	2	2	3	2	2	3	2	2	2	9.53	128
11 SB	3	3	4	5	2	3	2	6	2	3	3	3	4	5	4	4	3	4	8	124
9 SB	2	1	4	4	3	2	3	5	2	2	5	5	1	1	1	1	3	1	8	165
20 SB	3	4	3	3	3	2	2	1	4	2	6	3	1	2	2	4	3	2	-	116
24 SB	6	3	5	4	1	5	6	5	3	2	5	3	3	6	3	6	3	2	13	118
25 SB	2	2	1	1	1	3	2	2	6	5	3	3	1	2	2	1	1	2	14.11	113
23 SB	6	6	1	1	1	3	1	1	4	5	3	3	6	3	5	3	-	-	13.35	48
Medel	3.31	3.31	3.54	3.62	2.31	3.62	3	3.7	3.85	2.7	4.47	3.93	2.93	3.24	3.08	2.93	3.09	2.67	10.73	114.85
Standarda	1.49	1.49	1.49	1.7	1.78	1.21	1.08	1.76	1.64	1.46	1.14	1.45	1.33	1.69	1.63	1.27	1.39	1.19	1.03	3.24
1 VR	2	1	2	1	1	2	3	2	3	2	4	6	3	5	1	1	2	1	8.09	120
17 VR	3	2	5	5	2	3	2	2	1	3	5	6	3	4	1	2	4	3	12.06	81
4 VR	2	1	4	3	2	1	3	3	5	4	2	3	1	4	4	2	2	3	14.3	108
15 VR	2	4	4	5	5	4	3	4	5	4	3	4	1	3	3	6	3	2	12.53	90
5 VR	3	4	4	5	1	2	5	2	3	1	7	7	5	6	2	2	6	6	12.1	116
13 VR	2	2	3	2	2	3	2	3	1	2	5	5	3	3	3	2	1	2	9.58	74
12 VR	1	1	4	2	1	1	2	2	1	1	7	7	1	1	1	1	1	1	13.39	120
8 VR	2	1	2	2	2	2	2	2	2	3	6	6	2	2	2	2	2	2	5.43	115
10 VR	4	5	6	6	5	3	3	3	2	2	5	5	2	4	2	6	3	1	11.14	82
21 VR	1	2	1	1	1	4	1	1	4	2	3	3	4	3	2	1	2	3	10.5	77
18 VR	2	2	2	2	2	2	1	1	1	1	5	3	1	2	2	2	1	1	13.11	116
26 VR	2	4	5	3	4	2	3	3	2	2	4	4	5	4	5	5	5	5	12.59	95
22 VR	1	1	1	1	1	1	1	1	1	1	5	6	4	2	2	1	-	-	15.18	95
Medel	2.08	2.31	3.31	2.93	2.24	2.31	2.39	2.24	2.39	2.16	4.7	5	2.7	3.31	2.31	2.54	2.67	2.5	11.54	99.16
Standarda	0.83	1.39	1.54	1.69	1.43	1	1.08	0.9	1.45	1.03	1.44	1.42	1.44	1.33	1.14	1.79	1.55	1.56	2.54	16.72
S. Medel	1.23	1	0.23	0.69	0.07	1.31	0.61	1.46	1.46	0.54	0.23	1.07	0.23	0.07	0.77	0.39	0.42	0.17	0.81	15.69
S. Standa.	0.66	0.1	0.05	0.01	0.35	0.21	0	0.86	0.19	0.43	0.3	0.03	0.11	0.36	0.49	0.52	0.16	0.37	1.51	13.48

Appendix VII

Condensations of content analysis

SB SYSTEM (87 condensations)

Code 1: Visual insecurity (15)

Condensations:

- Does this change all choices or only the one in the image?
- Konstiga skuggor på köksluckorna
- I can’t see what this is, but i pick it anyway
- Jag får använda min fantasi för att förstå hur det skulle se ut
- Jag ser inte om det blir någon skillnad
- Ytterst lite skillnad när man byter på vissa val
- Jag vill hellre ha x, men det visas inte i bilden
- Jag tror denna är snyggast, men ser ingen skillnad
- När jag ändrar så syns inte det i modellen
- Väljer vad som ser bra ut på bilden eftersom ändringar inte syns
- Bilden visar knappt - irriterad
- Försvinner överskåpet då jag väljer fläkt, hur många?
- Händer något nu?
- Jag ser ingen skillnad
- Ser inte ens att handtaget ändras

Code 2: Desire to view from different angles/zoom (7)

Condensations:

- Går det inte att zooma?
- Kan man inte zooma?
- Kan man inte snurra runt här?
- I can’t turn the image around?
- Kan man zooma in?
- Kan man se olika vyer?
- Vill kunna se mer: Hur roterar jag?

Code 3: Willingness to read about choices (6)

Condensations:

- Mer information om blandaren
- Vill ha bättre koll på priserna
- Jag vill se specifikationer om saker som vitvaror
- Looking at the info on most of the choices
- Vill se mer info om golv, för golv är väldigt olika
- Jag läser allt som går att läsa

Code 4: Desire for quality (6)

Condensations:

- Pengar/värde ratio (tekniskt) är en viktig del
- Kvalitet för pengarna. - important aspect.
- Durability -important aspect of choice
- Det är värt med underlimmad diskbänk
- Golvkvalité är viktigt!
- The materials durability and suitability is important

Code 5: Desired choices missing (6)

Condensations:

- Hade velat ha knoppar på överskåp och handtag där under
- Det jag vill ha finns ej, otrendiga saker.
- Not any fitting design choices for this choice
- Har inte alla val jag skulle vilja
- Jag vill inte ha handtag, utan push
- Jag hade googlat och kollat på andra sorters fläktar

Code 6: Unique Codes: (9)

Code 6.1: Decision making

Condensations: Many choices makes it hard.

Code 6.2: Resemblance to reality

Condensations: Det här ser fett fake ut, det hade behövt lite skugga för fan.

Code 6.3: Construction plan

Condensations: Planlösning. det kan va kul att titta på!

Code 6.4: Price comparisons

Condensations: Måste jämföra priset själv.. -irriterad

Code 6.5: Disregarding choices relative to each other

Condensations: Looks more at the pictures of choices than the ones in the big picture.

Code 6.6: House value

Condensations: Väljer även med tanke på vad andra gillar - höjer värdet.

Code 6.7: Preknowledge

Condensations: Skulle vilja se pris sammanfattning innan hon börja ändra val.

Code 7: Products are expensive (4)

Condensations:

- Det blir dyrare, men finare
- Jävlar vad dyrt det va
- Det blir väldigt dyrt
- Man kanske inte skulle ha så dyra vitvaror

Code 8: Practicality (2)

Condensations:

- Practical - Viktig vid bestämmande av val
- “Practicality” är viktigt när man ska välja val

Code 9 : Choices are considered in relation to each other (5)

Condensations:

- Valde det här för att gå på svart tema
- Jag gillar ljusa golv, vill ha lite kontrast mellan väggar och golv
- Jag tog guldhandtag, så väljer guldblandare nu
- Hon kollar hur allt ser ut tillsammans
- Nu bytte jag x så kanske borde byta y också

Code 10: Choice made based on material (3)

Condensations:

- Bänkskiva, då blir det nog Ek
- Ask är nice
- Materialet är en viktig del för mig

Code 11: Not sufficient information (5)

Condensations:

- I want more practical details
- Can’t find info about materials and sink size
- Jag vill veta varför det ena alternativet är dyrare
- En sak som kostar mer helt random i listan
- Jag har inte tillräckligt med info för att göra ett sånt här val

Code 12: Makes the cheapest choice (4)

Condensations:

- Ser ingen skillnad, så tar det billigaste
- She chooses the cheapest one
- Finns det ingen större skillnad än utseende, då tar jag den billiga
- Inga dörrar efter smak, då tar jag det billigaste

Code 13: Choosing whatever looks good (3)

Condensations:

- Ingen prisskillnad, då väljer jag det snyggaste.
- Den här var vit så det var snyggt.
- Jag väljer vad jag gillar

Code 14: Budget consideration (5)

Condensations:

- Happ där gick vi över budget
- Råkade hamna över budget
- Nu går jag snart över min budget
- 1,130,00? det är lugnt.
- Det är ologiskt att lägga mer för att nå budget

Condensations:

- Har pengar kvar -> väljer dyrare saker
- Jag har pengar kvar, då vill jag köpa dyrare
- Jag har mer att spendera vill kolla igenom igen

Code 16: Uncertainty of the menu images (4)

Condensations:

- Otydliga bilder (höger menyn)
- Jag kan inte se hur bilden kommer passa in i miljön och dess omgivning
- Trycker jag info så kanske jag får se lite fler bilder
- Jag får inte så mycket info av bilden själv (höger menyn)

VR SYSTEM (70 condensations)

Code 1: Choices are considered in relation to each other (10) - (12)

Condensations:

- Det var snyggast, men passade inte med luckorna
- Bänkskivan mot det kaklet, de vette fan
- This choice fits better with the rest of the house
- Allt beror på vilket golv man har
- Ändrade val beroende på hur allt såg ut
- Jag kollar på färgerna till helheten
- Kollar på färger till helheten
- Var tvungen att se hur allt såg ut innan han blev nöjd
- Sakerna ska matcha med varandra
- Inget som passar till dessa golven

Code 2: Choices based on looks (10) - (12)

Condensations:

- I picked the other ceiling because i had the other one at home, and i hated it
- Vitt golv, det är fräscht!
- Taket valde jag för att det såg snyggare ut

- He is spending money to fit his liking
- Tänker mest på utseende
- Jag tänker att det ska se snyggt ut
- Har marginal så går bara på utseende
- Jag vill ha X, för det tycker jag är snyggt
- Inte nice med de här bänkskivorna
- Tänker nästan bara på utseendet

Code 3: Practicality (6) - (7)

Condensations:

- Functionality and comfort
- He wants to know how practical something is
- Den där är ju smidig när man diskar
- Det ska kännas rätt när man tar i den
- Kranen såg praktisk ut, så valde den
- Funktionalitet är viktigt. Vilka dörrhandtag som såg mest sköna ut.

Code 4: Navigates the environment to see choices (8) - (10)

Condensations:

- Letar efter val i världen och tycker det är smidigt
- Jag förflyttade mig närmre för att se bättre
- Måste gå till köket för att se mina val där
- Jag förflyttar mig så jag ser vad jag gör
- He sits down when choosing “lister” to see closer how it looks
- Backar ut för att se hela köket tillsammans med huset
- Kollar runt mycket innan hon börjar
- Kollar hur allt ser ut på olika avstånd

Code 5: Bad vision (5) - (6)

Condensations:

- Är det jag som inte ser?
- Tar texten väldigt nära för att läsa
- Jag har dålig syn
- Det är lite suddigt
- Lite svårt att läsa, kan bero på min syn också

Code 6: Desire to use all money (5) - (6)

Condensations:

- Försöker spendera för att uppnå budget
- Jag har budget kvar, så jag väljer lyxiga dörrar
- Långt ifrån budget, hur mycket pengar som helst

- Vad har jag för budget, ja jag har nog råd med det
- Jag kan köpa lite mer grejer då (Har pengar kvar)

Code 7: (11) - (13)

Code 7.1: Preview

Condensations: Förhandsvisning uppskattas

Code 7.2: Desired choices missing (2) - (2)

Condensations:

- Fönster - de går inte att byta?
- Vill ha fler golv att välja mellan

Code 7.3: Insufficient information (2) - (2)

Condensations:

- Vill se mer än bara pris (typ namn)
- Tech info on stuff

Code 7.4: Location aid

Condensations: Kollar på planlösningen för att hitta i huset och navigera runt.

Code 7.5: Hardware Limitations

Condensations: Headsetet åker ned och gör att det blir suddigt

Code 7.6: Visual excess

Condensations: Svårt att se vissa val, p.g.a gul markering

Code 7.7: Understanding feedback (2) - (2)

Condensations:

- Är det hela huset som jag ändrar i nu?
- I can see that everything changes

Code 7.8: Indecisiveness

Condensations: Det här hade tagit ett år att välja

Code 7.9: Information understanding

Condensations: Jag hittar inte kylskåp, står bara vitvaror

Code 7.10: Excessive information

Condensations: Jäklar vad mycket fakta

Code 7.11 Visual details

Condensations: He is interested in visual details

Code 8: (-)

(Merged with 4 and 7.11)

Code 9: Products are expensive (3) - (4)

Condensations:

- Vill ha fler billigare bänkskivor
- Det är så mycket pengar (om ett val)

- Vad mycket pengar bänkskivan kostade

Code 10: Consideration of environmental aspects (3) - (4)

Condensations:

- Jag gick lite i rummet för jag vill se i annat ljus
- Vilket golv passar bäst med ljuset
- Känns som att jag är i Alabama

Code 11: Disregarding money and price (3) - (4)

Condensations:

- Tänkte inte på sin budget
- Jag brukar inte kolla på pris
- Tänkte inte så mycket på pengar först

Code 12: Taking the budget into consideration (4) - (5)

Condensations:

- He passed his budget, so he picked the cheapest tap
- Jag får inte överskrida budget
- Jag fick inte komma över min budget
- Kollar pris och ändrar val för att hamna inom budget