Design and evaluation of a user interface for a WebVR TV platform developed with A-Frame

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Abstract

The market for virtual reality products has grown rapidly the last few years, and as the demand grows, the supply should naturally follow. More games, applications and also web sites for virtual reality are going to have to be designed and produced to support this demand. However, the guidelines and the literature for designing user interfaces specifically for virtual reality are few and often outdated. The purpose of this thesis is to help contribute to determine how to design user interfaces for virtual reality, when one is making selection with fuse-based clicks. In this thesis, a prototype for a TV-platform is designed and produced in WebVR, using the framework A-Frame. The prototype is then evaluated with usability tests and redesigned as according to an iterative design process. The evaluations showed that items were easily clicked by mistake and often unknowingly. Furthermore, the test user participants often failed to notice user interface objects if the objects were not placed in the centre areas of the user interface. The conclusion suggests that navigation paths within the user interface could mitigate accidental clicks, and auditory feedback could help users notice the accidental clicks. Moreover, between 700ms to 1000ms, but closer to 1000ms, could be an appropriate fuse time to facilitate ease of making selections at the cost of speed efficiency.
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# Contents

## Contents

- List of Figures vii
- List of Tables 1

## 1 Introduction

- 1.1 Motivation 2
- 1.2 Indentive AB 2
- 1.3 Aim 2
- 1.4 Research questions 2
- 1.5 Delimitations 3

## 2 Theory

- 2.1 Virtual Reality 4
- 2.2 Usability in user interfaces 5
- 2.3 Design of virtual reality user interfaces 6
- 2.4 A-Frame 9
- 2.5 Prototyping 10
- 2.6 Design evaluation 10

## 3 Method

- 3.1 Pre-study 14
- 3.2 Sketching 14
- 3.3 Implementation of first prototype 15
- 3.4 Usability test and assessment of first prototype 16
- 3.5 Implementation of second prototype 21
- 3.6 Usability test and assessment of second prototype 21

## 4 Results

- 4.1 Pre-study 22
- 4.2 Sketching 23
- 4.3 Implementation of first prototype 24
- 4.4 Usability test and assessment of first prototype 37
- 4.5 Implementation of second prototype 44
- 4.6 Usability test and assessment of second prototype 51

## 5 Discussion

- 5.1 Results 58
- 5.2 Method 61
- 5.3 The work in a wider context 63

## 6 Conclusion

64
6.1 Future work ........................................................................................................ 65

Bibliography .............................................................................................................. 67
List of Figures

2.1 Gear VR - the VR HMD that will be used in this thesis. ........................................ 5
2.2 Reticle - Google’s suggestion of visual aid ............................................................ 7
2.3 Head movement. Illustration made by Jean-Marc Denis ........................................ 8

3.1 Questionnaire - 1st section: Test participant information ..................................... 18
3.2 Questionnaire - 2nd section: User interface assessment ........................................ 19
3.3 Questionnaire - 3rd section: Nausea assessment .................................................. 20
3.4 Questionnaire - 4th section: User interface assessment ......................................... 21

4.1 A collection of some of the sketches ....................................................................... 23
4.2 Sketch of chosen design concept ............................................................................ 24
4.3 A few of the other design concepts that were sketched .......................................... 24
4.4 First screen of the user interface ............................................................................. 25
4.5 Second screen of the user interface ......................................................................... 25
4.6 Third screen of the user interface ............................................................................ 25
4.7 First design of menu ............................................................................................... 26
4.8 Indication box, changing channel buttons, and icons added ................................... 26
4.9 Highlighting hovered channel ................................................................................ 27
4.10 Moving channel list ............................................................................................... 27
4.11 Menu item added ................................................................................................... 28
4.12 Changing selected film .......................................................................................... 28
4.13 Design concept altered .......................................................................................... 29
4.14 Additional menu buttons added ............................................................................ 29
4.15 First design of the TV guide .................................................................................... 30
4.16 Menu repositioned to the top ................................................................................ 30
4.17 Web TV menu item added ....................................................................................... 31
4.18 Indication box added for top menus ....................................................................... 31
4.19 Top menu above screen ......................................................................................... 32
4.20 TV guide program enclosed in boxes ..................................................................... 32
4.21 Background colour changed, program boxes made wider, and cursor enlarged ...... 33
4.22 Web TV channels replaced and indication bar added ............................................. 33
4.23 Indication boxes redesigned and repositioned ....................................................... 34
4.24 Design of the screen and the channel list for the first usability tested prototype ... 34
4.25 Design of the film selection for the first usability tested prototype ......................... 35
4.26 Design of the TV-Guide for the first usability tested prototype ................................. 35
4.27 Design of the WebTV selection for the first usability tested prototype ..................... 36
4.28 Design of the settings for the first usability tested prototype ................................... 36
4.29 Design of the screen and the channel list for the second usability tested prototype ... 44
4.30 Channel list no longer moves when channel is clicked ........................................... 44
4.31 Channel list moves when scrolling button is clicked ............................................. 45
4.32 Design of the film selection for the second usability tested prototype ..................... 45
4.33 Second top menu repositioned to the left of menu item windows .......................... 46
4.34 Scroll button fades when film list runs out of films .......................... 46
4.35 Design of the TV-Guide for the second usability tested prototype ........ 47
4.36 Highlighted programs of selected category ........................................ 47
4.37 Channel list scrolling buttons ......................................................... 48
4.38 Second top menu repositioned ....................................................... 48
4.39 Web TV channel pertaining text ..................................................... 49
4.40 Active settings ................................................................. 49
4.41 Turning off an active setting ......................................................... 50
## List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Time results from first usability test</td>
<td>40</td>
</tr>
<tr>
<td>4.2</td>
<td>Comparison of questionnaire answers</td>
<td>51</td>
</tr>
<tr>
<td>4.3</td>
<td>Curio questionnaire answers</td>
<td>51</td>
</tr>
<tr>
<td>4.4</td>
<td>Time results from second usability test</td>
<td>53</td>
</tr>
<tr>
<td>4.5</td>
<td>Time results comparison of the usability tests</td>
<td>54</td>
</tr>
<tr>
<td>4.6</td>
<td>Number of resigns comparison</td>
<td>54</td>
</tr>
<tr>
<td>4.7</td>
<td>Number of fails comparison</td>
<td>54</td>
</tr>
</tbody>
</table>
1 Introduction

1.1 Motivation

The advancement of hardware technology has reached a point where it is now feasible to produce hardware for Virtual Reality (VR) that are actually highly usable, and most importantly, affordable for many consumers. Thus, VR is rapidly gaining new grounds, and attaining an interest from a wide variety of people, but especially for people in the gaming community. However, there are more areas of use to VR other than just games. Watching films/television and browsing the web are just a few examples of everything that is possible in VR. Even though the web and television has existed for quite some time now, web browsing and watching television in VR is a fairly scientifically unexplored area. Therefore, the information about how to develop user friendly and intuitive websites and applications customised for VR is rather limited.

1.2 Indentive AB

Indentive is a software development company with a large focus on internet protocol television (IPTV). By order of Indentive, this thesis project is about investigating the possibilities of making a VR TV-platform by producing a prototype of a user interface of a VR TV-platform using the WebVR framework A-Frame.

1.3 Aim

This thesis’ purpose is to try to make a contribution to the limited research on how to develop highly usable user interfaces for web applications in VR. The aim is, more specifically, to investigate and try to determine how the design of a user interface for a VR TV platform on the web would look like to best satisfy both the requirements for usability and the product’s intended user group.

1.4 Research questions

Usability in user interfaces could imply countless of things, and thus it would be difficult or even impossible for this thesis project alone to establish what amounts as usable in user
interfaces. However, a small contribution could at least be made by evaluating a narrow piece of usability for WebVR. An important part of what defines usability is efficiency in navigating and making selections.

- How to design a user interface in WebVR to facilitate efficiency in making selections with only a Samsung Gear VR headset?

1.5 Delimitations

The more advanced VR-headsets that are currently available on the market are very limited, and the ones that exist are all quite expensive. Because of this, I unfortunately did not get access to any other advanced VR-device than the Gear VR (generation 1) headset which I was provided with. Oculus Rift and HTC Vive are supposed to be powered by powerful computers with graphic cards in the upper bracket, and will both have a maximum frame rate capacity of 90 frames per second. The Gear VR, however, is only powered with the hardware of a smart phone (in my case my personal Samsung Galaxy S6), the performance is very limited. A frame rate of 60 fps is the maximum capacity of the smart phones compatible with the Gear VR, which is also exactly the minimum fps necessary to avoid severe nausea when using a VR headset. Thus, it will be very important to try to keep the fps at the maximum capacity. Moreover, the HTC Vive and Oculus Rift both have a field of view of 110 degrees compared to the generation 1 Gear VR headset which have a field of view of only 96 degrees.
2 Theory

2.1 Virtual Reality

Virtual reality is a complex concept and may be in need of a formal definition; "A medium composed of interactive computer simulations that sense the participant’s position and actions, providing synthetic feedback to one or more senses, giving the feeling of being immersed or being present in the simulation" [5, p. 1]. The definition says that virtual reality senses the participant’s position and actions. An example of this could be that if the user turns his head, the device will detect this with orientation tracking, where all rotation of the axes in three dimensions (3D) will be tracked, using its embedded gyroscope. As a result of the head turn, the device will give the user an appropriate synthetic feedback. The so called synthetic feedback mentioned in the definition could be feedback in form of haptics, smells, and audio. But the most common form of feedback is the visual feedback, which will also be the focus of this thesis. This feedback could be displayed using large screens surrounding the user or displayed in a device, called head-mounted display (HMD), which sits on the head of the user with displays centimetres away from the eyes. The HMD is now probably the most commonly used type of device for displaying visual virtual reality. Examples of current various HMD available to private consumers are Oculus Rift, HTC VIVE, and the Samsung Gear VR, whereas the last is going to be utilised in this thesis work and is displayed in figure 2.1 [22]. The three HMDs just mentioned all have a MEMS-based inertial measurement unity (IMU), which in turn consist of a microcontroller, gyroscope, accelerometer, and magnetometer. The three latter components work among other things to reduce head tracking latency and to increase the motion stability [15].
2.2 Usability in user interfaces

Usability is a term that could include a lot of various things. Barnum gives a definition of usability with three additional terms; effectiveness, efficiency, and satisfaction. For a product to have the usability quality it should allow the user to use it with effectiveness and efficiency, which could be translated into that a user interface should facilitate accuracy and quickness for navigating and making selections. Furthermore, usability also demands that using a product is perceived as satisfactory by the user, which could in turn mean that the user should consider the design to be visually pleasing, not be infuriated by the functionality of the user interface, etc [2, pp. 11-12] Naturally, it is of great importance in order to get a successful product when producing user interfaces that one designs for high usability. [3, pp. 79-84].

The human mind can get its perceptions biased depending on how the user interface objects are aligned in the interface, which is especially important to take into consideration when designing interfaces for virtual reality. By structuring the user interface objects according to a visual hierarchy it may make it easier for the users to know what is important within the user interface and thus should focus on. So by aligning some specific user interface objects in the centre of the user interface, it will naturally give the user a clear signal that those objects are also the most important/relevant ones [14, p. 30]. Furthermore, to aid the users in their navigation within user interfaces and help increase the efficiency, designers should convey functions with pictures, symbols or icons that the users may associate with the specific functions [14, p. 114]. By being consistent with the design, such as having the same symbols, colour or text for the same functionality it allows the users to more easily navigate the user interface and it also prevents causing confusion. Even fundamental design ideas, such as using specific colours for specific things, and the combination of various colours can also improve on the user's experience of the design. This is especially important to take into consideration when designing user interfaces for colour blind people. To avoid fatiguing and alienating users by having them read lots of text, it is recommended to keep the amount of text in the user interfaces at a minimum. The user interface should only contain the most necessary text in order to allow the users to quickly find what they are looking for. [14, p. 50]

Adapting the design to the targeted users

In order to get high usability when designing user interfaces it is of great importance to adapt the design to the targeted users [2]. Benyon explains that a human centred approach is about putting the user first and designing what the users want and involving them in the design process [3, p. 14]. When putting the focus on the intended users of the software, the designers can determine what suits their target audience and what does not. This helps
2.3. Design of virtual reality user interfaces

Creating a product that the users actually perceive as user-friendly, and might help it survive in a competitive market. If the designers on contrary have a product centred approach where they focus on the product alone, it is a substantial risk that the product will not be perceived as user-friendly or meet the requirements for having high usability [2, ch.4]. Therefore it is important to find out who the intended users are. What type of persons are the targeted users? What knowledge and skills do they possess? What attributes can the users expect the product/user interface to have, and what attributes can the product expect the user to have? This is all information that may greatly help to create well designed user interfaces, accommodated to its targeted users [24]. Therefore it is imperative to conduct research to obtain all the necessary information of the interface’s intended users. By actually getting to know the users, and finding out some specific facts about that specific user group, an interface design developer will be able to make necessary decisions that could be critical to the design.

Design developers often create a mental image of what their users are like even without having met any intended users [17]. Tidwell specifies several questions you should try to seek answers to when researching the user group [24]. One question that Tidwell specifies, and that needs to be answered, is what the user want to accomplish by using the software. Another question to be answered is what skills do the users have using similar software [17, pp. 4-7]. People that frequently uses the web, navigate faster than those that do not. However, these experienced users are more easily confused when encountered with new design. In order to not baffle or overwhelm users that are experienced in web navigation, one should consider positioning the objects were the users are used to finding them. An example of this could be to have the "back to home" button in the left top corner of the user interface [2, pp. 85-86].

2.3 Design of virtual reality user interfaces

When designing an application for virtual reality, it is necessary to understand that there is a significant difference to designing applications for traditional 2D environments. There is literally another dimension that needs to be taken into consideration. Because of this, it is especially important that the user is in focus in the design process, since all mechanisms revolve around the user [20, p. 2].

The virtual environment could be presented in various ways, depending on what the purpose of the application is. When developing virtual reality applications one must figure out if it is important to mimic the real world, or if a more abstract environment is preferred [5, p. 26]. The use of conventional idioms from the 2D-environment, like pull-down menus, could help bring a familiar feeling to the virtual reality user interface. Although, this could also mean that one does not use the fully potential that a virtual 3D environment brings. [5, ch.1.7].

Jean-Marc Denis, former senior immersive designer at Google Daydream, emphasises the importance of sketching on paper in the beginning of the design phase when designing for virtual reality due to how incredibly fast it allows the designer to physically realise their ideas [7].

User interaction in VR

When using a regular computer, users are mostly using a keyboard and a mouse or trackpad for the interaction between the user and the interface. However, virtual reality opens up for new possibilities of interaction. One could decide to use previously available computer-accessories also for virtual reality interaction, such as a mouse. This could probably make
users feel more familiar and comfortable in the interaction when trying out this fairly new medium. However, utilising old techniques of interaction might prevent the interaction within virtual reality to reach its full potential in e.g. usability and efficiency. Making selections in an IP-TV platform for virtual reality could be made with a remote control, which would be a familiar tool for interaction. A not as familiar alternative could be to track the hands of the users with motion sensors (e.g. Leap Motion) and let the user make selections by tapping or pointing with her or his fingers [5, pp. 27-30]. However, the use of hand tracking as a main input method is discouraged at this point of time, due to the technology not yet being reliable enough. Furthermore using a game controller could cause physiological discomfort and constrains the freedom that virtual reality gives [7]. An alternative, which does not demand an additional device other than the HMD, could be to instead make use of the motion sensors inside the HMD itself, and make the selections by tilting the head so that the item is perpendicular to the eyes and use a button on the side of the HMD (i.e. Gear VR) to confirm or just use a time-based fuse to click.

In the virtual reality environment where one does not have a mouse cursor that shows the user the x-, and y-position of where the user is in the user interface, it can be difficult for the user to know what objects that he or she is focusing on. A solution to this is to have some sort of cursor symbol attached to the user/camera’s raycaster. In Google’s guideline “Designing for Google Cardboard”, the guideline discusses what one should think of when designing user interfaces for virtual reality. The guideline recommends displaying a dot, or circle, (reticle) as a visual aid for the users, which would help the users with precision when aiming at targets. An illustration of this is displayed in Google’s guideline and can also be seen in figure 2.2 [12]. They also suggest that this visual aid should only be displayed when it is needed, so that it does not affect the immersive feeling unnecessarily much [10].

Another solution to let the users know what they are focusing on, would be to instead of having a cursor, just give visual feedback to the users. The visual feedback could consist of highlighting objects perpendicular to the users. Not having a mouse also brings a need to find a substitute for making selections. How does one, with lack of better words, “click” the user interface objects one wants to select? One possibility is to activate a selection when the user’s raycaster has been intersecting an object for a specific amount of time.

Google’s guideline brings up techniques of having buttons that gets triggered by the user focusing on them. They advocate giving the users a visual feedback in form of fusing the reticle or having a fusing cursor or a timer, with a visual countdown to the actual clicking of the object. If not using a feedback, the user can easily get confused about what is going on, which could result in unintentional clicks. Furthermore, the guideline recommends having the buttons that triggers fusing quite large and also not too close to each other, to prevent
unintentional clicks as well. On the other hand, they warn that using fusing or timer options may result in the interaction being experienced as too slow for the user. Therefore they recommend giving the users the possibility to choose another way to more quickly activate the object; preferably by being able to click by tapping the physical button of the HMD. Another solution would be to utilise hand held motion tracked controllers (e.g. Oculus Touch). However, this thesis will focus on making selections without any extra hardware, and only with the help of the HMD itself. Furthermore, the GearVR and the Google Cardboard both have the possibility to make selections with a tap on the side of the HMD. The Gear VR headset even have a trackpad and a back button as well.

Förslag: Denis suggests that one should carefully consider how the user interaction should work so that it does not over-fatigue the users. Some physical interactions are just not suitable for extensive use, according to ergonomic rules. Having to repeat these unergonomic physical interactions for an extensive period of time may cause serious discomfort. Moreover, Denis discusses the danger in having the user move their head to non neutral positions, due to that the pressure on the neck increases. Long term use could in turn cause nerve damage. Designers should therefore carefully consider to avoid interactions where the user keep their head in non neutral positions during extended periods of time. Alex Chu, former lead interaction designer at Samsung Research America and developer for Gear VR gave a presentation “VR Design: Transitioning from a 2D to a 3D Design Paradigm”, in which he among other things gives design insights for Gear VR. Chu claims that a normal person can turn its head horizontally 30 degrees comfortably and maximum 55 degrees. The degrees one can turn the head vertically differs between whether the head is tilting up or down. Looking up 20 degrees and looking down 12 degrees is considered comfortable. A maximum for looking up is 60 degrees and looking down is 40 degrees. In order to keep the interaction from getting uncomfortable one should place the main user interface objects within the area that Chu claims are comfortable. Denis has made an illustration, showed in figure 2.3, to illustrate where the comfortable zone is for user interaction with green colour, respectively where to avoid having the user have to look for extended time with the red colour.

Avoiding nausea

Denis explains that the most essential rules to remember when designing for virtual reality is to keep the frame rate from getting too low, as well as maintaining head tracking. Maintaining head tracking translates into continuous tracking of the position of the user’s
head while having the objects in the virtual environment at their fixed positions. One should also take scrupulous care that the head tracking is not unintentionally frozen at times, which can be the result of assets demanding too much resources [11]. Furthermore, Denis and other experts in the subject, advocates that in order to avoid motion sickness one should preferably not use acceleration and deceleration of the user, or be very careful when doing so anyway. This is due to the fact that when humans are exposed to acceleration or deceleration they expect to feel the force that changes their velocity. Since this is not yet possible to realise with only a HMD, the users would feel ill when this force does not appear [6]. It is therefore recommended to keep a constant velocity, either constantly moving or having the user in one place. Keeping the line of the horizon static is also important in order to not put the users at risk of experiencing a sea sickness effect. Denis also discourages extreme environments naturally due to the fact that people may have phobias. For example one should avoid creating an environment that is too small due to risk of users experiencing claustrophobia [7].

Michael Alger, virtual reality designer at Google, has made a post graduate thesis titled “Visual Design Methods for Virtual Reality”. In this paper Alger discusses, among other things, how one should design the working environment in virtual reality. As discussed in section 2.3 to avoid risking the user experiencing nausea, one should avoid high heights. Naturally, this requires the environment to have a ground/floor in combination with having a static horizontal line to make the user feel that he or she is not floating. Having a flat floor through the entire environment will, however, also mean that one cuts the environment in half, which results in significantly less space to place user interface objects in. Alger suggests that a viable substitute to having a flat ground could be to instead have the ground decline gradually, or just place the user on a cliff, but far from the edge to minimise the risk of nausea. However, Alger suggest that it is probably best to have some middle-ground, like having a 50 degrees slope angle decline [1].

2.4 A-Frame

A-Frame is an open source three.js framework made by Mozilla, that uses the WebVR Api. The framework utilises an entity-component-system pattern and an asset management system [16]. The entities alone are basically empty containers, without any attributes, unless components are inserted into the entities’ sockets. Components are what makes the entities have visibility, colour, animations, functionality, etc. For example, say you would first want a plane. Then I would need to use the component Geometry to define that I want a plane. This is very easy, due to that a plane is one of the default primitives that A-Frame provides.

```html
<a-entity geometry="primitive: plane"> </a-entity>
```

Below is the source code from A-Frame for a plane. As you can see, the init function has width and height as input parameters, but since I did not declare anything for width or height, the plane will have the default values shown in the schema.

```javascript
registerGeometry('plane', {
  schema: {
    height: {default: 1, min: 0},
    width: {default: 1, min: 0},
    segmentsHeight: {default: 1, min: 1, max: 20, type: 'int'},
    segmentsWidth: {default: 1, min: 1, max: 20, type: 'int'}
  },

  init: function (data) {
    this.geometry = new THREE.PlaneGeometry(data.width, data.height);
  }
});
```
2.5 Prototyping

There are some recommendations one may want to follow when designing user interfaces to minimise the cost and need for extensive revision late in the design progress. One recommendation is to first make a prototype and then conducting usability tests on that prototype [19]. If one early on in the design process can receive relevant feedback, one can make necessary adjustments to the design of the prototype in the start of the design process, while the adjustments are still cheap to make. This prototype could be as basic as drawings on some sheets of paper. Warfel puts it this way "...if you haven’t been proto-typing, you’ve been missing opportunities for innovation and significant cost savings. The benefits of prototyping far outweigh the initial cost." [25, p. 4]. With prototyping comes the possibility to experience the design before it is in its final form. It lets the designers know in time, whether a design is user-friendly or not, and give the designers the possibility to make necessary changes to it. This could in turn help projects significantly reduce the waste of time, cost and work effort [25, pp. 12-16].

Warfel explains that a complete prototyping process consists of four steps. Whereas the first step consists of sketching, where the purpose is to express creativeness and put down the design ideas on e.g. paper, white boards, or in code. Sketching on paper is often advocated due to its simplicity and how easy revisions are made. The second step includes presenting the sketches and then receiving critique from a person with experience or knowledge about product design. The presentation and the critique sessions needs to be kept short. A few minutes each is recommended. During the critique is presented, notes should be taken and written down. The third step is about choosing which sketched concept to continue with, refine the details of its design and create a more advanced prototype. How to model this prototype should depend on what type of end product the prototype is designed for. For example, a web application prototype at this point could be made in HTML. When the prototype has been created, another set of session of presenting and critiquing should be made, however now the amount of time limited to the sessions should not be as short. The fourth and final step concerns testing, where evaluation with both the customer and the end users should be conducted [25, pp. 28-44].

2.6 Design evaluation

To identify problems or faults in the design and to receive a product with higher usability, conducting evaluation of the user interface is needed. The product that is going to be evaluated does not need to be a stable and fully operational product. It is sufficient that it is partially functional, or that only a part of the product is tested. It is however important that there is a possibility to correct the issues found in the evaluations, in order to refine and improve the design [3, p. 10]. Hence, the results from having one usability test could present the problems of the first prototype, which one could try to find adequate solutions to. These
solutions may mitigate those previous problems but it is although not certain that they will not create new issues. Therefore, in order to ensure that the new solutions have not created any new major problems, and to correct the minor ones, having at least an additional, second usability test is recommended by Barnum [2, p. 19].

According to Benyon there are two main categories of evaluation techniques to be used on user interfaces. The first category, the expert-based methods, involves having some type of expert in usability that reviews the user interface. The other category, the participant-based methods, instead involves having people from the product’s target group participating in usability tests [3, p. 226].

If there are no external usability expert available or the only experts available to evaluate the design are the designers themselves, utilising the expert-based methods are discouraged by Benyon. He explains that the designers themselves have already an extensive knowledge of the design and thus will not give the design an unbiased and adequate evaluation [3, p. 229]. Since the participant-based methods does not require usability experts to conduct the evaluation, they are more feasible to utilise for this thesis work and thus will be focused on. There exist a few different participant-based methods. Cooperative evaluation is one of those methods. This method has the participants as co-evaluators which the design evaluators discuss with during test sessions. Another method is the Co-discovery method, which consists of having two individuals, preferably friends, explore the design and discuss it while interacting with it. Documenting the discussion between the participants will give the evaluators helpful feedback of the design of the user interface. The last method is the method of Controlled experiments, in which the evaluator sets up a controlled environment in order to test a particular part of the design. This method is especially good for comparing different designs, in order to find the one with highest usability.

When testing a product, in order to get a testing process with structure it is important to decide on the essentials and plan for the testing process [2, pp. 111-112].

- What should be tested? For example, should every feature in a user interface be tested, or is it enough with testing only three features?
- Where should the tests be held? An answer to this should determine if the test is to be conducted e.g. at the test participant’s home, or at a public place or an office.
- How would the test be conducted? Is it a single design or various designs that is going to be compared? How long is each test session going to last?

A test plan could help structure the usability tests in order to more easily determine the answers to the questions of what, where and how. Thus, having a test plan is important in order to get valuable results from the usability tests. More specifically should a test plan explain in detail what is going to be done in the tests, and thus needs to contain information about, among other things, how the tests should be executed, with which participants and under which circumstances. This is to prevent getting unorganised tests in which things are forgotten when they are conducted. Depending on how detailed one wants the test plan to be, one needs to include various descriptions. However, a typical basic test plan could contain descriptions of the following [21, pp. 65-67]:

- The research questions of the tests
- The characteristics of the participants
- The list of the tasks and goals to accomplish
- The environment to conduct the test in
2.6. Design evaluation

- The data that needs to be collected

Rubin et al. explains that the research questions of the user test are of utter importance to the test plan. Getting the answers to these questions helps getting to know what would need to be changed in order to increase the usability in the user interface [21, pp. 70-71]. The characteristics of the participants of the tests should list information about the participants that are relevant to the test. It is important that these characteristics of the participants of the tests should match the characteristics of the users from the intended user group [19][14, p. 51]. In order for the evaluation to yield valuable results and finding issues with the usability of a design, it is recommended to have the test participants accomplish various tasks when using the user interface in the user tests. Hence, the test plan should therefore contain a list of the tasks and goals of the user tests that the participants should accomplish. When determining the goals of the tasks in the user tests one should try to form the goals so that they could give answers to if the user interface facilitate high effectiveness, efficiency and satisfaction, and thus having high usability, as discussed in section 2.2.

It is suggested that these tasks should be modelled from what a user would typically do, and also what is expected that the users want to accomplish in practice when using the product [2, p. 19] [21, p. 79]. The list of the tasks should also contain information about what initial state the tasks starts in, what state to be in for completion, and what makes a task being unsuccessful. An unsuccessful task could mean that e.g. the time limit is exceeded, the participant gives up or gives a wrong answer [21, pp. 79-86]. To determine what data that needs to be collected one should look at the research questions that were specified. Say for example a research question is: how easy do the test users find what they are looking for? Then the data that needs to be collected should, among other things, at least include the time it takes for them to complete each step of the tasks [21, pp. 88-90].

Some very valuable data that is difficult to collect for the test moderator if the test participants do not decide to share it, is the test participants thoughts while using the user interface. A think-aloud process, where the test participants are encouraged to speak their mind out loud while trying to accomplish the tasks, could give valuable information about how the user’s perceive the user interface. Using this process could help understand why the test users choose different actions and what they are looking for when trying to navigate [3, p. 154].

The data that is going to be collected according to the test plan should be analysed in order to evaluate how well execution of the tasks were completed. For example, for determining the usability of the user interface one could analyse the task accuracy. This could involve calculating the percentage of the participants that managed to complete a task, the percentage that managed to complete it within the limit, and the percentage of the participants in a specific age range that could not complete the task [2, ch.8]. Before the user tests are conducted a minimum or maximum percentage should be set for these different values of task accuracy. If the results from the user tests show that the value calculated for the task accuracy are below the minimum thresholds or above the maximum thresholds, one can conclude that there is a fault in the design of the user interface and it needs to be refined [21, pp. 81-82]. A successful completion criteria should define what it takes for a user to actually succeed with the completion of a task. A useful measurement for the successful completion criteria is time. However, it is difficult to determine what would be an appropriate time limit for each task. Furthermore, if the participants are supposed to think out loud while they are using the user interface, the time it takes for them to accomplish the task would most likely be prolonged [2, p. 80].

In order for the user tests to yield adequate and accurate results, it is important to de-
2.6. Design evaluation

termine how the user test environment should be and what the test moderator is going to do during the tests. The environment that the tests are going to be held in should, in what ever extent possible, simulate the environment that the product would actually be used in [21, p. 87]. It is suggested that an ideal testing environment is quiet, has enough space to fit test participant and the test moderators, and also supplies the basic equipment for the test (e.g. a separate room with a table and a computer) [2, p. 26]. For a product that is supposed to be used in the user’s home, conducting the tests in a noisy public place would perhaps not give as adequate results as if the test would have been held in the user’s home. Furthermore, it is important to determine what the test moderator will do during the test sessions, to ensure that all test participants are treated the same way. Making a script or a checklist that the moderator could follow could help in making the test sessions more structured and consistent for all the tests sessions with each test participant. This script or checklist is recommended to contain explanations to the test participants about, among other things, what the purpose of the test is, the equipment that will be used, and how the user test is going to be conducted and what role the test participant will have in it [2, p. 167].

After receiving the initial explanations from the test moderator but before letting the test participant start trying to complete the various tasks that have been predetermined, a training phase could be held. Prerequisite training for the test participants could be used for allowing them to get used to using a specific technology or user interface, which could potentially be a new experience for them. After the training phase and when it is time to give the test users the various tasks, one cannot expect that the test participant will remember all the tasks if they are given them all at once. Furthermore, even if they are given each task separately, the current task to be performed, it is most likely that someone will forget what the task was. Thus, how the test moderator presents the task to the test participant could have a large affect on the user test’s outcome. One could let the test participant read each task just before starting them, or the test moderator could read them out loud for the test participants. Which method is best suited for each specific test could be affected by how complicated the task is, and how it is supposed to be accomplished [21, pp. 223-224].
3 Method

3.1 Pre-study

Intended users
In section 2.2, it was pointed at the importance of getting to know the target user group before starting to design, if one wants to produce a product with high usability. How would an average user of a virtual reality TV platform on the web look like? Research about the demographics of the intended users would be needed to determine this. Since this product is a Web based TV platform in Virtual Reality, the best thing would have been if I found statistics on the demographics of potential users for this specific product. But naturally, this kind of statistics does not exist, at least not yet. As a next best thing I therefore researched how a typical user for a web based TV platform, respectively a virtual reality product would look like. So first, I searched for data on how the average person would be that watch TV online, rather than watching traditional linear TV. Then I searched for data to find out the characteristics of the average user of Virtual Reality products.

Framework
In order to be able to get a better understanding of what would be feasible to create with the fairly unexplored A-Frame framework some research had to be made. It was thus researched about what had been previously made by peers and also how various components for the framework were made.

3.2 Sketching
In section 2.3 and section 2.5 it was advocated to sketch the initial design ideas on paper. This was therefore implemented. A variety of different concepts of design of the user interface were sketched on paper. In section 2.3 the recommendations when designing user interfaces for Virtual Reality were, among other things, to keep the user interface objects in the comfortable zone, as illustrated in figure 2.3. It was also recommended that the user interface objects were not too close to each other to prevent unintentional clicks on other user interface objects. Thus, these recommendations were considered when sketching the
3.3 Implementation of first prototype

It was recommended in section 2.5 that after refining the design one should produce a more advanced prototype. Furthermore, how one should produce that prototype should be based on what type of end product the prototype is made for. Since in this case the end product would be a WebVR TV platform, it would be more appropriate to produce this prototype directly in a framework that is adapted to WebVR. A-Frame was described in section 2.4 as a publicly available framework made by a highly respected organisation (Mozilla), and at the time this thesis work started it was also the most extensive framework for WebVR, thus it was naturally chosen to develop this advanced prototype. The development of the prototype in A-Frame was started. The design was first based on the sketch of the chosen design concept section 4.2. Although, the more time spent with producing this digital prototype, the more the design evolved from what was in the original sketches.

A few alternatives to how one should give feedback to the user what objects they are currently intersecting was discussed in section 2.3. During the early phase of development it was decided to follow the recommendation to display a reticle as visual aid, since it helped making the navigation faster while development testing.

It is discussed in section 2.2 how the user interface objects are aligned do affect how the human mind percects the user interface, which therefore needed to be especially taken into consideration when aligning the user interface objects. Therefore, when deciding on where to position the menu items in the advanced prototype various pros and cons with various positions of the expanded menu were weighed. Furthermore, to ease the user’s navigation in the user interface it was advocated, in section 2.3 that designers should use symbols, icons, or images to help users associate what functionality specific buttons had. Thus, icons were utilised in the design of the user interface in a reasonable extent.

As was discussed in section 2.3 highlighting user interface objects that are currently intersected helps users navigate more easily in the user interface. This was therefore implemented in the prototype.

To keep the user interaction in the user interface consistent and allow the users to more easily navigate the user interface, it was recommended in section 2.2 to use symbols to help users understand the functionality of e.g. a button. Furthermore, it was advocated that one should use symbols that were alike for the same kind of functions. An example of when this
was enforced was that icons were pertained to buttons and the appearance of the icons were
chosen so that they would match the functionality of the buttons.

### 3.4 Usability test and assessment of first prototype

In order to be able to identify and correct the issues in the prototype it was necessary to
review the user interface. For this, the participant-based methods or the expert-based meth-
ods should be utilised according to section 2.6. Since an external expert in usability was
not available to consult, one of the participant-based methods had to be utilised. Of the
participant-based methods, the co-discovery method consisted of having two individuals
exploring the prototype together. These methods would not be possible to utilise with one
HMD. The cooperative evaluation, however, would not necessarily need two participants
evaluating at the same time. The cooperative evaluation implied having the designers or
test moderators discuss the design together with the test participants. In the controlled envi-
ronment method was recommended if one wanted to compare different design and parts of
a design 2.6. Both the cooperative evaluation and the controlled environment method both
seems suitable for the prototype. Thus, both these methods are combined and used in the
evaluation of the prototype. First, the controlled method is used, and then the cooperative
method, where design is discussed together with the test participants.

In section 2.6 it was proclaimed as important to have test participants that possess the
characteristics that matches the characteristics of the intended users. Thus, in order to con-
duct the usability tests, a number of participants with the characteristics that matched those
that was retrieved from section 3.1 had to be gathered in order for the evaluation to yield
useful results. Luckily, the company that this thesis work was conducted at had about 20
employees that fitted into the target group. Thus, these employees and two other persons
from another company were asked to participate in the usability tests.

As discussed in section 2.2 it is important in order for a product to be successful that
the design for the user interface has high usability. Furthermore, to meet the criterias of effec-
tiveness, efficiency and satisfaction that was discussed in section 2.2, it would be appropriate
to set up a few characteristics that should be fulfilled and considered when evaluating the
design. Therefore, I decided on four very relevant characteristics for meeting the definition
of usability, which are the following:

- It must be possible for the users to be able to do what they want to do in a reasonable
time.
- It must be simple for the users to understand how to achieve what they want to do.
- The user interface must hold adequate functionality and have it organised in a compre-
hensive way.
- The user interface should not have a visual design that is disliked.

As recommended in section 2.6 a test plan had to be created ahead of the test in order to
gain valuable results from the tests. It was proclaimed that with the help from this test plan
one needs to find the answers to what, where and how a usability test should be conducted.
For the test sessions to not be too time demanding, I had to limit the amount of features that
would be tested in the user interface. However, I wanted to test at least one feature in every
one of the five menu items; Screen, Film, TV-guide, Web-TV, and Settings.

Before the participants were assigned the tasks of the usability test they were informed
of the purpose of the evaluation. The participants were also informed that the events of the
3.4. Usability test and assessment of first prototype

The procedure would be taken notes of. The usability tests were conducted with the participants separately, and each session was started by first presenting the user interface to each test user participant, who would then be given the tasks to complete.

The test users were encouraged to "think aloud" while using the prototype, as was recommended in section 2.6 and to freely comment on the design. If the participant gave comments about the design, these comments were not contested, but were taken notes of. The data collected from the usability tests was then analysed in order to find what would need to be refined in the next iteration of designing the user interface.

In section 2.6 it was discussed that it could be difficult to determine a maximum time a test participant should have to accomplish a specific task and still be regarded as successful. However, one way to set this maximum time limit is to have one test participant, experienced with that specific type of products, accomplish each task and record the amount of the time each task takes. Then one can multiply the time for each task with a specific factor in order to get a suitable time for maximum time limit. Thus, I had a test participant that I knew had much experience of using VR user interfaces accomplish each of the tasks in the task list first. This test participant was asked to "think aloud" while performing the tasks, since the rest of the test participants also would be asked to think aloud. I multiplied the time it took for this test participant to accomplish each task with 2. The factor’s value was set to 2 because then the rest of the test participants would have twice as much time, than an experienced VR user, to complete each task in order to succeed in doing so.
To not miss out on any valuable information from conducting these usability tests, the test participants were asked to fill out a form where their answers would give an assessment of the user interface and using a TV platform in Virtual Reality. This form was separated into four sections, where the first section consisted of questions that was supposed to be answered by the test participants before the test, and the other three sections after the test. The first section of the questionnaire contained questions that would give valuable information about the participants, that would be relevant to the product. An example of one of the questions was "How familiar are you with using VR products?". The rest of the questions in the first section of the questionnaire can be seen in figure 3.1.

Figure 3.1: Questionnaire - 1st section: Test participant information
It could be difficult for the test participants to express their thoughts verbally or critique the design directly to the test moderator. Especially in this case, when test moderator is also the designer of the prototype. Having qualitative assessment questions in a questionnaire could give more truthful critique from the test participants. Thus, the second section in the questionnaire, displayed in figure 3.2, consisted of these kind of questions, which would be answered after accomplishing the tasks in the usability test. One example was "Did you find it easy to find what you were looking for?", which refers to what they were looking for within the user interface.

Figure 3.2: Questionnaire - 2nd section: User interface assessment
3.4. Usability test and assessment of first prototype

As discussed in section 2.3, nausea is a serious issue when it comes to VR. If one experiences nausea while using a product, which is not unlikely when it comes to VR products, it could naturally have a significant negative affect on how the test user views the prototype. Therefore, it is important to collect information about the participants experiences when it comes to nausea, which the questions in the third section are for. An example of a question is "Did you experience any physiological discomfort? (e.g. motion sickness)". All questions about nausea is shown in figure 3.3.

Figure 3.3: Questionnaire - 3rd section: Nausea assessment
The final section in the questionnaire, as seen in figure 3.4, included questions that were not used to assess the prototype per se, but rather to assess Web-VR TV platforms in general and its potential future. The results from these questions would be discussed in future work, section 6.1, in the conclusion chapter.

![Figure 3.4: Questionnaire - 4th section: User interface assessment](image)

3.5 Implementation of second prototype

The results from the first design evaluation process revealed the major issues of the design. Solutions to these issues were suggested, compared, and chosen based on the most appropriate option. These solutions were then implemented into the design.

3.6 Usability test and assessment of second prototype

The second, which was also the final usability test, was conducted on the refined prototype. This usability test was conducted in the same way as the first one, with the same tasks to accomplish and the test moderator giving the same instructions, and the test participants receiving the same questionnaire to fill out. However, the test participants had been replaced with new ones, so that the results would not be affected by the participants previous experience of the prototype. The results from this usability test were assessed separately, but were also compared with the results from the first test. This assessment and comparison gave information about what could need additional revision or what worked better in the previous prototype.
4.1 Pre-study

In 2015, Sweden, watching TV in the traditional way, where the TV shows are broadcasted according to preset schemas is slowly decreasing in popularity. Instead, people are spending more time watching TV online, where they do not need to adapt to any schema. In the age-range 16-25 the average time spent each week watching TV online was 4 hours. Age 26-35: 3.4 hours. Age 36-45: 2.5 hours. In the ages 46 and above, less than 2 hours. However, in every age-range the average time spent watching linear TV is still significantly higher than the time spent watching online. For example, in the age-range 36-45 an average 9.7 hours is spent on linear TV [23]. In a study Ericsson has made, they found that the reason to why linear TV is still very popular is “mainly due to its access to premium viewing and live content, like sports, and its social value”. However, the study also says that the reason to the decreased popularity is due to “Half of consumers watching linear TV say they can not find anything to watch at least once a day. Consumers feel that recommendation features are simply not smart or personal enough” [8].

Since being able to experience Virtual Reality requires one to posses a VR HMD, and the cost of acquiring this could be considered by many as an unnecessary expense, it may at first result in that the early purchasers are the most interested and computer savvy persons purchase these items. Especially people within the gaming community are willing to purchase virtual reality hardware due to most virtual reality content is games. Thus, it would be necessary in order to determine what an average user for VR looks like to find the average user of computer games. In 2015, Sweden, the younger generations were playing the most. For age-range 15-24 48% was playing video games daily. For age-range 25-44 32% was playing daily, and for age-range 45-64 this digit decreases even further, to 23% [15]. In 2015, Sweden, in each of the age-ranges 16-25, 26-35, 36-45, more than 34 percent consider themselves as very computer savvy. In the age range 46-55 this percentage drops to a low 23 percent, and is even further decreased in the higher age ranges [23]. This information indicates that the time spent watching TV online is increasing, mainly because the possibility to get to actively choose the content without the need to adapt to any broadcast schema. It also tells us that why the linear TV is still dominant is much because of its social value.
4.2 Sketching

One could use all of this information to determine what the target group of the product is for the prototype, since the user interface that is produced in this thesis work is for a web based TV platform in Virtual Reality. The data and assumptions made makes it possible for us to draw the conclusion that the average user would be a person in the age-range 16-45, that may watch TV alone, and is a tech savvy person that likes to play video games and thus has probably an extensive experience navigating in user interfaces. As was proclaimed in 2.3 this is all important information to be kept in mind when in the design process, since it is necessary to adapt the design to the product’s intended users to get a usable product.

4.2 Sketching

In the sketching phase nine design concepts of design were sketched, whereas a compilation of some of these is shown in figure 4.1.

Figure 4.1: A collection of some of the sketches

Of the nine concepts of design shown to the professionals, both of them suggested the same design alternative, shown below in figure 4.2 to be pursued and refined. They motivated the choice with that it would be most wise to start from a simple design so one would not experience that one has bitten off more than one can chew. The chosen alternative had thus one of the most basic, simplistic designs and was also the first design I came up with when I started sketching the design ideas.
4.3 Implementation of first prototype

Below, in the figure 4.3, are a few of the other alternatives which were presented to the professionals, but were dismissed.

Figure 4.3: A few of the other design concepts that were sketched

4.3 Implementation of first prototype

In figure 4.4, one can see the first design sketch that was realised in A-Frame.
4.3. Implementation of first prototype

I added a 360 background picture, a sky box, to the user interface, and also made the height of the channel buttons higher and the space between each channel button greater, as can be seen in figure 4.5.

As I was about to add the buttons for changing channels I noticed that if I would have placed the buttons at the same position as I drew in the sketch 4.2 below the screen, it would be very difficult to see to what channel one switched to. Both the channel buttons and the channel displayed on the screen, would be very far away from the buttons for changing channels. Therefore I decided to position the buttons so that one could better see which channel was selected, and more easily receive the necessary feedback. This can be seen in figure 4.6.

In the design sketches, one alternative was to place the expanded menu items so that they would cover part of the screen. Another alternative was to just position it to the right of the menu buttons. The latter alternative was chosen so that the screen would not be full other
4.3. Implementation of first prototype

user interface objects. The menu item was rotated to face the user, so it would be possible to see all of its content easier, as displayed in figure 4.7.

![Figure 4.7: First design of menu](image)

Icons for the various channels were added to ease the user’s navigation by association. Provisional icons for the menu buttons were added as well. Furthermore, the buttons for changing channel up and down were designed as up and down triangles, which functionality therefore easily could be recognised. Also an indication box behind the selected channel was added to clearly display which channel that was currently active, as can be seen in figure 4.9. Also, the fuse time to activate a click was increased to 700 ms. The previous time had been about 500 ms, which I experienced as a cause to misclicks, since it was too fast. During the fuse time the cursor was decreasing in size to illustrate that the cursor was "clicking", which would give the user visual feedback of the fuse click.

![Figure 4.8: Indication box, changing channel buttons, and icons added](image)

In addition to displaying a reticle as visual aid of where the user is intersecting, I added the functionality of highlighting the selectable objects that the user is currently intersecting, to prevent unintentional clicks. This is shown in figure 4.9.
4.3. Implementation of first prototype

Figure 4.9: Highlighting hovered channel

When a channel had been clicked, it was moved to the position of the currently selected channel to prevent any potential confusion of what channel is currently active, which is displayed in figure 4.10.

Figure 4.10: Moving channel list

In 4.1, the results from the pre-study of the targeted users showed that users were using more On demand-TV online, so that they could actively choose by themselves what to watch. Thus, On demand content, such as TV-series and films, were added to the TV platform in order to adapt to the targeted users, so that they had the possibility to actively choose content. This is seen in figure 4.11.
4.3. Implementation of first prototype

Figure 4.11: Menu item added

In figure 4.12, one can see that the buttons for choosing film were designed the same way as the buttons used for scrolling and selection of channels, to be consistent within the user interface.

Figure 4.12: Changing selected film

When clicking a menu item and setting a menu window to visible it caused a frame rate drop that was very apparent to the user. Thus, I felt I needed to find another solution to how the menu windows would be displayed. I created a circle with a high height and a large radius that I intended to use as background for the menu items. The background and its menu items would then be rotated so that the menu button clicked would cause its menu item to rotate to be straight in front of the user’s vision. The menu items would not need to be loaded each time a menu button was clicked, in order to be displayed. Instead all menu item windows would be preloaded and visible as the web application loaded in the start. This would cause a longer preloading time, but this would be to prefer in order to avoid apparent frame-rate drops. An additional two thumbnail posters were also added, since three were a bit few, and now there would be room to add more. Moreover, the title for each menu item was added and positioned in a circle above the main content circle, as can all be seen in figure 4.13.
4.3. Implementation of first prototype

A menu, where one could choose between New, Top, and Downloaded films was added and positioned above the menu item window, as can be seen in figure 4.14. Also, category selection would be necessary when choosing a film, thus a menu for choosing category was placed below the menu item window.

An early version of a TV guide was created, which is shown in figure 4.15. In the figure, it is also more clearly shown how the various menu items will be attached to the circle background.
4.3. Implementation of first prototype

When having the menu buttons to the right of the menu windows, it limited the valuable space of the menu windows and forced the user to turn the neck more to the side than comfortable. Thus, it was necessary to reposition the menu buttons, and the most suitable position that was available was above the circle background. The second top menu was moved down to give room to the top menu, which is displayed in figure 4.16.

Figure 4.16: Menu repositioned to the top

In figure 4.17 a Web TV menu item was also added to the user interface, which had an appearance very similar to the Film menu item window, with exception to the provisional Web TV channels. Furthermore, the position of the title of each menu item was raised to above the upper circle, in order to give room to the top menu.
4.3. Implementation of first prototype

There was a need for indicating which menu item that was currently selected, thus an indication box for both the top and second top menu was added, as can be seen in figure 4.18. Also, a different cursor design was tested to compare the difference between having a ring and a filled circle.

In figure 4.19 it is shown how the screen item window now looks after the change of design of the menu buttons which was repositioned to the top.
4.3. Implementation of first prototype

The programs in the TV guide were each one enclosed in their own box to clearly separate each program, which can be seen in figure 4.20.

The background to each menu item window was given a different background colour. The cursor was enlarged to be more visible in the user interface. The program boxes in the TV guide were made wider and the design of the buttons for changing channels and time were altered. This is all apparent in figure 4.21.
4.3. Implementation of first prototype

The provisional Web TV channels were exchanged with actual icons, and an indication bar was added to display which Web TV channel that was currently active, as seen in figure 4.22. The cursor was also enlarged due to the previous, smaller size made the shakiness of the cursor more apparent also easier to lose sight of.

Having the indication boxes, that were used to clearly display which items were currently selected, behind the selected item gave a very "pixelated" look. Therefore, the indication boxes were remade and either positioned to the side or beneath the selected item, which can be seen in figure 4.23.

Figure 4.21: Background colour changed, program boxes made wider, and cursor enlarged.

Figure 4.22: Web TV channels replaced and indication bar added

Figure 4.23: Indication boxes remade and positioned to the side or beneath the selected item.
4.3. Implementation of first prototype

Figure 4.23: Indication boxes redesigned and repositioned

In the next five figures, 4.24 to 4.28, the user interface is displayed as it was in the first usability test. In figure 4.24, the text had been replaced with icons in the top menu. All of the icons are acquired from fontawesome.io/icons [13].

Figure 4.24: Design of the screen and the channel list for the first usability tested prototype

In figure 4.24, a play button had been added, as well as the scroll arrows buttons. The colour of the cursor was also altered, to prevent the potential loss of the sight of it. Furthermore, the size of the cursor was made smaller, since it was larger than some of the smaller user interface objects.
4.3. Implementation of first prototype

The colours for the programs and its background had been changed to more clearly display the TV flow, in the TV guide window, as shown in figure 4.26.

The Web TV channel buttons were moved to the left of the menu item window, as can be seen in figure 4.27.
4.3. Implementation of first prototype

A menu item for settings was designed and added, with three different settings alternatives and their appurtenant on-and-off button, as can be seen in figure 4.28.

Figure 4.27: Design of the WebTV selection for the first usability tested prototype

Figure 4.28: Design of the settings for the first usability tested prototype
4.4 Usability test and assessment of first prototype

Test plan

In order to get structured usability tests, a test plan was made. This test plan consisted of a checklist for the moderator, which in turn contained explanations that would be given to the test participants before conducting the usability test.

1. Checklist for test moderator - Explanations to the test participants about

- **Purpose of the test**
  To find usability issues within the user interface.

- **The equipment that will be used**
  A head mounted display for virtual reality powered by a smart phone (Gear VR with Samsung Galaxy S6).

- **How the usability test is going to be conducted**
  The test participant is going to get a training phase of 20 seconds in which they can look around in the virtual environment and for example try to click on a user interface object. After this training phase, one task will be given to the user at a time. The test moderator presented the task on paper which could be read by the test participants themselves. They were also presented with the option that the test moderator could read the task out loud to them instead. The goal of these tasks were supposed to be accomplished within a time limit and without too many errors.

- **What role the test participant will have in it**
  Think out loud while you are trying to accomplish these tasks.

2. The research questions of the tests

- How easily does the test users find what they are looking for in the user interface?
- How well do the users comprehend the functionality of the user interface?
- How well do the users understand how to make selections?
- How do the users perceive the visual design?

3. User profile / The characteristics that should be fulfilled in order to be one of the test participants

- Must be within age range 16-45
- Must be tech savvy

4. The task list

a) Switch to channel 1, then switch to channel 7, 6, 5, 4, 3, 2.
b) Find and play the new drama film Woody Allen.
c) Find what program that start at 10 today at channel 6.
d) Play the first program in the list in SVT play.
e) Find an animated top film with title text “filmanimated1”.
f) Turn off the transparent background.
g) Determine which of the channels 1-5 that have weather programs at 10 today.

5. The environment to conduct the test in and the equipment used
4.4. Usability test and assessment of first prototype

- The tests are going to be conducted while the person is sitting up in an excluded office room.
- The equipment that the test participants will use is a Samsung Galaxy s6 placed in a Gear VR headset. The tests will be streamed to an external monitor with Google Chromecast, which will be monitored by the test moderator.

6. The data that would be collected during the test sessions:
- The time it took to complete each task given.
- Observations of erroneous navigation.
- The thoughts from the thinking out loud technique.

Thinking out loud comments and observations

The thinking out loud comments and remarks were written down for each task and test participant. The most substantial comments made by the test participants together with the observations made by me as a test moderator are stated below for each task.

Task 1: Switch to channel 1, then switch to channel 7, 6, 5, 4, 3, 2.
Comments and observations:
- Sometimes it was hard to click on a specific channel because the channel list was moving up and down when you accidentally clicked a channel. (Had to move around the channel list)
- The channels switched too fast.
- It was difficult to see that the video changed to the right.
- The appearance of the buttons for changing channels did not clearly indicate they were buttons.

Task 2: Find and play the new drama film with poster name Woody Allen (title text: film-drama1).
Comments and observations:
- Difficult to find the category selections, since they were at the bottom.
- Difficult to see the text for each category. (Too jittery / small)
- No feedback about the film list reaching its end.
- The titles of the films were missing
- Not enough hover time before clicking the films

Task 3: Find the program number of the program that starts at 10:00 today at channel 6.
Comments and observations:
- The TV guide is expected to be found next to the channel list and screen.
- Is believed that if one first selects channel in the channel list next to the screen, and then proceed to the TV guide that the selected channel will be active.
- Time-line was unclear. It was difficult to distinguish what programs starts at 10.
- In the top menu Tomorrow is accidentally clicked.
4.4. Usability test and assessment of first prototype

- Not apparent which channel is active, since there are 5 channels simultaneously.

**Task 4:** Find and play the first program you see in the Web TV channel SVT play.

**Comments and observations:**
- The Web TV channels do not have any text that clarifies which icon that is a specific Web TV channel.
- The arrow buttons for changing are not the same colour, which makes one expect that the darker button implies that the list is empty in that direction.
- The click fuse is easily interrupted if one goes outside the fuse box.

**Task 5:** Find and play the Top animated film with the title text “filmanimated1”.

**Comments and observations:**
- New and Top is easily clicked by accident.

**Task 6:** Turn off the transparent background.

**Comments and observations:**
- Having the colour orange to display the setting as active is confusing.
- Would like an icon for on and off instead of just colour.

**Task 7:** Determine which of the channels 1-5 that have weather programs at 10:00 today.

**Comments and observations:**
- Expected to find category text on each program.
- Did not expect that one should choose category in the bottom.

**Assessment of the first usability test results**

The maximum time for success for each task completion was calculated by taking the time it took for the first test participant with much experience of VR user interfaces, and multiplied that time with 2. The time results for each test participant and tasks to accomplish is shown in table [4.3]. In the first row in the table is the time results of the first test participant, which the maximum time for success was calculated from. The maximum time for success is seen in the second row in the table, which is coloured in teal. The cells in the table that are coloured in red implies that the maximum time for success for that task has been exceeded by the test participant, and thus failed with the task. A cell coloured in orange means that the test participant resigned on the task because he or she could not find the goal state of the task. In the last row, the average time that was calculated from the test participants that did not resign, is displayed.
Table 4.1: Time results from first usability test.

<table>
<thead>
<tr>
<th>Test participant</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Task 5</th>
<th>Task 6</th>
<th>Task 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test participant 1</td>
<td>42s</td>
<td>50s</td>
<td>20s</td>
<td>29s</td>
<td>35s</td>
<td>10s</td>
<td>25s</td>
</tr>
<tr>
<td>Maximum time for success</td>
<td>84s</td>
<td>100s</td>
<td>40s</td>
<td>58s</td>
<td>70s</td>
<td>20s</td>
<td>50s</td>
</tr>
<tr>
<td>Test participant 2</td>
<td>50s</td>
<td>61s</td>
<td>67s</td>
<td>Resigned</td>
<td>30s</td>
<td>24s</td>
<td>50s</td>
</tr>
<tr>
<td>Test participant 3</td>
<td>91s</td>
<td>62s</td>
<td>54s</td>
<td>21s</td>
<td>19s</td>
<td>11s</td>
<td>39s</td>
</tr>
<tr>
<td>Test participant 4</td>
<td>40s</td>
<td>Resigned</td>
<td>Resigned</td>
<td>22s</td>
<td>15s</td>
<td>14s</td>
<td>59s</td>
</tr>
<tr>
<td>Test participant 5</td>
<td>24s</td>
<td>67s</td>
<td>56s</td>
<td>17s</td>
<td>12s</td>
<td>10s</td>
<td>25s</td>
</tr>
<tr>
<td>Test participant 6</td>
<td>19s</td>
<td>63s</td>
<td>34s</td>
<td>19s</td>
<td>30s</td>
<td>18s</td>
<td>25s</td>
</tr>
<tr>
<td>Test participant 7</td>
<td>36s</td>
<td>41s</td>
<td>88s</td>
<td>63s</td>
<td>35s</td>
<td>10s</td>
<td>43s</td>
</tr>
<tr>
<td>Test participant 8</td>
<td>29s</td>
<td>Resigned</td>
<td>Resigned</td>
<td>25s</td>
<td>20s</td>
<td>14s</td>
<td>67s</td>
</tr>
<tr>
<td>Test participant 9</td>
<td>26s</td>
<td>110s</td>
<td>57s</td>
<td>27s</td>
<td>19s</td>
<td>20s</td>
<td>30s</td>
</tr>
<tr>
<td>Test participant 10</td>
<td>58s</td>
<td>49s</td>
<td>83s</td>
<td>23s</td>
<td>15s</td>
<td>16s</td>
<td>32s</td>
</tr>
<tr>
<td>Test participant 11</td>
<td>42s</td>
<td>45s</td>
<td>67s</td>
<td>20s</td>
<td>35s</td>
<td>23s</td>
<td>53s</td>
</tr>
<tr>
<td>Average time</td>
<td>41.5s</td>
<td>53s</td>
<td>63s</td>
<td>26.3s</td>
<td>29.8s</td>
<td>15.7s</td>
<td>39.3s</td>
</tr>
</tbody>
</table>

It would be too time consuming to try to solve each and every problem that was discovered in this usability test. Therefore, the most significant or the most easily solved problems had to be determined. With this knowledge one could find solutions to these problems in order to improve the design as much as possible with the limited time available. In figure 4.1 one can see that it is quite apparent that the number of test participants that either failed to accomplish Task 3 or resigned was very high. Thus, it is obvious that the most significant problem within the design has to do with the TV guide, since Task 3 was a TV guide task. Also task 2, 4, 6 and 7 had at least two or more test participants that either failed or resigned, thus it is important to also focus on fixing the problems related to these tasks.

**Problem 1**

When completing task 1 the design detail that caused the most perplexity was that the channel list had not a static position and that it was not always clear which channel had been selected.

- **Solution A)** Keep the position of the channel list static when a channel is clicked and move the indication box beneath the selected channel.
- **Solution B)** When the channel arrows are clicked, move the channel arrows so they are adjacent to the selected channel.
- **Solution C)** When the channel arrows are clicked, keep both the position of the channel list and the channel arrows static, and only move the indication box.
- **Solution D)** When the channel arrows are clicked, keep the position of the channel arrows static, but move the channel list and the indication box.
- **Solution E)** Reposition and redesign the indication box so it more clearly indicates which channel is selected.

**Chosen solution(s) to problem 1:** Solution A, D, and E were implemented. Solution A was chosen because the test participants found it frustrating when the channel list was moving when clicking a channel in the channel list. Solution D was chosen so it would be possible to scroll the channel list to be able to view the additional channels that are not currently visible. Solution E was chosen so the indication box would more clearly indicate which channel is active and also because it should be more consistent with the rest of the user interface.
Problem 2
The second most significant problem for completing task 1 was that the buttons for changing channels were often not recognised as buttons that could be clicked.

- **Solution A)** Exchange the icons of the channel arrow buttons so they look more like click-able buttons.

**Chosen solution(s) to problem 2:** Solution A was implemented because it was an easily fixed solution.

Problem 3
For task 2, the most important problem was without doubt that the test participants searched for too long before they found categories at the bottom of the user interface.

- **Solution A)** Change position of the categories so it is just beneath the top menu.
- **Solution B)** Change position of the categories so it is on the left or right side of the main content.
- **Solution C)** Raise the position of the categories menu up a few length units.
- **Solution D)** Increase the size of the category boxes.

**Chosen solution(s) to problem 3:** Solution C was chosen because it would make the categories menu more visible but at the same time it would not demand a complete redesign of the menu item windows. Solution D was chosen because it would further increase the visibility of the categories menu.

Problem 4
Text for each menu item of the categories was too difficult to see.

- **Solution A)** Increase the size of the text in the category boxes.

**Chosen solution(s) to problem 4:** Solution A was chosen because the solution would make it easier to make out the words of the text.

Problem 5
It is quite apparent that the success rate of task 3 was rather low by looking at the table 4.1, thus one can conclude that there is a significant problem in the design that prevents efficiency in completing the task. If one examine the thinking out loud thoughts and observations recorded from task 3, one will notice that the design of the time line caused confusion.

- **Solution A)** Add more programs to the TV guide, so that it is not just two columns.
- **Solution B)** Add more time text to the top of the time line.
- **Solution C)** Make horizontal lines that should more clearly show which programs pertains to the various channels.
- **Solution D)** Make vertical lines that should more clearly show which time a program starts.

**Chosen solution(s) to problem 5:** Solution A, B, C and D were all implemented to make the design of the TV guide more intuitive.
Problem 6
Several test participants expected to find the TV guide adjacent to the channel list beside the screen.

- Solution A) Add a button next to the channel list with the possibility to open the TV guide so it appears besides the screen.

Chosen solution(s) to problem 6: No solution was implemented, due to the problem was not considered severe enough that it was worth spending the time necessary to implement the solution.

Problem 7
Task 4 was completed rather quickly by almost everyone of the test participants. However, two participants failed to accomplish the task, whereas one participant, which was not Swedish, did not complete the task due to him not knowing what SVT Play was, and since there were only icons and no text he could not find it.

- Solution A) Add pertaining text to the Web TV channels.

Chosen solution(s) to problem 7: Solution A) was implemented.

Problem 8
The arrow buttons for changing films / Web TV program had different colours for the different directions, which was misinterpreted with that the darker coloured button implied that the list of films were empty in that direction.

- Solution A) Make the arrow buttons the same brighter colour.
- Solution B) Make the button, in the direction that the film list is empty, not visible.

Chosen solution(s) to problem 8: Both solutions A) and B) were implemented to prevent unnecessary waste of time due to misinterpreting the buttons.

Problem 9
Task 5 was the only task which everyone of the test participants did succeed in accomplishing. However, several participants accidentally clicked one of the items (New, Top, Downloaded) in the middle menu, and a few of these also did this unknowingly.

- Solution A) Extend the fusing time for click.
- Solution B) Reposition the menu with New, Top, Downloaded so it is not as easily clicked by accident.
- Solution C) Change or enhance feedback of clicking a menu item.
- Solution D) Add sound for click.

Chosen solution(s) to problem 9: Solutions A) and B) was implemented to prevent accidental clicks when navigating the user interface in general and more specifically for the second top menu. Solution D was implemented so that accidental clicks would not go unnoticed.

Problem 10
What prevented the test participants from accomplishing the 6th task with ease was the colour for an active setting was orange and there was no icon to further imply if something is active.
• **Solution A)** Change the colour of active to green and inactive to red. Also add icons for on and off.

**Chosen solution(s) to problem 10:** Solution A) was implemented to more clearly display when something is active or not, and give appropriate feedback to switch activeness.

**Problem 11**
For the 7th task, the test participants expected to find the category text on the box of each program, and not have to choose category in the menu at the bottom.

• **Solution A)** Add category text next to the name of the program for each box.

**Chosen solution(s) to problem 11:** Solution A) was implemented so that the users would be able to faster see what category a program had.
4.5 Implementation of second prototype

The solutions that were found and chosen were implemented in the refinement of the first prototype in order to attain the second prototype. In figure 4.29, one can see the results from the chosen solutions to problem 1 and 2. The indication bar was redesigned and repositioned beneath the selected channel. The icons for the buttons for changing channels were exchanged to look more like click-able buttons.

![Figure 4.29: Design of the screen and the channel list for the second usability tested prototype](image)

In figure 4.30, one can see that now when a channel is clicked in the channel list, the position of the channel list will not change, but the indication bar will. Furthermore, the appearance of the indication bar has changed and been repositioned beneath the selected channel.

![Figure 4.30: Channel list no longer moves when channel is clicked](image)
4.5. Implementation of second prototype

In figure 4.31, it is shown that when the channel arrows are clicked, the channel list will still change position.

![Figure 4.31: Channel list moves when scrolling button is clicked](image)

It is displayed in figure 4.32 that the category boxes and their pertaining text have been enlarged and its position raised upwards. The fuse time for a click was increased from 700 ms to 1000ms too further prevent misclicks due to that it would seem that the short fuse time caused accidental clicks.

![Figure 4.32: Design of the film selection for the second usability tested prototype](image)
In figure 4.33, it is apparent that the second top menu, with the New, Top and Downloaded menu items have been moved down and to the left.

![Figure 4.33: Second top menu repositioned to the left of menu item windows](image)

In figure 4.34, it is shown when one has gone too far to the left and the film list is empty. The opacity of the left button is greatly reduced and the thumbnail boxes also show that the list does not have any more film titles to the left.

![Figure 4.34: Scroll button fades when film list runs out of films](image)

In the TV guide, the second top menu, with Today, Tomorrow and Calendar, have also been moved down and to left of the main content, as can be seen in figure 4.35. The design of the time line has received a very different look from before. Now it has more apparent vertical bright lines to clearly display time, and horizontal planes to more clearly show which programs belongs to what channel. Furthermore, categories for each program have been
pertained. They have all received different colours to more clearly indicate their difference. These colours have also been added to the text of each category box in the bottom of the content window.

Figure 4.35: Design of the TV-Guide for the second usability tested prototype

In figure 4.36, one can see when a category is selected, all programs that will belong to that category will be highlighted.

Figure 4.36: Highlighted programs of selected category
There is now a different button for scrolling the channel list, and it is only displayed if there are more channels in that direction in the channel list, which is seen in figure 4.37.

![Figure 4.37: Channel list scrolling buttons](image)

The second top menu, with New, Top and Watched have been repositioned to the left, as shown in figure 4.38.

![Figure 4.38: Second top menu repositioned](image)

In figure 4.39 one can also see that the Web TV channels have been moved to the right to give room for the second top menu. Furthermore, the Web TV channels now also have pertaining text.
4.5. Implementation of second prototype

There is now a green icon that indicates that a setting is active. This can be seen in figure 4.40.

If one hovers over an activated setting it will display a red colour to indicate that it soon will turn inactive, which can be seen in figure 4.41.
Figure 4.41: Turning off an active setting
4.6 Usability test and assessment of second prototype

In both the usability tests the test participants were given a questionnaire, that consisted of four sections which were shown in figures 3.1 to 3.4. The questionnaire were answered by the test participants by checking one of five check boxes, that each represented a value. The check boxes were valued with 1 to 5, where 1 represented "Not at all", and 5 meant "Very much so". The average of the test participants answers for each usability test and their difference were calculated and is shown in the table 4.2. As one can see from the table, the test participants answers to the second usability test reported a 11% better result to if they found it easy to find what they were looking for, compared with the first usability test. The results for the ease of making of selections was increased with 19%, and the ease of navigation was increased with 23.5%. The adverse results found when comparing the results between the two questionnaire answers were that the results to the question about experiencing physiological discomfort was increased by 8.7% in the second usability test, as well as the experience of the velocity of making selections had decreased with 8.6%.

<table>
<thead>
<tr>
<th>Questionnaire question</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>How familiar are you with using VR products?</td>
<td>1.9</td>
<td>1.8</td>
<td>-0.1 (-5.3%)</td>
</tr>
<tr>
<td>How familiar are you with using web applications?</td>
<td>4.7</td>
<td>4.7</td>
<td>0</td>
</tr>
<tr>
<td>Did you find it easy to find what you were looking for?</td>
<td>3.7</td>
<td>4.1</td>
<td>+0.4 (+11%)</td>
</tr>
<tr>
<td>Did you find the aesthetics of the design visually pleasing?</td>
<td>3.5</td>
<td>3.7</td>
<td>+0.2 (+5.7%)</td>
</tr>
<tr>
<td>Did you find the making of selections easy?</td>
<td>2.6</td>
<td>3.1</td>
<td>+0.5 (+19%)</td>
</tr>
<tr>
<td>Did you find the making of selections fast and not frustrating?</td>
<td>3.5</td>
<td>3.2</td>
<td>-0.3 (-8.6%)</td>
</tr>
<tr>
<td>Did you find it easy to navigate in the user interface?</td>
<td>3.4</td>
<td>4.2</td>
<td>+0.8 (+23.5%)</td>
</tr>
<tr>
<td>Did you experience any physical discomfort?</td>
<td>1.7</td>
<td>1.8</td>
<td>+0.1 (+5.9%)</td>
</tr>
<tr>
<td>Did you experience any physiological discomfort?</td>
<td>2.3</td>
<td>2.5</td>
<td>+0.2 (+8.7%)</td>
</tr>
<tr>
<td>Did you experience any environmental discomfort?</td>
<td>1</td>
<td>1.1</td>
<td>+0.1 (+10%)</td>
</tr>
<tr>
<td>Did you notice a low fps or lag while using the user interface?</td>
<td>3.4</td>
<td>3.4</td>
<td>0</td>
</tr>
<tr>
<td>Did a low fps affect your opinion negatively of the user interface?</td>
<td>3.1</td>
<td>3.44</td>
<td>+0.34 (+11%)</td>
</tr>
</tbody>
</table>

Table 4.2: Comparison of questionnaire answers

In table 4.3 one can see the test participants answers to the more general questions about VR TV platforms.

<table>
<thead>
<tr>
<th>Questionnaire question</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you think it is likely that VR TV platforms will be commonly used within 5 years?</td>
<td>3.3</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>How likely do you think it is that you would be an early adopter to a VR TV platform product?</td>
<td>2.45</td>
<td>2.1</td>
<td>2.275</td>
</tr>
<tr>
<td>What impact would the lack of social interaction in a VR TV platform have for you?</td>
<td>3.3</td>
<td>2.2</td>
<td>2.75</td>
</tr>
</tbody>
</table>

Table 4.3: Curio questionnaire answers

Thinking out loud comments and observations

The second prototype that was produced in section 4.5 was, just like the first prototype, usability tested. The thinking out loud comments and remarks were also in this test written down for each task and test user. These comments together with the observations made by me as a test moderator are summarised and stated as below for each task.
Task 1: Switch to channel 1, then switch to channel 7, 6, 5, 4, 3, 2.
Comments and observations:

- Difficulties to aim at the channel buttons since they were a bit small and the cursor was rather shaky.
- The colour of the indication box is almost the same colour as a channel highlighted. Would have made it difficult to see that a specific channel was selected if the video box to the right gave feedback.
- The channel arrows were often ignored.

Task 2: Find and play the new drama film with poster name Woody Allen (title text: film-drama1).
Comments and observations:

- The hover text was a bit small and it was confusing that it was just beneath the hovered film, instead of being in the middle.
- A few times the top menu with the five icons was ignored at first since they did not see the film icon.
- The Web TV icon was seen before they saw the Film icon and was chosen a few times.
- Looked for a search box in which they wanted to search for Woody Allen.

Task 3: Find the program number of the program that starts at 10:00 today at channel 6.
Comments and observations:

- Remains from previous prototype: The TV guide is expected to be found next to the channel list and screen.
- The button to scroll the channel list in the TV guide was too small.
- The icon in the top menu was a little unclear if it was TV guide.

Task 4: Find and play the first program you see in the Web TV channel SVT play.
Comments and observations:

- Would like the text of each Web TV channel to be beneath the channel instead of above.
- A few were a bit uncertain that they were in fact in the Web TV window when they had selected from the top menu. Would like title text "Web TV" above the window.
- Would like a different icon for Web TV that was less alike the Film icon in the top menu.
- Was perplexed that the channel list in the Web TV window was to the right when the other menu options were to the left.

Task 5: Find and play the Top animated film with the title text "filmanimated1".
Comments and observations:

- Would have wanted the category boxes to be positioned just beneath the Top menu.
- Would have wanted more space between each category box.
- Wanted a "go back" button, to show the previous window.
• Would have wanted sound feedback for the category selection as well.
• Would have wanted to bend the neck less to reach category boxes.

**Task 6:** Turn off the transparent background.

Comments and observations:
• Since it is possible to see the Settings window in the periphery to the left, one test participant turned the neck, instead of clicking the top menu icon.
• Would have wanted the buttons for on and off to be a bit larger.

**Task 7:** Determine which of the channels 1-5 that have weather programs at 10:00 today.

Comments and observations:
• The colours of the text for categories News and Film were too alike.
• Thought the category text in each program box was a bit too small.
• Thought there were too many different colours.

**Assessment of the second usability test results**

The time results from the second usability test are shown in table 4.4. Also in this table, a red coloured cell implies that the test participant failed to complete a specific task. An orange coloured cell means that the test participant resigned while conducting the task. Furthermore, the average time that is displayed in the last row is calculated from the tasks that the test participants did neither fail to accomplish or resigned when trying to do so.

<table>
<thead>
<tr>
<th>Maximum time for success</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Task 5</th>
<th>Task 6</th>
<th>Task 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test participant 1</td>
<td>84s</td>
<td>100s</td>
<td>40s</td>
<td>58s</td>
<td>70s</td>
<td>20s</td>
<td>50s</td>
</tr>
<tr>
<td>Test participant 2</td>
<td>26s</td>
<td>49s</td>
<td>33s</td>
<td>27s</td>
<td>100s</td>
<td>17s</td>
<td>17s</td>
</tr>
<tr>
<td>Test participant 3</td>
<td>21s</td>
<td>27s</td>
<td>29s</td>
<td>16s</td>
<td>33s</td>
<td>8s</td>
<td>13s</td>
</tr>
<tr>
<td>Test participant 4</td>
<td>47s</td>
<td>Resigned</td>
<td>29s</td>
<td>39s</td>
<td>41s</td>
<td>12s</td>
<td>24s</td>
</tr>
<tr>
<td>Test participant 5</td>
<td>42s</td>
<td>Resigned</td>
<td>31s</td>
<td>13s</td>
<td>20s</td>
<td>10s</td>
<td>16s</td>
</tr>
<tr>
<td>Test participant 6</td>
<td>26s</td>
<td>Resigned</td>
<td>42s</td>
<td>36s</td>
<td>50s</td>
<td>15s</td>
<td>30s</td>
</tr>
<tr>
<td>Test participant 7</td>
<td>41s</td>
<td>39s</td>
<td>18s</td>
<td>13s</td>
<td>15s</td>
<td>10s</td>
<td>11s</td>
</tr>
<tr>
<td>Test participant 8</td>
<td>22s</td>
<td>55s</td>
<td>20s</td>
<td>50s</td>
<td>45s</td>
<td>15s</td>
<td>38s</td>
</tr>
<tr>
<td>Test participant 9</td>
<td>17s</td>
<td>97s</td>
<td>16s</td>
<td>16s</td>
<td>23s</td>
<td>13s</td>
<td>15s</td>
</tr>
<tr>
<td>Test participant 10</td>
<td>35s</td>
<td>39s</td>
<td>31s</td>
<td>28s</td>
<td>23s</td>
<td>11s</td>
<td>34s</td>
</tr>
<tr>
<td>Total average time</td>
<td>32.6s</td>
<td>48.7s</td>
<td>27s</td>
<td>25.7s</td>
<td>40.7s</td>
<td>12.1s</td>
<td>23.7s</td>
</tr>
</tbody>
</table>

Table 4.4: Time results from second usability test

In table 4.5, one can see the difference of the results between the two usability tests. A green coloured cell implies that the average time passed for accomplishing a task in the second test is less than the average time passed in the first test. Thus, a green cell is favourable and means that the result is better in the second usability test. A red coloured cell implies the exact opposite; that the average time for accomplishing a task is higher for the second usability test. One can see that the results are almost exclusively favourable, except for the time results to Task 5. What is indubitably the best result for Task 3, where the average time spent trying to accomplish it has decreased with 37.25 seconds.
4.6. Usability test and assessment of second prototype

<table>
<thead>
<tr>
<th>Task</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average time in seconds in test 1</td>
<td>41.2</td>
<td>62.1</td>
<td>64.25</td>
<td>26.3</td>
<td>23</td>
<td>16</td>
<td>42.3</td>
</tr>
<tr>
<td>Average time in seconds in test 2</td>
<td>32.6</td>
<td>48.7</td>
<td>27</td>
<td>25.8</td>
<td>40.7</td>
<td>12.1</td>
<td>23.7</td>
</tr>
<tr>
<td>Difference:</td>
<td>-8.6</td>
<td>-13.4</td>
<td>-37.25</td>
<td>-0.5</td>
<td>+17.7</td>
<td>-3.9</td>
<td>-18.6</td>
</tr>
</tbody>
</table>

Table 4.5: Time results comparison of the usability tests

The number of test participants that resigned when conducting the various tasks in the usability tests are compared and displayed in table 4.6. Two tasks got favourable results. For Task 3, the number of test participants that resigned decreased with two, and for Task 4 the quantity decreased with one. Task 2, did however get an unfavourable result, because the number of test participants that resigned in the second usability test was one more than for the first usability test.

<table>
<thead>
<tr>
<th>Task</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of resigned in test 1</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of resigned in test 2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Difference:</td>
<td>0</td>
<td>+1</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4.6: Number of resigns comparison

We can see from the results in table 4.7 that the number of times that test participants have exceeded the maximum time limit when conducting the tasks has significantly decreased. Only for task 5 was the number of failures higher in the second usability test. The total amount of failures decreased with 9 for the second usability test, and could thus be considered as a very favourable result.

<table>
<thead>
<tr>
<th>Task</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of failed in test 1</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Number of failed in test 2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Difference:</td>
<td>-1</td>
<td>-1</td>
<td>-6</td>
<td>-1</td>
<td>+1</td>
<td>-1</td>
<td>-3</td>
</tr>
</tbody>
</table>

Table 4.7: Number of fails comparison

In the assessment of the first prototype, only the most severe and the most easily solved problems were listed, discussed and given suggested solutions to. However, in this iteration all problems identified will be listed, and not only the most severe and easily solved problems. Moreover, in this assessment of the second prototype, solutions to the problems identified will not be implemented, but only suggested. Therefore, in this case, all the problems that were identified will be listed and given suggested solutions to. Although, none of the solutions will actually be implemented.

**Problem 1**

Difficult to aim at the channels since they are a bit small and the cursor is rather shaky.

- **Solution A)** Increase the height of the channel boxes.
- **Solution B)** Make the cursor smaller.
Problem 2
The buttons for changing channels were often not recognised as buttons that could be clicked.

- **Solution A)** Choose another icon for the buttons.
- **Solution B)** Remake the shape of the arrow buttons.

Problem 3
The colour of the indication box is almost the same colour as a highlighted channel.

- **Solution A)** Change the colour of the indication box.
- **Solution B)** Change the colour of the highlighting.
- **Solution C)** Remove the highlighting.

Problem 4
The hover text was a bit small and it was confusing that it was just beneath the hovered film, instead of being in the middle.

- **Solution A)** Position the hover text just beneath the film that is being hovered.
- **Solution B)** When hovering over a thumbnail, temporarily change the large film poster and its title to that specific thumbnail film.

Problem 5
A few times the top menu with the five icons were ignored at first since they did not see the film icon.

- **Solution A)** Add pertaining text to each button in the top menu.
- **Solution B)** Make the top menu more apparent by enlarging it.
- **Solution C)** Reposition the top menu to a position beneath the screen.

Problem 6
The Web TV icon was seen before they saw the Film icon and was chosen a few times.

- **Solution A)** Change the icon to Web TV to icon that is similar to the TV4 play icon, which also contains the PLAY text.

Problem 7
A few test participants looked for a search box in which they wanted to search for Woody Allen.

- **Solution A)** Add a search box.

Problem 8
Some considered the button, used to scroll the channel list in the TV guide, too small.

- **Solution A)** Make the scroll button bigger.

Problem 9
The icon in the top menu was not recognised as a TV guide for everyone.

- **Solution A)** Add pertaining text to each of the top menu buttons beneath each button.
- **Solution B)** Add pertaining text to each of the top menu buttons above each button.
Problem 10
Some had difficulties understanding if a Web TV channel’s title text was positioned beneath or above the TV channel.

- **Solution A** Add additional space between each Web TV channel, and place the text beneath and close to the Web TV channel.

Problem 11
A few were a bit uncertain that they had in fact navigated to the Web TV window when they had selected the Web TV button in the top menu.

- **Solution A** Bring back each menu item’s title above its window (i.e. add the title text “Web TV” above the Web TV window).

Problem 12
Was perplexed that the channel list in the Web TV window was to the right when the other menu options were to the left.

- **Solution A** Place beneath the second top menu, with the New, Top, and Watched.

Problem 13
A few experienced it to be difficult to choose a category since there was not a lot of space between each category box.

- **Solution A** Increase the space between each category box.

Problem 14
There was no “go back” button, to show the previous window.

- **Solution A** Add a go back button that brings you back to the previous selected menu window.

Problem 15
Would have wanted sound feedback for the category selection as well.

- **Solution A** Make all user interface objects trigger a sound feedback.

Problem 16
Would have wanted to bend the neck less to reach category boxes.

- **Solution A** Reposition the category boxes to be just beneath the Top menu.
- **Solution B** Reposition the category boxes to be to the right of the window instead.

Problem 17
Since it is possible to see the Settings window in the periphery to the left, one test participant turned the neck, instead of clicking the top menu icon.

- **Solution A** Move the Settings window counter clockwise in the circle background.
- **Solution B** Make the radius of the circle background longer.
- **Solution C** Make the circle background to an elliptic background.

Problem 18
The buttons for on and off could be hard to aim at since they were small

- **Solution A** Make the buttons wider.
- **Solution B** Increase the size of the buttons.
Problem 19
The colours of the text for categories News and Film were too alike.

- **Solution A)** Change the colours so that the colour of News are much brighter than the colour of the Film.

Problem 20
Thought there were too many different colours.

- **Solution A)** Remove the colours and have all categories in white text.

Problem 21
Some test participants had difficulties distinguishing the category text in each program box.

- **Solution A)** Increase the size of the text.
- **Solution B)** Reposition the category text in the program box.
- **Solution C)** Replace the full text with a big capital letter of the first word of each category.
- **Solution D)** Remove the category text in each program box.
5 Discussion

5.1 Results

A-Frame was an embryonic framework at the time this project was executed. As a result of this, much time was spent on trying to find solutions to issues that I thought existed due to inadequacies in my own code. However, in multiple cases these issues were in fact because of faults in the framework’s builds. The builds of the framework that were available were altered very frequently. An example of a result of this was that various components would all of a sudden not function properly, because a build would just have been updated. I would then have to use another build, which, would result in other components not functioning properly.

The professionals consulted when deciding on which concept of design to pursue, in 3.3, were much aware of what purpose the prototype would have, and they both also had multiple years of work experience in the development of products and user interfaces. Therefore they would be able to give valuable feedback on what concept would be feasible to create an actual prototype of. However, since the prototype in this thesis work is supposed to be created in WebVR (A-Frame) and at the time the work was started there were not many advanced user interfaces made in WebVR. Therefore it would be difficult, even for experienced professionals, to determine what features or design would be feasible to create using this API.

After having made the first screen in A-Frame I experienced major performance issues. This, I believe, was mostly due to that WebVR is extremely demanding and I was viewing the prototype in a Gear VR headset with a Samsung Galaxy S6, and not on any of the more high performance capable HMDs that are running on a desktop computer’s hardware. This forced me to not only adapt the design to what was actually possible to do with this newly developed framework, but also to adapt the design so that it would demand as little performance as possible. For example, I had to settle for only displaying a picture of a selected film instead of having an actual video player that played the videos, due to video playing was too performance demanding.

When the phone was plugged into the Gear VR headset, Oculus home and its accompanying software was started, which included the Samsung internet browser. When launching the web application in this browser, both the picture quality and the frame rate was extremely
low, which made it intolerable to use. Thus, I had to prevent Oculus home from starting and use a different web browser that was compatible with WebVR. This meant that one could not use the tap-pad on the side of the Gear VR, which was disappointing since it could have been interesting to compare the fusing click with the tap click.

In the theory section about Virtual Reality 2.1, there is information about the components which the Gear VR headset uses to increase motion stability and to reduce head tracking latency. Since it was not eligible to have an active Gear VR in the usability tests conducted, there was no additional hardware to increase motion stability and reduce head tracking latency. Because of this, the cursor was experienced as very “shaky”, which is repeatedly commented about in the usability tests. Furthermore, this issue made it more difficult to aim at specific user interface objects. Therefore, it is possible that the results from the usability tests would have been very different if a Gear VR would have been utilised.

I had only access to one VR HMD more advanced than a basic cardboard headset, the Gear VR. Thus, I was limited to the performance delivered by the Gear VR and the mounted Samsung Galaxy S6. Although, the Gear VR could not be utilised, as just described. This lead to many issues with performance and spending much time to correct these, in order to even be available to conduct user tests without causing the test participants severe nausea due to extremely low frame rates.

In the result chapter, in section 4.6, table 4.2 showed the comparison of the results from the questionnaire. For Test 1, the test participants answers to the question “Did you find the making of selections fast and not frustrating?” resulted in an average value of 3.5. For Test 2, the results for the same question was 3.2. A low value represented "Not at all", and a high value represented "Very much so". Thus, this meant that the test participants in the second usability test experienced the making of selections not as fast as the participants in the first test. Furthermore, the figure also shows that in the first usability test the results to the question "Did you find the making of selections, easy?", the test participants in the first test answered in average a 2.6. Whereas in the second usability test, the test participants answered a 3.1. The making of selections was consequently experienced as more easy in the second usability test, but not as fast as in the first version of the prototype. This result I believe is much because of the change of fusing time between the two usability tests. For the first version of the prototype the fusing time was set to 700 ms, but was increased to 1000 ms as part of a solution to a problem found in the first usability test.

The table with the comparison of the results from the questionnaire also showed that in the first usability test the average value that the test participants answered to the question “Did you find it easy to navigate in the user interface?” was 3.4. In the second usability test the value was 4.2. This means that the test participants experienced ease of navigation was increased with 23.5% to the second version of the prototype. A higher ease of navigation could also be gathered from the table as the difference of time used to accomplish the tasks have significantly decreased. The improved results would most likely be a result of the solutions implemented in the implementation of the second prototype, shown in section 4.5. It is highly unlikely that the improved results would be due to the swap of test participants between the two tests. This is because the characteristics of the first and second test participant groups did not differ much. The test participants in both the first and second usability test answered on average a 4.7 to the question “How familiar are you with using web applications?”. Moreover, on the question “How familiar are you with using VR products?” the first group of test participants answered a 1.9 to, on average, which is 0.1 higher than the average the second group of test participants answered.

The time results displayed in table 4.5 showed that the average time it took accomplish
5.1. Results

Task 5 in the first usability test was much lower than the average time of the second usability test. However, this I strongly believe was because a mistake made by me as a test moderator. The original task assignment had been "Find and play the top animated film with the title name ‘filmanimated1’". However, in the first usability test, when the task assignment was written down on paper I wrote the task assignment as "Find and play the first animated top film". Oblivious of this error I had made, I produced new task assignment papers for the second usability test, but this time with the actual original task assignment. Because of this error, the time results for this task was significantly worse in the second usability test. This was because the test participants in the second usability test had to scroll in the film list in order to accomplish their task, whereas to accomplish the task in the first usability test it was enough to play the first top animated film one saw.

It was stated by quite a few of the test participants that they had difficulties distinguishing words in text, or noticing smaller user interface objects. At the same time, some test participants had no difficulties at all with distinguishing text or detecting objects. Thus, there was a great difference between how smaller user interface objects were experienced by the various test participants. One easy solution would have been to enlarge every smaller user interface object and make them more easily distinguishable. However, it is at the same time important to keep user interface objects within the comfortable zone, so one does not have to turn the neck uncomfortably much. Thus, there is a trade-off that must be made when setting the size of the user interface objects.

Sound, in form of auditory feedback to clicks, was added to the second version of the prototype. However, in the second usability test very few accidental clicks were made, which most likely was due to an increased fusing time, and also because specific user interface objects had been repositioned. Because of the very low number of misclicks, it was difficult to distinguish how well the auditory feedback worked with preventing accidental clicks to stay unnoticed. Although, I am confident to say that the auditory feedback made the test participants more aware of when a click was executed or not, which is very important when one makes a selection with time based fuse click. Furthermore, an auditory feedback could easily get tiresome with time, and should thus come with the option to turn it off when one is more accustomed to the user interface.

In the beginning of making the design for the user interface I added a sky box which was a picture portraying the view from the top of a mountain. I had not intended to keep this, since in the theory chapter, in section 2.3, it was advocated to not create an environment with high heights since this causes environmental comfort. However, I wanted to conduct at least one usability test with an environment with high heights, so I kept the sky box as it was and used it in the first usability test. To not make it appear like the user is floating in mid air, I added a small circular deck in the middle of the user interface, which would be where the user would be positioned. Everyone of the test participants in the first usability test answered a 1 to the question "Did you experience any environmental discomfort? (e.g. fear of heights)". Consequently, no one experienced fear of heights, despite an environment that is at an obvious high height.

What was apparent from the usability tests were that time based fuse click could generate stress for the test participants and make them more careful in their navigation within the user interface. Some of the test participants were afraid to move the cursor over areas which contained click able user interface objects, because of the cursor starting to fuse when its raycaster intersected objects. Some test participant would want longer fusing time for the click. However, this could make the user interaction significantly less efficient. Furthermore, since it was the first time experiencing a user interface in VR for the absolute majority of the test participants, it is no wonder that some did not feel so confident while navigating.
5.2. Method

Although, if one would want to design a VR user interface more adapted to new VR users, it could be appropriate to design the user interface so it contains "transportation routes". These "routes" could be areas free of click able objects that the test participants can move the cursor over, without being afraid of clicking anything by mistake.

5.2 Method

If I would have had access to a Oculus Rift CV1, powered by a powerful computer with a graphic card in the upper bracket, I am quite certain that I would not have had to spend so much time to correct issues correlated to performance demands. WebVR/A-Frame is very demanding in computational resources, and the hardware to power a web application in WebVR needs to be able to handle high performance demands. Therefore, I believe that I would most likely not have encountered the same performance issues if I instead of creating a web application with WebVR/A-Frame would have used Unity to create a virtual reality user interface for a native Android application. Furthermore, the visual editing tool I used while designing the prototype was very difficult to use for the early builds of A-Frame and did often not work properly. Thus, ridiculously much time was spent trying to just get a reasonably acceptable appearance of the design of the user interface, since just positioning basic user interface objects could be problematic. If I instead would have used Unity, the design phase would probably had progressed much faster since Unity has a much more stable and advanced design editor made for creating 3D environments.

In the usability tests, the efficiency of accomplishing the various tasks were measured. However, what was not evaluated was the user experience of using the user interface freely, without any specific tasks to accomplish and without any time pressure. I believe that conducting such usability tests could also be valuable in order to determine how usable a user interface is. Considering there is more to user experience than just the efficiency of the navigation and the making of selection within the user interface. Some solutions to the problems found in the usability tests could have been shaped in another way if additional usability tests, without specific tasks, would have been conducted. Furthermore, it is questionable if only ten participants per usability test would be enough to yield valuable results. However, the most severe problems are most likely all found in the usability tests even if there are only 10 participants. Since there were only time to implement the solutions to the most severe problems, I would not consider the number of usability test participants as an issue.

The usability tests conducted on the two versions of the prototype did not evaluate only the design of the user interface that was directly correlated to a virtual reality environment. The tests also evaluated "trivial", non-VR related things within the user interface, such as the appearance of icons and colours. Solutions were made to correct the problems with the non-VR related things, as well as for the problems that were correlated with VR. Because of this, it is hard to determine how large the positive affect of the change of the design that was a result to the solutions implemented to VR related problems. To get a more accurate evaluation of the VR related problems to the user interface, should perhaps only design that was strongly related to VR have been altered between the two usability tests. Although, the demand of high usability in general for the prototype produced in this thesis work aggravated this.

The questionnaires, given to each test participant after each test session, contained questions of e.g. what they disliked with the user interface. These questions were answered very briefly in text, and quite often the sentences in the answers of the questionnaires had already been uttered while the test participants thought out loud, or wanted to discuss after having
completed all the tasks. Thus, I would say that having a questionnaire with questions about issues with the user interface was redundant, and should perhaps be replaced with a formal discussion with the test participants instead, where the test moderator takes notes of the comments the test participants make. Moreover, some of the questions in the questionnaire may have also been easily misinterpreted. If the questions would have been reformulated so that they would have been more easy to to not misinterpret, it is possible the results from the questionnaire would have been different and perhaps given a more reliable result.

The maximum time to be counted as successful for each task completion was determined from the time it took for an experienced VR user to accomplish each task in the usability tests. However, since this determination of the maximum time limit depended on just one person, the human factor has an impact of the appropriateness of the maximum time set for each task. Perhaps I would have received more appropriate maximum time limits if I would have estimated a time limit, for each task individually, from what would seem reasonable for each specific task. Or perhaps, a better way could have been to let the first test participant use Eagle, the company’s own TV platform, and perform equivalent task and record the time it took. This time times a factor could then have been a better value to compare with or have as maximum time for each task.

Replicability
Since there is a design process in this thesis, it would be almost impossible to get the same design results, even if one redoes the same study and follows the method scrupulously. However, getting equivalent results e.g. when it comes to where to place and not place user interface objects within a virtual reality environment to attain high usability would be more likely.

Reliability
In this thesis all work is done by only one person. This means that it is almost inevitable to not get the research tainted by personal bias. In the user tests, there was only one test moderator that simultaneously monitored, listened to the test participants thoughts, and took notes. This means that it is likely relevant information were disregarded or were just not noticed by the test moderator. After the usability tests the results were assessed and the issues with the design were identified and listed. This problem identification could have had a different result if another person would have done it. It is possible that issues with the design actually experienced by the test participants in the user tests were overlooked, but would perhaps not have been so if someone else did the problem identification. Furthermore, it is almost certain that the various solutions that were suggested to the identified problems would have been different if there was another person suggesting these.

Validity
Since my goal was to get a product with high usability I tried to correct all issues with the design of the user interface, and not only those that were correlated to virtual reality. Thus, the design changes made after the first usability test did not only depend on the user interface objects that were correlated to virtual reality. It was most likely also affected by e.g. changing the appearance of the buttons etc. Therefore, it is hard to determine how the design changes that were correlated to virtual reality affected the product, respectively how all the design changes affected the user interface.
Source criticism

The scientific research on VR is limited, especially the scientific research that is up to date with the latest technology. Because of this, several references in this paper have little to no scientific proof, but is still information that skilled professionals, with work experience in highly respected companies, have acquired through their research outside the academic world. This information will thus still have great significance to the research conducted in this thesis project.

5.3 The work in a wider context

One may discuss whether it is ethical or not to develop tools for minimising the effort in navigating and making selections while using a technical product. Perhaps it would be more morally reprehensible to evaluate other tools that are more physically demanding than just turning your head for navigating and making selections. Having to only to turn your head for user interaction could potentially make people more physically inactive. In a world where most people are not being nearly as physically active as they should be to be healthy, there is clearly a need to physically activate these people. Thus, more research should perhaps be conducted in how to form an efficient user interaction where the user is also being physically activated. At the same time, research of efficient user interaction using just one’s head, as conducted in this thesis could be beneficial for people that are paralysed from the neck down, or for some other reason cannot move anything but their head. Paralysed people could, for example, become less reliant on care givers if there is an efficient way for them to use software, watch TV, and play games. More of this kind of research may in fact make everyday life significantly more enjoyable for people with reduced physical freedom.

Another ethical aspect correlated to the virtual reality prototype produced in this thesis work to consider is the social aspect. Today, many people come together in front of the TV and socialise while watching. If people started using more products like the prototype in this thesis, it could perhaps have a negative affect on the social life of its users and their relatives. The users vision are limited to the HMD they have on, and there would no longer be a need to sit next to each other in front of the TV. These things could lead to less social interaction. Therefore, if virtual reality TV-platforms should become popular in the future, I believe there could be a need to find out a solution to making it more socially integrable.
So, how to design a user interface in WebVR to facilitate efficiency in making selections with only a Samsung Gear VR headset? The results in this thesis, in terms of usability in VR, confirms a few things that may be regarded as already known information. Furthermore, the results from this thesis are mostly relevant to virtual reality user interfaces that utilises time based fuse click.

Some people seem to have problem with the vision when using a VR HMD and consequently difficulties with distinguishing smaller user interface objects. Smaller sizes of the user interface objects that the designer might feel comfortable with, may in fact be experienced as way too small for some users. This applies especially much to text objects. Therefore, it could be wise to design small user interface objects a bit larger in size than one would normally do. Although, at the same time, space is scarce within the comfortable zone in VR and it is naturally important that the user interface objects are not too large so they take up valuable space within the user interface. Thus, it is crucial to carefully consider the size of the user interface objects. One also has to make an important trade-off when it comes to taking up valuable space within the user interface and having enough space between the clickable user interface objects, so that one does not easily misclick.

Clickable user interface items should be placed so that they are not in the way of a navigation path that is often taken within the user interface. This is to prevent these user interface objects from getting accidentally clicked, but also to reduce the anxiety of the users moving the cursor and being afraid of unintentionally clicking something. Having a time based fuse click seems to be generating stress for the users, and thus it is important to make "navigation paths" within the user interface where the users may feel free to navigate without hesitation.

The anxiety experienced by the test participants of making unintentional clicks was also a result of how fast the fusing time was for a click to be executed. Thus, when setting the fuse time, it is important to consider that a faster time makes the users more stressed and also makes it more difficult to make a selection. Although, a too long fuse time makes the users experience frustration since the making of selections are too slow. From the results of the usability tests, one could interpret that the fuse time should for best results, in concern
6.1. Future work

to efficiency and mitigation of frustration, be between 1000 ms and 700 ms but also closer to 1000 ms than to 700 ms.

Auditory feedback indicates clearly to the user that something has been chosen so that neither accidental clicks passes by unnoticed, nor does it cause confusion whether the click was acknowledged. Auditory feedback is thus especially important to utilise in a user interface where the user makes a selection with time based fuse click. Although, some users may find auditory feedback very irritating, and should therefore be an optional feature that could be inactivated by choice.

A virtual reality environment with high heights did not seem to have a significant negative effect, as was proclaimed in the theory chapter. At least not for the test participants in the usability tests conducted with the prototype produced in this thesis work. However, an important factor to why the test participants were not negatively affected was most likely due to that they had a small platform beneath them in the virtual environment so they did not appear to be floating. Thus, I think it is possible to draw the conclusion that having a virtual environment with high heights does not necessarily have such a negative impact if one also has a decent sized platform to stand or sit on in the virtual environment.

In the usability tests the cursor was often experienced as very shaky. This was because of the lack of a functioning VR HMD with an IMU that would reduce head tracking latency and increase the motion stability. Therefore, to facilitate the making of selections and mitigate the problem with the shaky cursor, it would be important to set the size of the cursor so that the shivering would not be as prominent. A larger size of the cursor would make it appear as the cursor was trembling less, although a too large cursor would also make it more difficult to aim with. I find it difficult to determine exactly how large the cursor should be made, but I believe that it would be best to at least have the diameter of the cursor to be half the length of the height or width of the smallest object in the user interface. Furthermore, it is also important to choose the colour of the cursor to be one that does not occur within the user interface, so that the cursor will always be visible within the user interface.

If we set usability aside, the results from this thesis also give us some insight on the WebVR framework A-Frame. The results from this thesis show that it is difficult to achieve a smooth user experience in advanced user interfaces in web applications for smart phones developed in A-Frame. This was because of the framework being too performance demanding.

This thesis’ aim was to make a contribution to the research on usability in user interfaces in VR. The thesis has perhaps not yielded any new revolutionary discoveries. However, the thesis makes a contribution of scientific research that affirms previously known information.

6.1 Future work

For future work I would suggest evaluating and comparing different tools or techniques for navigating and making selections in Virtual Reality. For example, I would suggest a study in which one conducts user tests where one divides the test participants into several different user groups, where each user group uses a unique tool. Furthermore, each user group should also be divided into two sub groups. Whereas one should have people age 25-45, and the other should only consist of people age 46-66. These tools would include various types of handheld controllers, such as Xbox controller, TV-remote, smart phone, Oculus touch, but also motion trackers that tracks hands. More tools that could be evaluated in this research could be voice control and eye tracking. All test participants should then complete various tasks, and the results from each user group is compared to the other user groups. The research
could give insight in which tools that are best suited for efficiency in navigation and making selections in the younger generations, while another tool is found to be easier to use, and thus is preferred by the older. This could help companies in future development of virtual reality products target their audience group and in turn get a successful product.
Bibliography


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