SEE MORE IN VIRTUAL REALITY

Helping people to see objects outside their field of view

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ABSTRACT

This report describes VR, it's patterns and tools to see more. It starts of by explaining what Virtual Reality means and setting the boundaries for the project. It then continues identifying interaction patterns by covering papers, literature, blogs, interviews and researching actual VR applications on the HTC Vive, Google Cardboard and Playstation VR.

After this the direction towards guiding attention is taken as current Head Mounted Displays only allow to see what is in front while virtual worlds allow content all around.

Using the work from Stigchel, a theory for guiding attention is set up. Together with other resources, three tools are developed that guide attention to objects outside the field of view in unique ways. An arrow in the peripheral vision, organic lines in the background that converge on a certain point and an animated sphere that moves towards a point of interest.

These three tools are tested and evaluated; the arrow is most professional and effective, the animated object is most fitting in VR and very effective, while converging lines are very subtle and not always effective. Recommendations for their implementation are given in the report.

Three more tools are developed that do not necessarily guide attention to a specific point, but allow users to be more aware of interesting objects in their environment; a mirror ball that reflects everything behind the user, a radar that helps with orientation and shows points of interest and finally a birds-eye view that allows the user to see the virtual world from up high.

These tools are tested and compared with the guiding tools. It is found that participants do not have a preference for any one tool, but do prefer being guided towards an object of interest.

The mirror ball is least liked though because the reflection requires more thinking. It could be improved by making it more convex and filtering the image. The radar could be improved by showing distance to objects and showing map elements. The birds-eye view can be improved by showing a miniature world and filtering it so that points of interest are more apparent.

The report concludes with sketching a possible scenario in a chemistry lab in which each of the tool is demonstrated.

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1. INTRODUCTION

1.1 CHALLENGE

The oculus rift, announced in 2012 (kickstarter, 2012), has brought Virtual Reality(VR) back into the game. Since then the HTC Vive, Google Cardboard and Playstation VR have been introduced and several tech giants have been investing in Virtual Reality (Terdiman, 2015). Expectations for Virtual Reality are high and more than $2 billion has already been invested in developing VR in 2016 alone (DIGI-CAPITAL, 2016). Bellini et al (2016) report in a Goldman Sachs publication that they expect VR to be an 80 billion dollar market in 2025 with a possible 315 million users.

So experts are predicting VR to become big and in the coming year many developments to VR are to be expected. The expectations and possibilities with VR are high:

> ***"The combination of an infinite working volume with spatially organized tasks in an ideal environment result in people being both happier and more productive." Alger, 2015***

Now that hardware like the Oculus Rift, HTC Vive and Google cardboard (Funnekotter, 2017) have hit the market, VR is becoming more and more accessible. At the Dutch VR awards (appendix A.3) the consensus was that it is now up to the content creators to design good content for VR. These content creators are challenged with a medium that allows new and innovative ways of interaction. With the many developments for VR, interactions standards are still being developed (Oculus, n.d. –a).

This report explores a multitude of good and common interaction patterns for VR and then focuses on one challenge: guiding the attention of people in VR towards objects that are outside their field of view.

1.2 DESCRIPTION OF VR

In this report Virtual Reality, in short VR, is considered an immersive experience that uses a Head Mounted Display (HMD) to place a user inside a virtual world generated by a computer. By tracking the position and angles of a user's head, the correct visual representation of the world can be rendered. Head Mounted Display have one display for each eye. The tracking and separate rendering of images allows the immersant to look around the virtual environment and see depth (Alger, 2015).

A major difference with VR and conventional displays is that the image is no longer framed.
When Gibson (1979), a psychologist, writes about how we see the world he suggests that our vision is more than just snapshots; it is also ambient and ambulant. With

ambient the ability to look around with your head is signified and with ambulant the ability to move through a space.

Some VR sets also enable this by tracking movement through space (Playstation VR, Oculus Rift, HTC Vive). In that case, you can move and walk around in the virtual world. The parallax effect adds to the depth perception experience (Laurel, 2016).

Besides seeing and moving through a virtual world there are also possibilities to interact with this world. This can be done through conventional controllers or by capturing real hand motion as the Leap Motion allows one to do([utype] 2015).

Most content is developed for the use of the head and input through the hands; the rest of the body is mostly ignored.

There are attempts to include more of the body by, among others, back-pack vibrators that vibrate a large part of the body or constructions that allow you to walk in place. The focus on efficiency and information processing might be one reason for the neglect for the rest of the body. Computers, with their displays for information and buttons and touchscreens for input, have accustomed people to work efficiently with their eyes and digits.

In a blog by Laurel (2016) it is argued that Virtual Realities are complete, surrounded environments, in which gestures and movements can be used (so no game-controllers). For VR to be immersive users must be able to make their own decisions, instead of being taken on a ride, which is the case in 360° video. In her updated book, Laurel (2013) writes that a user must be able

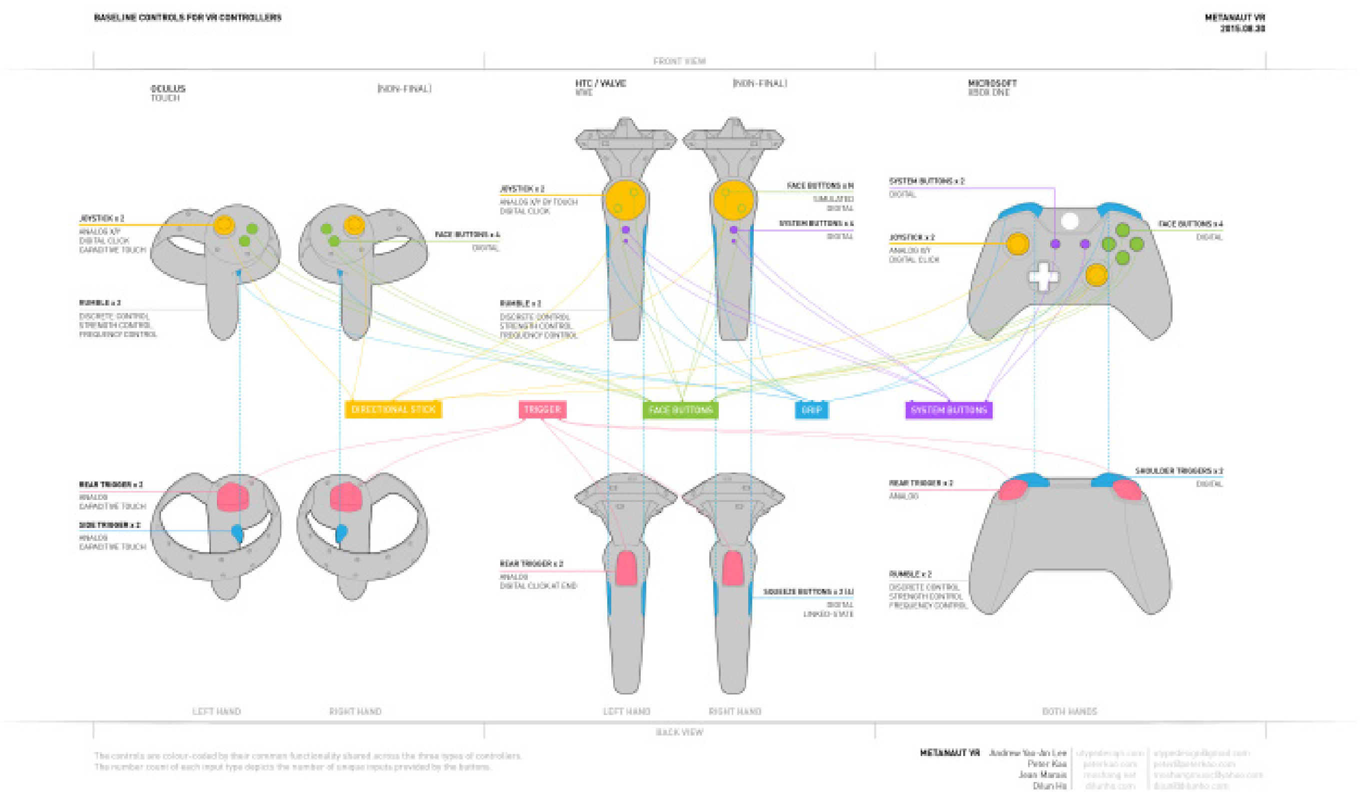


Figure 1:[utype] 2015: overview of controllers and corresponding buttons used with the Oculus Rift and HTC-Vive.

to interact with the environment and that both the software and user must be seen as agents that can make decisions.

In the same book she refers to people using VR not as “users” but as “immersants”, just like people going to the movies are called moviegoers and people studying are called students. This report will likewise refer to immersants when writing about users of VR.

1.3 CONTEXT

According to Colerdige (1971) people are willing to suspense their disbelief in order to enjoy a story even though they are aware of it being fictitious. Virtual Reality allows immersants to more easily suspense their disbelief as VR is better capable of convincing the human senses of the authenticity of the presented illusion. The more complete and successful this trickery, the more convincing the presence of the virtual environment is (Abrash, 2014). For this, light, motion sound and space all need to work together to create the illusion. The movement of the head and the presented renderings also need to match at the exact same time to give the immersant the feeling he actually looks around. When the renderings arrive to late, there is a high latency.

Motion Sickness
Many people still experience motion sickness after they have been in a VR experience and Kolasinski (1995) expresses that high latency can be one of the biggest contributors to this motion sickness. The immersant expects to look at a certain direction, however this does not seem to be so.

People know what direction they look at through proprioception which allows humans to know where their body is through different sensors (Brain Balance Achievement Centers, 2015). This perception is done through the combination of vision, by measuring where the body parts are relative from each other and by using the vestibular system. With an HMD, however, only the vision can be fooled which explains the motion sickness.

Rapid movements or unexpected camera movements (without the body actually moving) could signal to the body that something is off, to which the body responds with the feeling that you are sick. Poisonous food might explain the discrepancy between senses, so the body proceeds to get rid of the poison by throwing up (Google, 2015).

1.4 SCOPE

Physical Solutions
UNITiD is a digital design agency. They do not develop their own physical products and their digital products are designed on demand. They make use of current tools and platforms and are better assisted with design principles than hardware solutions. Therefore, tangible, physical VR products are discarded and the focus is on digital solutions.

Virtual Worlds
Many virtual worlds already exist in the form of digital games. Unlike VR, these world can only be seen as through a window and the interactions are mostly based on the use of a keyboard and mouse. VR allows new ways to interact with these virtual worlds.

Most commonly is the use of controllers ([Utype], 2015). There are also efforts to track hands (Kruit, 2014), for example with the Leap Motion. Alger, (2015) writes that future VR set-ups will most likely use tracking of one hand in combination with a controller.

Figure 2 shows a simplification of the different hardware parts and how they work in the Virtual World.

Virtual Reality
According to Abrash (2014) Virtual Reality's immersion and presence are dependent on the level of success in fooling the subconscious perceptual systems. For this, many elements need to be designed; audio elements, visual elements, animations, interactions, environments, character design, content etc. This report though, will primarily focus on interaction patterns. More precisely put; ways in which people interact with the virtual reality environment and how to design for this. The latter part, how designers should design interactions for VR, will include other elements like visuals and audio, but it is not the main topic and will not be covered.

UNITiD is specifically interested in design patterns for Virtual Reality. This could include a description of a menu, it's visual elements, the animations, the mechanics behind the menu and the controls and interactions to interact with the menu.

Elements in VR
A distinction can be made with 2D graphical elements and 3D objects. 2D graphical elements are often used to convey extra information, for menus or for buttons that activate specific actions. 3D objects are often part of the environment and allow certain actions to be done manually.

In their blog that explains how they design for VR, Deruette & Applebee (2017) use the words "interface" and "environment" for this. They distinguish between complex environments & interfaces and non complex

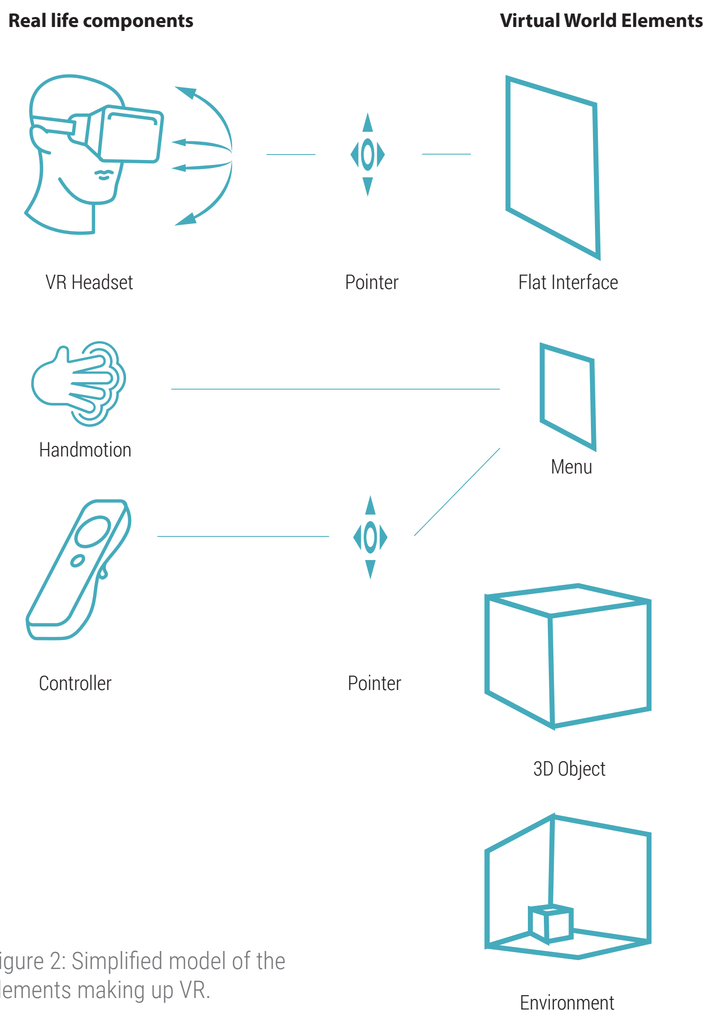


Figure 2: Simplified model of the elements making up VR.

environments and interfaces (see Figure 3). Gibson (1978) dissected the visual world and created a section called images; 2D representations that don't bear any depth. As UNITiD primarily develops for companies that are not necessarily asking for gameworlds or complex stories, it is not in their interest to create rich and complex worlds. Additionally, since UNITiD is very fluent in creating the interfaces for almost everything that has a screen, it seems appropriate that two dimensional interfaces are also considered.

Alger (2015) presents a list of application categories. Combined with interviews and applications presented at the conference "Virtual (R)evolution" (Appendix A.2) it seems that 2 of these groups were largely presented: applications used for training & education and applications used for showcasing and presenting products. These applications would also need some sort of interface to convey information to the immersants and allow them to make decisions.

Sources
Alger (2015), Google (2015) and Oculus (n.d. –a) all state that the User Interaction for virtual reality is still in its early stages. As a result they state that standards still need to be developed and that there are few resources for those standards. So they developed their own standards based on their own experience, the experiences of others and online forums and blogs. This report uses scientific literature where possible and will include information from blogs and online guidelines for the patterns as they tend to be more prevalent and up to date.

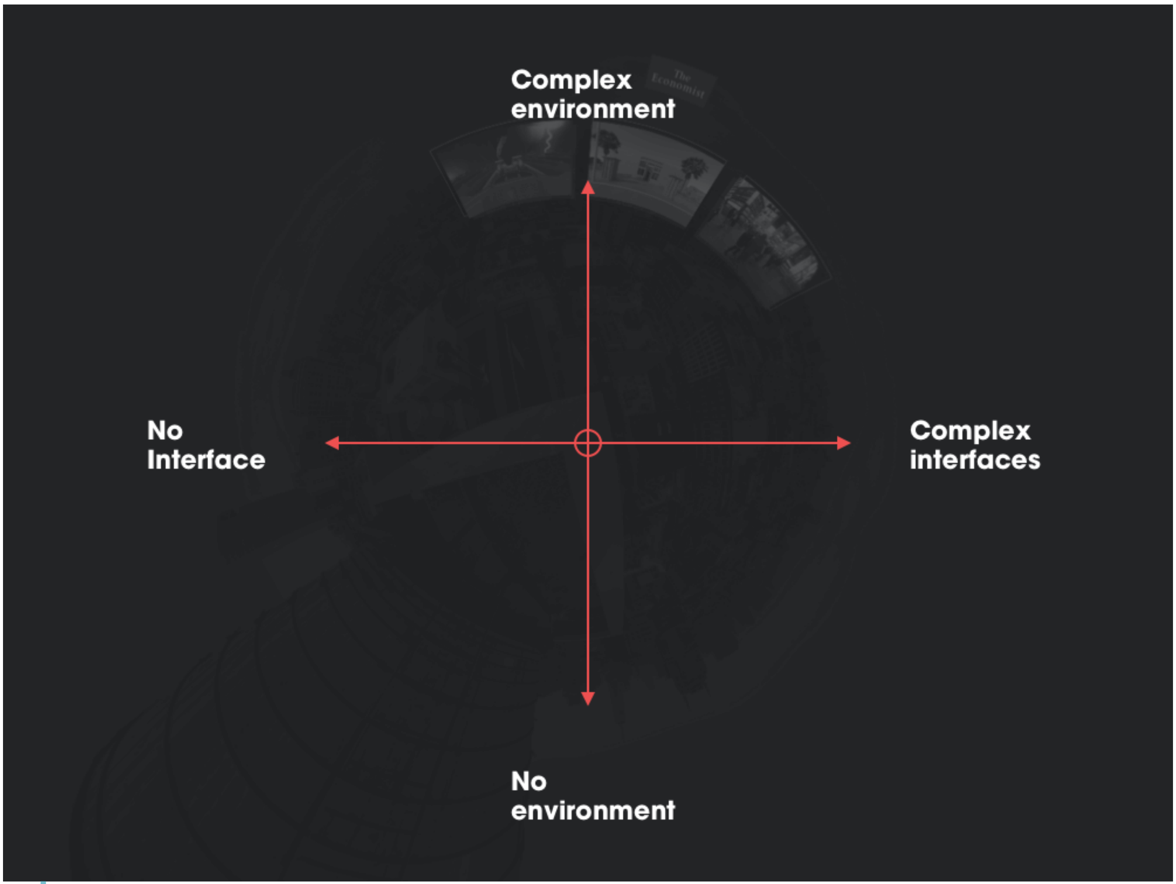


Figure 3: Four different quadrants in which you can place VR applications according to Deruette & Applebee (2017).

1.5 PRODUCTS ON MARKET

At the Dutch VR Awards (appendix A.3) Digitas LBi Amsterdam gave a presentation on the future of VR in which they visualized the current products (Figure 4).

A distinction is made in efforts for mobile VR, rendering VR and Physical Set ups. With Google's cardboard, Daydream and Gear VR, steps have been made into getting VR on small, accessible devices. Unity, Valve and Unreal have been supporting the development of VR applications while Oculus, Leap and Vive have developed hardware that supports physical set ups that allow you to physically move and either use controllers or your hands.

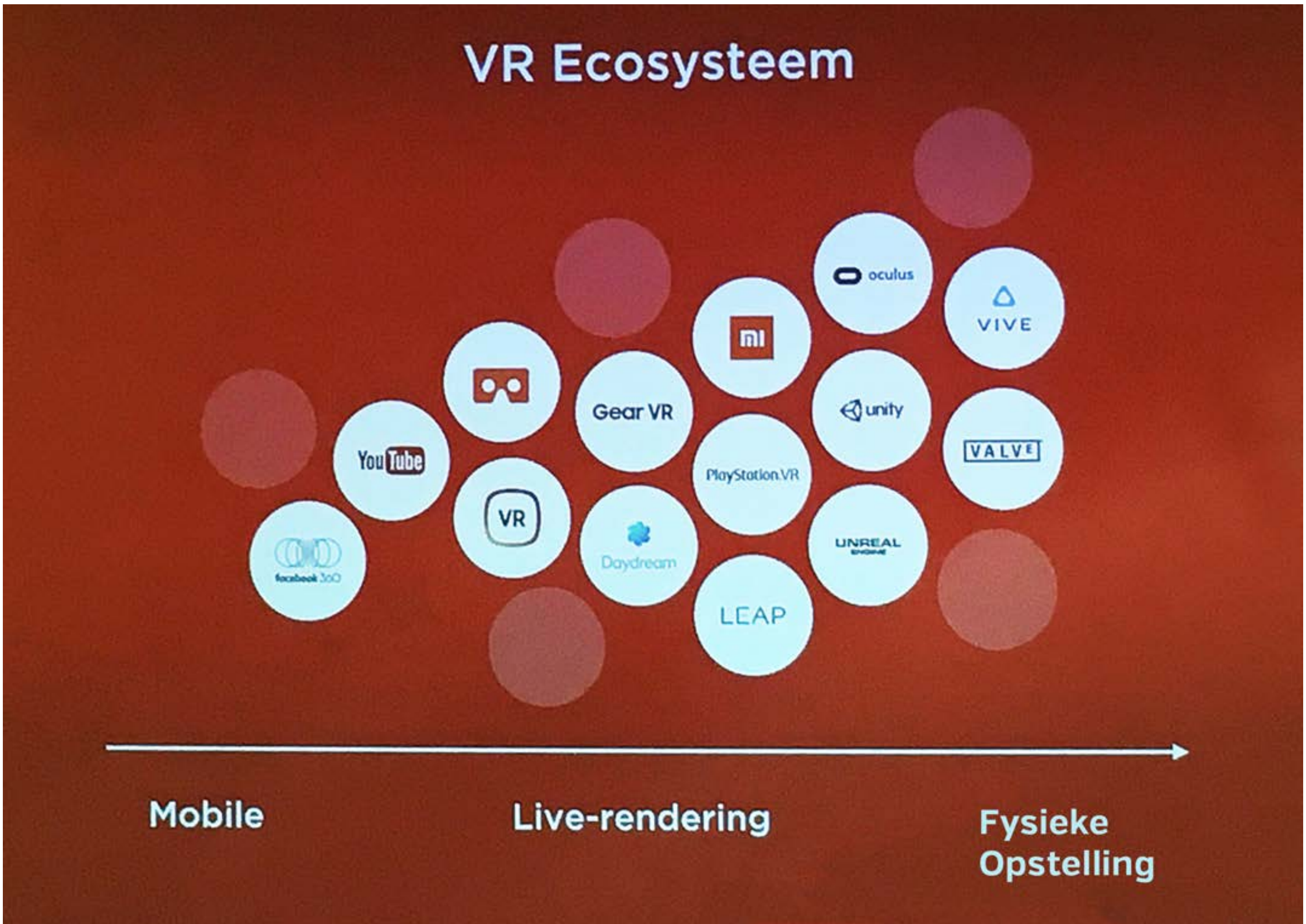


Figure 4: Digitas LBi Amsterdam: the VR Ecosystem

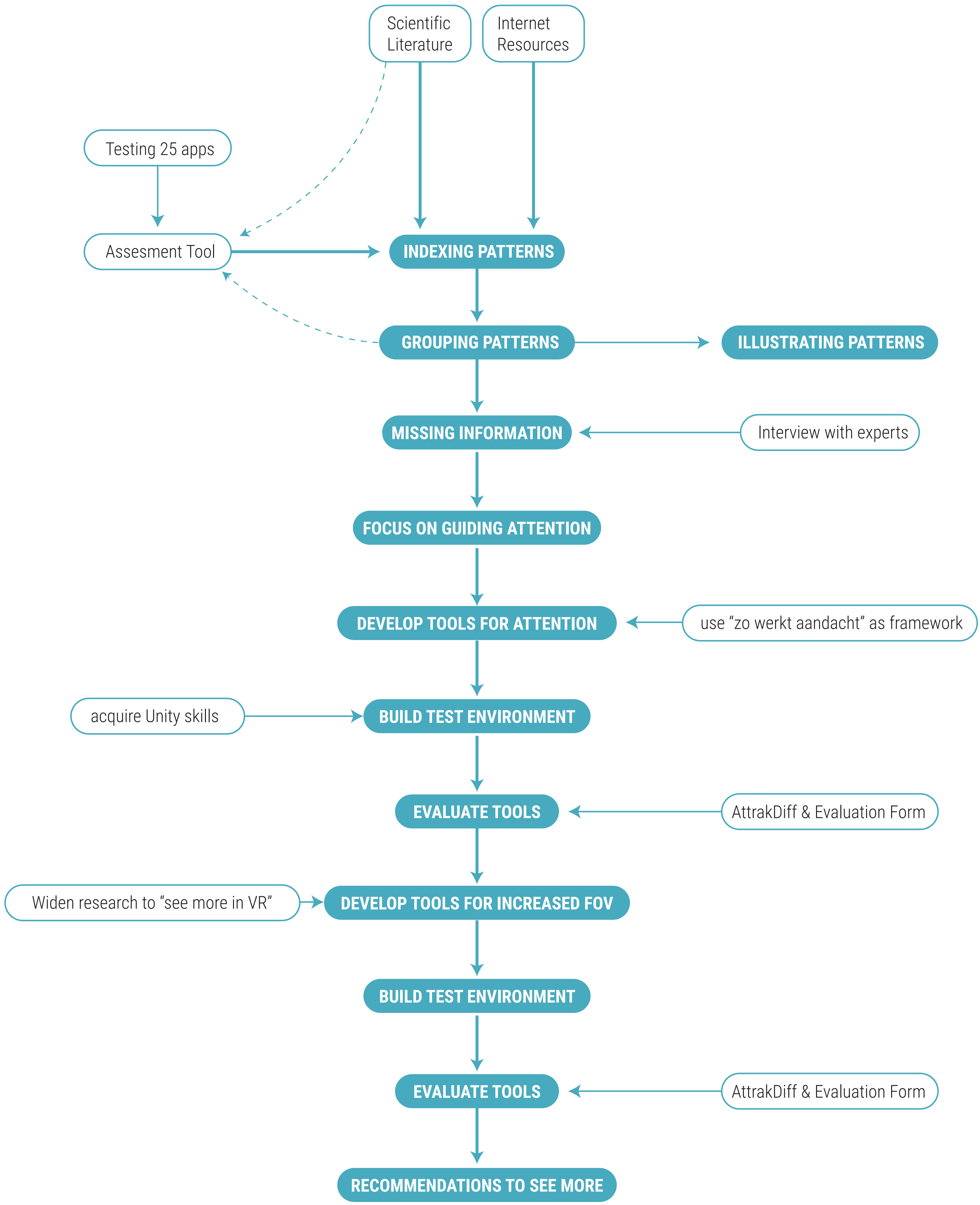


Figure 5: The steps covered in this research.

2. RESEARCH SETUP

Many platforms, engines, setups and applications already exist for VR. Currently, advancements for VR have been on the hardware side. Oculus, HTC and Leapmotion all have created hardware. Hardware development, however, don't mean that interactions with the hardware are smooth. Designing software for VR is quite an endeavor; beside the functionality that needs to be programmed, it needs to work seamless with the VR hardware and, of course, the user. Did the user experience have the same progress as the hardware?

Are the apps that have been published easy to use? How do they shape their interaction? Can reoccurring interaction patterns be observed? This culminates into the initial research question of this report:

Research Question 1:

What design patterns, regarding fitting, common and intuitive interactions, are there for applications in virtual reality?

Furthermore, when this question has been answered sufficiently, can gaps be found? More specifically; what area of interactions pattern could be further researched so that VR applications become easier to use? This results into the subsequent research question of this report:

Research Question 2:

How can the use of Virtual Reality Applications be improved so that immersants can use Virtual Reality applications more efficiently and with more ease?

Several other supporting questions were developed which can be found in Appendix A.0. Since they won't be literally answered in the rest of this report, they are not reproduced here.

Figure 5 visualizes the chronological order of the steps that are taken in this project.

Figure 6: Picture of "The Sensorama" from the wikimedia commons website.

3. INTERACTION PATTERNS

Virtual Reality has been around for quite a long time; one of the first examples would be the Sword of Damocles in 1968 (Sutherland 1968). Therefore, a considerable amount of literature regarding VR exists. However, a boost in VR developments has occurred in the last couple of years (Appendix A.3). Development of the Oculus Rift and HTC Vive have suddenly made Virtual Reality economically accessible to larger audiences. UNITiD is most interested in developing for these platforms. General rules and implications of Virtual Reality with Head Mounted Displays can be found in older papers, but the developments and trends of interactions and implementations of VR can be found in more recently published literature.

The companies that developed the HTC Vive, Oculus Rift, Google Cardboard and LeapMotion have focused on designing experiences in VR and have shared their findings on their websites through guidelines and blogposts.

Other developers have also published their findings online. For this reason, many of the practical interaction pattern literature are sourced from the developers and publishers websites.

3.1 CATEGORIES

The interactions for Virtual Reality, including best practices, efficient and intuitive implementations and guidelines found in the literature, are recorded as patterns and stored in a database where they are categorized and complemented with imagery.

During the creation, the database was structured several times by grouping the, new, found patterns. The main categories are:

(A) General Guidelines
(B) Specific Patterns; Interaction actions
(C) Specific Patterns; Core Virtual Reality Elements
(D) Guidelines supporting Elements

Certain guidelines are always applicable to VR and are hard to apply to a specific situations (A). They are more about natural tendencies of people. Next, many patterns are not about the VR world or it's elements, but specifically about the actions you can do within the world and how you can do them (B). The Virtual Reality world is built through the combination of several elements. These building block were grouped in (C). Finally, there are patterns related to finishing and polishing the VR experience. VR applications can essentially do without them and they have a supportive role (D).

The general guidelines (A) hold “Natural Interactions”; guidelines for interactions that always hold true, “Guiding Attention”; how to guide the attention the immersant’s attention, “Physical Ergonomics”; what is comfortable related to bodily qualities, “Virtual Reality Sickness” how can you prevent or ease sickness resulting from VR, and “Testing”; what methods are there for testing the VR experience.

The actions used for interactions (B) that are identified are Pointing & Gazing, Selecting & Activating, Translation, Manipulation and Controllers. A distinction was made between gaze, where a person looks or where the HMD is directed at, and pointing with the use of a controller or remote. They are indicated respectively as gaze and wand.

The elements VR is built of (C) are divided into 2D interfaces and 3D objects. The “Environment/Interface” domain by Deruette & Applebee (2017) also make this distinction between a flat interface and a 3D environment. These groups are then further divided into specific elements like Spatial Dimensions, Affordances, Menus and Limitations. Some of these also hold subdivisions as grouping patterns on this level should increase clarity.

Finally, the supporting elements (D) are the “Visuals”; aspects relating to color, opacity and the like, “Audio”; the element of sound in VR and “Animations”; programmed movement for elements in VR.

Excluded Categories
Because the patterns database became very large, certain pattern groups were excluded to keep focus and to be able to study the included subjects on a more deeper level in the restricted amount of time.

Locomotion, Avatars, Platform Specifics, Hardware and Programming are either found to be not relevant enough for interaction patterns (e.g. programming), require their own study (e.g. Platform Specifics) or are already heavily being researched and tested (e.g. Locomotion).

3.2 FINDINGS LITERATURE

General Findings
About 150 patterns from literature are indexed (Appendix A.4). More general guidelines are often found in the papers while more specific and practical patterns come from online guidelines and presentations. Many guidelines are primarily concerned with preventing virtual reality sickness.

Some topics have patterns, but they are either specific or there are little. “Guiding attention” primarily holds patterns for specific small items. But it doesn’t hold any patterns that aid with placing elements to aid with efficiently using an application.

Translate doesn’t have any patterns either. It was observed (Appendix A.1) that most applications translate by “grabbing” an object (first targeting, then selecting the object) and then move it. Either with the hand/controller or with a (in)visible beam projected from the remote or HMD.

Manipulation neither had a lot of patterns. The main observed manipulation iss resizing and rotating, always done with two hands grabbing parts of the object. Other manipulations to a design were done through “tools”. Controllers would take the form of a certain tool (e.g. paintbrush) through which the object can be manipulated (painted a different color/ pattern).

More about gestures is learned from the Leap Motion (n.d.) blog. They describe the "grabbing" gestures as direct gestures (Figure 7). Their index of gestures can be insightful for analyzing gestures. They write that there are direct gestures that should be clear to anyone (e.g. grabbing and throwing objects). Abstracts gestures on the other hand are not clear to everyone (e.g. waving goodbye or sign language) and they often need learning. For instance, most people in the Netherlands will have learned that to stop a bus you would need to raise your hand. Metaphorical gestures are in between, they refer to a real-life event but afford a different action (e.g. pinching). From this it could be learned that "natural" gestures everybody can use are restricted to only a few actions. If the application can do more than is possible in the real world, or when it's possible to do the same in less steps, new interactions must be taught to users. Metaphorical gestures could ease the learning process.

2D interfaces in VR are primarily displays to present information or menus and quite a lot of information in literature could be found about these. From the observations (Appendix A.1), the notion grew that menu structures were taken from current graphical user interfaces found on flat displays (computers screens, tablets, smartphones).

As stated before, Gibson (1978) writes about 2D images as a distinct element in our visual world. The idea of removing any 2D image or interface in a virtual world because it is not "natural" therefore seems misapprehended. Furthermore, 2D representations allow users to more easily attain an overview and efficiently use space. Real world examples would be maps or menu cards in a restaurant. Finally, many 2D interfaces allow more efficient use. When looking for a book, many libraries allow searching their index on a computer screen, as searching and walking through all the aisles would take more time. Stripped of extra information, Gestalt principles (Wagemans et al, 2012) are also easier to perceive.

3D objects patterns were sparser. There are some general tips for designing affordances in VR objects, but no specifics. This probably has to do with the fact that designing 3D functional objects is an entire study of its own and is very content, context and function specific to make general statements about. Neither is any specific information about the placement of these objects and the relation with the interaction easy attainable.

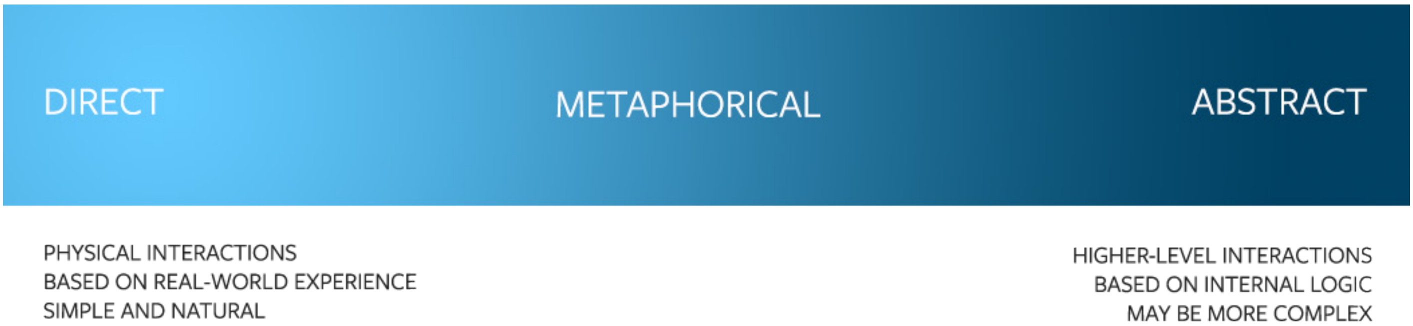


Figure 7: A scale of direct to abstract gestures from the Leap Motion (2017) blog.

3.3 APPLICATION ANALYSIS

With the Dutch organizing their own "VR" awards (Appendix A.3), it must be possible to conclude that there is already a large number of VR apps that are available. What kind of interactions do these VR apps have? Are there interactions that occur in multiple apps and can they be the standard the industry is settling on?

For this reason, 25 apps on three different platforms were tested and assessed. A full description of the setup, methods and results can be found in Appendix A.1.

Method

Screenshots of each app were taken. The screenshots were grouped and when possible linked to themes of the Patterns list. These screenshots and their groups can be found in Appendix A.5.

Findings

Using an assessment tool, described in Appendix A.1, many examples of the patterns found in literature are confirmed. The two main themes that are not covered in the literature phase are the use of tools, for example the "Painter's Palette" and the info screens.

Many patterns found in literature are actually applied in the applications. However, not all "patterns" are necessarily used by every application.

Some interesting findings that were not found in literature are that most controllers are visualized in VR and show labels to explain the buttons at a certain point. Vibration is also used extensively to indicate interactive objects, add to the action that is happening or indicate an error. Finally, audio and animation are also extensively used to support and reinforce interactive elements, actions and the environment.

3.4 VISUALIZATIONS

The findings from the study are grouped in a list in Appendix A.4. Appendix A.5 shows examples of these patterns through screenshots of the tested apps. But in addition, visuals have also been created to conceptualize the patterns and are presented on the following pages.

The findings from Appendix A.4 are combined with the visuals, the screenshots from Appendix A.5 and gifs and placed in a dropbox paper file, which is more easily availble and can be used to create a website. The link for the dropbox paper is:

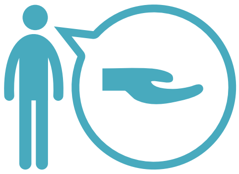
https://paper.dropbox.com/doc/VR-Interaction-Patterns-ffQNxuGJmLTwKVVclSzOb

Figure 8: QR code to the dropbox paper with all the findings on interaction combined. Website might be slow on mobile.

A1 General Guidelines

Natural Interactions

Embody content through a personal assistant

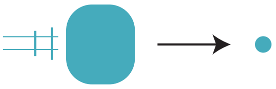


Characters eye-contact makes experience more immersive

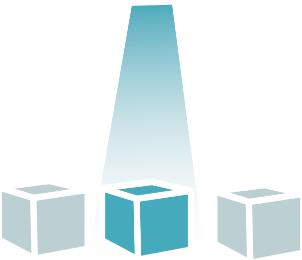
People think in boxes and lines

Guiding Attention

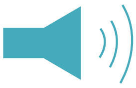
Use direction of animation to point users attention



use light cues to guide the user



Use sound to move attention to desired position



Use gaze to direct attention

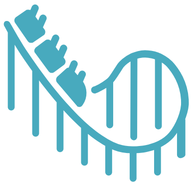
Physical Ergonomics

Allow users to set the origin and orientation.

Virtual Reality Sickness

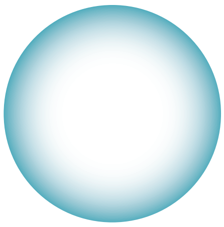
Keep the horizon straight

Avoid fast accelerations



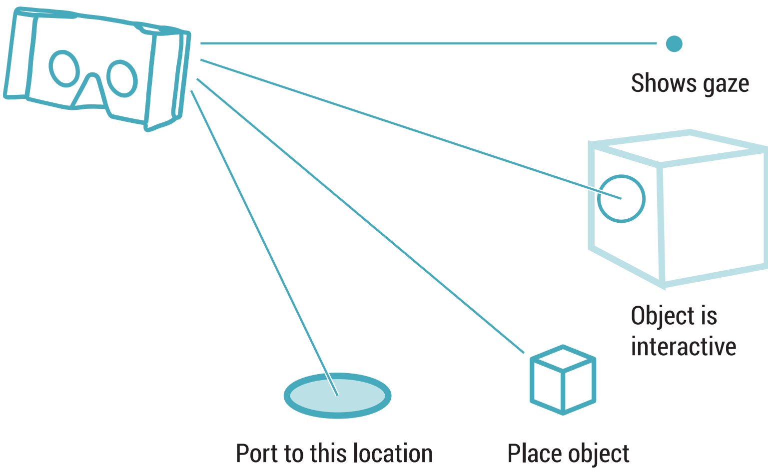
use a cage or cockpit in fast moving scenes

Use a vignette to blur sides

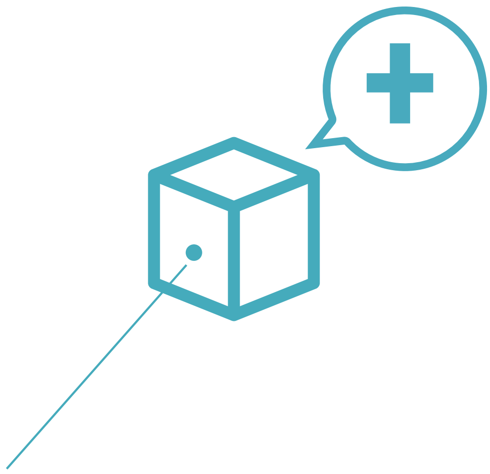


B1 Pointing / Targeting

Reticle/pointer changes depending on what it is pointing at



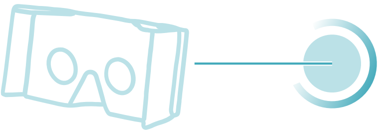
Show extra information when something is selected



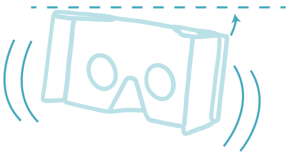
B2 Activate Confirm

Gaze

Fuse timer to select objects



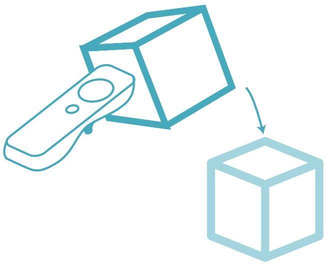
Use orientation, acceleration
or position for selection



Wand

Assign a button to confirm actions

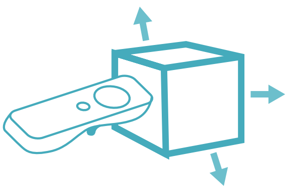
Move object over another, or yourself, to apply it



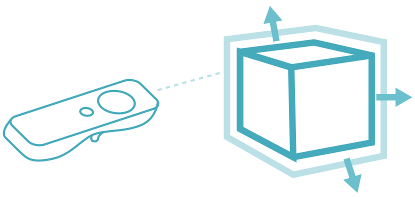
B3 Translate

Wand

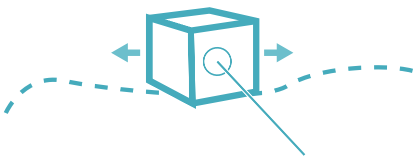
Move object by grabbing them



Move objects like you have a magical
wand that can levitate objects

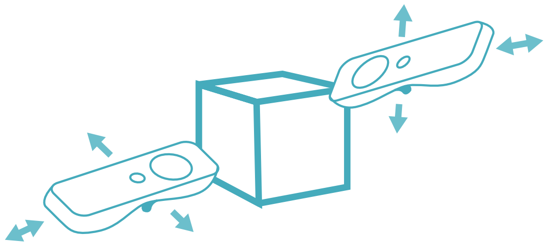


Object follows a rails



B4 Manipulate

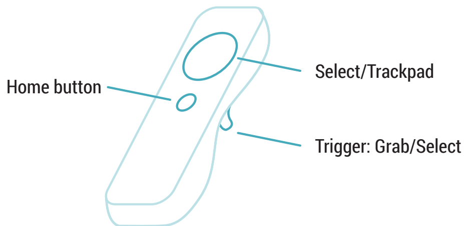
Resize objects by pulling or pressing with two controllers.



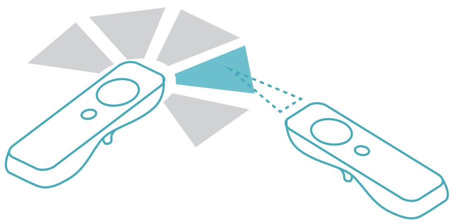
B5 Controller Design

Wand

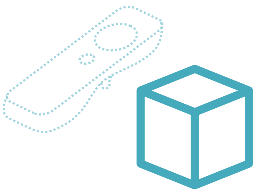
All controllers have a home button, a trackpad/selector and a trigger



Use a painter's palette: one controller holds the options while the other can select them



Make controllers see-through close to objects.



Controllers can change form to represent new functions

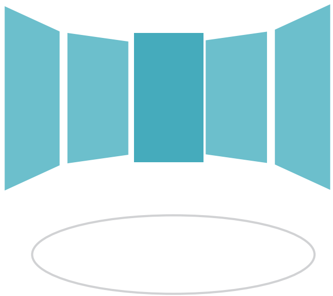
C1 2D Interfaces

Place & Size

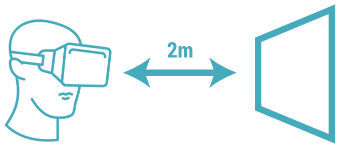
The UI should fit in 1/3rd of the viewing area

Menus can go around hands

Place menus at eye-level and you can make them circular

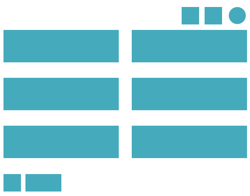


Place elements at least 2m from the head

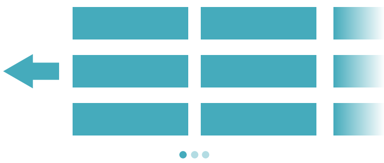


Menus

Keep menu 1:1



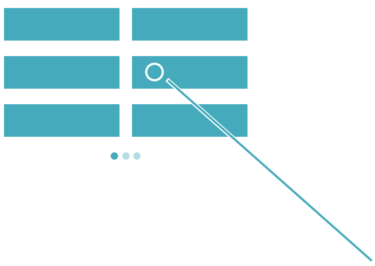
Scroll horizontally, in chunks



Animate buttons to point attention

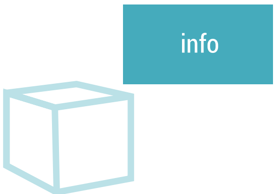
Move content instead of the button to make place

Move content directly and spatially

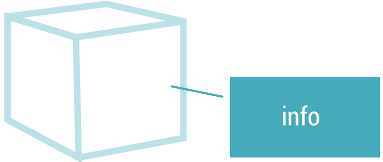


Info

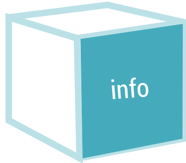
Let info hover close to an object, at eye-level



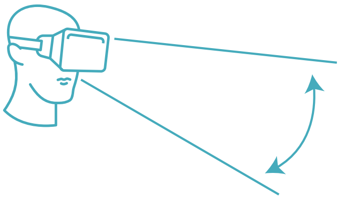
Anchor information to an object



Incorporate information into the 3D world



The angular range of text should be limited and close to the middle



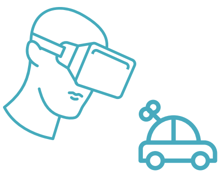
Loading screens and important info can be anchored to the gaze

Use spoken commands to inform users

C2 3D Objects

Place & Size

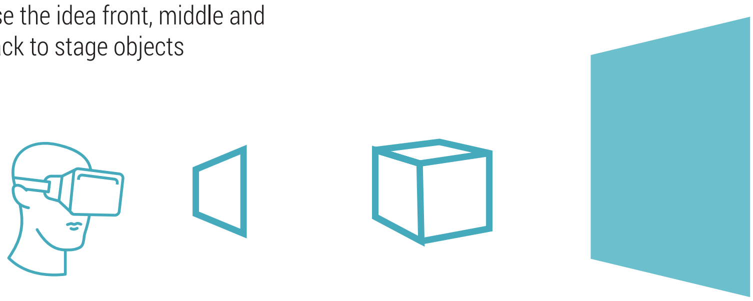
Small objects will feel like you can pick them up



Large objects will make users feel fenced in

Dimensional buttons clearly communicate how to activate them

Use the idea front, middle and back to stage objects



Theatre set-up:

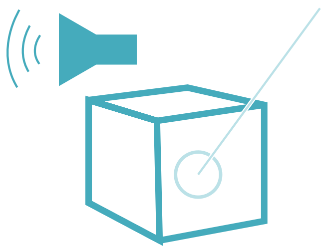
Front
(Meta)

Middle
(action)

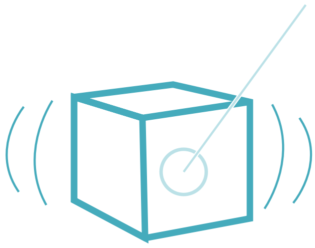
Background
(environment)

Affordances

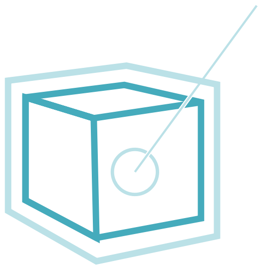
Objects make a sound when they have an action



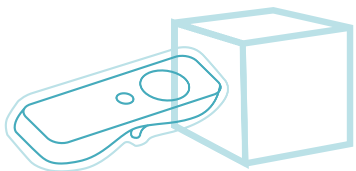
Objects animate when they have an action



Objects are highlighted when they have an action

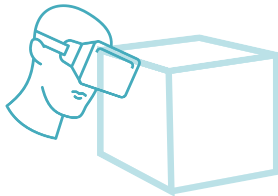


The controller is highlighted when an object has an action

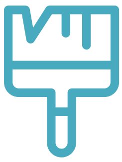


The controller vibrates when pointing at an interactive element

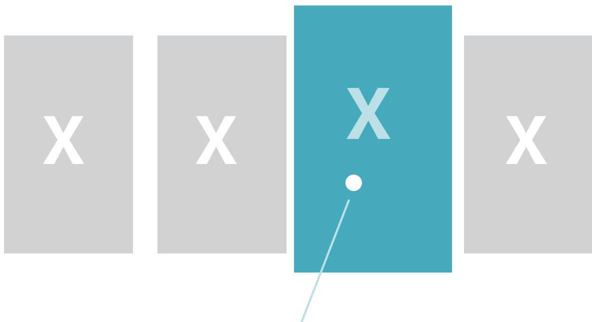
Make objects or the environment see-through when looking close at it



If an object looks like it can be picked up, knocked over or pushed, users will try to do so



Make selected elements stand out through distance, size, position, color and other aspects



3.5 INTERVIEWS

To complement the findings and find inspiration on what could be developed more intensely regarding interactions, contact was sought with developers. Literature provides structured and abstracted information, testing provides hands-on experience and a gut-feeling for VR applications, but experiences with designing VR applications are still lacking. Therefore, interviews were held with developers. As previously mentioned the “Virtual (R)evolution” conference was visited and 8 booth-holders were interviewed about their products. The Dutch VR awards were also hosted here and provided inspiration as developers would expand on the process behind creating the applications. A detailed report can be found in Appendix A.2.

An in depth interview was held with Jonatan Bijl, a developer of a VR safety-training-simulator for the Rotterdam Port. A summary of this interview can be found in Appendix A.3.

Overall it became clear that most developers were mostly focused on the technical aspects. Few could expand on the difficulties of designing interactions. Interesting challenges concerning interaction that did surface were the following ones:

- Guiding attention. How can you grab the attention and direct it to a specific element?
- Audio. It was mentioned this could still very much be improved.
- Showing possibilities. One vendor talked about difficulties with conveying what is possible in VR.
- VR native menus. Menus are currently designed largely the same as menus for flat screens. Are there better fittings menus?

3.6 FURTHER RESEARCH

One thing that stands out is the use of menus. Menus designed for flat GUI’s seem to be copied straight to Virtual Reality. One concern, expressed by people like Martin Tirion (Appendix A.3), is that is not appropriate as it is not designed specifically for virtual Reality.

However, almost all VR applications do use flat menus which don’t seem to be inappropriate. Two reasons for this could be that, one, people are used to these menus and how they work. Secondly, flat menus work very efficient. In real life, many examples could be thought off in which multiple options are offered which are placed on 2D surfaces; menus, maps, SCRUM Walls, Post It’s. Ordering receipts or post-its with observations is easier on one big flat surface then on a curved surface. So one could argue that “flat” menus will always occur and will most likely complement 3D menus.

Another big information gap in interaction design for Virtual Reality is the design of affordances for 3D objects. However, it is deemed that enough information can be found in contemporary design literature and that the subject is quite context dependent.

It was observed that many applications change the appearance of the controllers to accommodate the function of the controller. For instance, when using the controller to paint, the controller would turn into a paintbrush. Or when you can grab objects it will turn into a hand or a “hover device”. Often tools are used in conjunction. One will be a brush while the other will be the palette from which color can be selected. Although not much has been recorded regarding this pattern, the implementations seem to work and don’t deem to require more research.

Many patterns were found that aim to grab the attention of the user. Think of vibrating controllers, use of shadow, light and contrast, highlighted objects, animated objects, object placement and arrows and icons. Still, many developers expressed their struggle with guiding the attention of the user to the designed and possible actions. But what is the best way to communicate to the user what is possible? How can the user be aided in the use of the virtual environment without diminishing the freedom?

3.7 FOCUS

Based on the previous considerations it seems guiding attention within virtual reality is worthy of being researched. Or stated in the analogy with theatre that Laurel (2013) makes; how can the possible action be portrayed and where should this take place?

Context

The realization is made that attention could be quite context specific. Watching a movie in VR will automatically place all the attention on the "virtual" cinema screen while standing in a virtual ocean filled with all kinds of fish swimming around, attention could go almost anywhere.

Appendix A.6 identifies five themes in which it is helpful to guide attention. The first is when you call something that will appear outside your field of view. The second is when automated actions like animations and media happen outside your field of view. A third is when a designer wants the attention away from where a user is looking to see more around him or her and instead highlight or feature certain parts to the immersant. A fourth one is when an immersant is looking around, but his attention needs to be back at one spot where the main action will be. Finally, there could be objects that await a certain input before an immersant can progress. Unaware immersants can be guided towards the waiting object.

Two practical examples would training applications and applications intended to sell.

Virtual Reality trainings can cut costs significantly since difficult or expensive situations can be simulated. Therefore, VR is very fitting for training situations. Companies also seem to use the possibilities of VR to explain their product, taking away nescience as a hurdle of not buying products. Think of a construction store that explains how to construct your own bathroom.

It is important for instructions that users follow along and are guided. Knowing where to look or how to interact is very beneficial for the immersant.

The second kind of application is in sales or showcasing. Suddenly people at home can see a product in 3D. A much better picture can be created about the product that is sold. This applies to consumer products as diverse as clothes, electronics and houses, but also applies to business who want to show the factories they sell or airplanes they build to their clients.

In these implementations, it is important for the providers to convey certain information. One could think of product details, alternatives to the products or discounts. Where would you need to put that information? How can you guide immersants in discovering what possible with the products?

In the before mentioned cases it is important that designers know how they can guide the users' attention.

Research
Several suggestions are already made on how to catch the attention of users. These will be evaluated to see which ones work best for what situation.

This report will make suggestions on how to guide attention. These suggestions are then evaluated through testing to finally conclude with patterns that should help designers in creating the interaction for applications in Virtual Reality.
The second research questions can now be partially answered:

Research Question 2:

How can the use of Virtual Reality Applications be improved so that immersants can use Virtual Reality applications more efficiently and with more ease?

The functions in Virtual Reality applications can be used more efficiently and with more ease when designers know how they can guide the attention of immersants in VR.

The rest of this report will be focused on attaining the information needed to know how to guide this attention.

4. GUIDING ATTENTION

4.1 POSITIONING VS GUIDING

Youtube features a heat map option for developers so that they can see what viewers are looking at in their VR videos. In their blog (Youtube, 2017) they explain that this should help creators in understanding how viewers engage with the video.

You won't have to attract attention to a certain place if you place elements at the positions where people will expect them and search for them. From that perspective, it is useful to research where people expect elements to reside.

Gibson (1979) writes about affordances and explains that they are information that is perceived and tells what a product affords. This goes both ways; products and objects hold attributes that allow certain possibilities, but it is also the perceiver that addresses possibilities to objects. In that sense, it is dependable from person to person to perceive what is possible. When designing objects a designer can try it's best to incorporate certain possibilities, but this doesn't necessarily mean users will be able to perceive what is possible. In the same way, you could place elements at positions that should be logical, however, what is logical depends from person to person. So then, elements might be placed in a certain place with the intention of being discovered, but the user doesn't necessarily have to discover it, depending on many factors like culture and character. You would then need to attract the attention of the user to that element.

In that sense, it seems more useful to research how to attract the attention of a user to a certain place or element. Cultures change, as do applications, needs and trends. Consequential, layout and designs of application and environments will have elements that will change location. The results from youtube (2017) on VR videos found that 75% of time is spent in the front 90 degrees of a video. Their advise to make viewers see more is to "get their attention". Helping (new) immersants find their way to element is therefore deemed more constructive than the placement of objects which is more sensitive to change over time. It also seems that the workings of attention can be applied on a more general level and are less dependent on individuals. Stigchel (2016) explains many principals of attention that have to do with how the brain works and that are applicable to the general public. Hence, this report will focus on guiding attention primarily, as it varies less per individual.

4.2 VR SCENARIO

What should attention be guided towards? What are elements that need attention? What is the context of guiding attention. To help with answering these questions two categories of VR applications are chosen (Appendix B.1); VR applications used for informing and VR applications used for training.

Five instances in which it can be useful are reported previously. Contrasting those five instance, these two scenarios focus on a complete sequence of steps and should help the reader to create a notion of what the steps in VR applications could be and where guiding attention could take place.

Scenario 1 – Training

- Select specific topic
- Be informed about the tools
- Explanation of environment
- Instruction of how to do first task
- Example of how 1st task is done
- Extra information accessible while doing task
- Status indicator of task progress and performance
- Closing task
- Evaluating instruction

Scenario 2 – Informing

- Load the environment
- Show the product
- Allow to walk around the product/rotate the product
- Option to see more info about the product
- Show specific information about product
- Option to customize and manipulate product
- Menu to select different product
- Menu to order product

4.3 NATURAL ATTENTION

To support observations and help with eventually designing suitable solutions for guiding attention, literature research is used to create a theoretical framework for guiding attention. The book "Zo werkt aandacht" by Stefan van der Stigchel (2016) is very valuable in getting an overview in this field of research and helps in generating ideas on how to shape tools for VR to guide attention.

Van der Stigchel explains that attention works like a spotlight (Figure 9). The spotlight can be big to get an overview, but we need a small spotlight to know what we are seeing specifically. Our eye has a part, the fovea, with a higher density of sensors, so more details can be seen here. The rest of the eye is also able to see, but with less detail. The ability to have an overview is called the "Useful Field of View" and changes with age. Children and elderly have a smaller useful field of view.

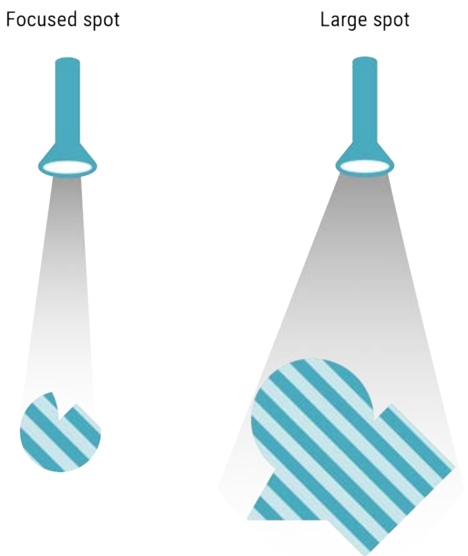


Figure 9: Example of the spotlights.

The smaller spotlight is constantly switching points (Figure 10) to see more details and we focus sequentially. We can not see two items at the same time. However, about 3 to 4 objects can be stored in our memory at the same time.

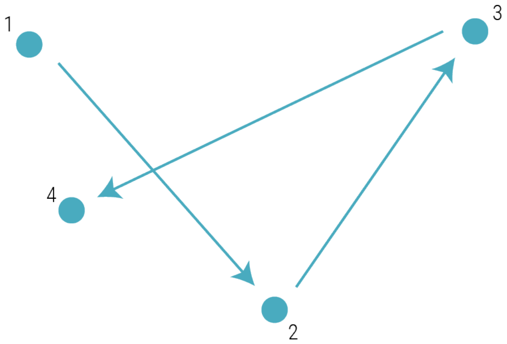


Figure 10: Attention switches points sequentially.

Objects that are not in the focused spot of the eye tend to not grab our attention. Objects that have more space around them, are larger or differ from their surroundings, do stand out and grab our attention more easily; the pop-out effect (Figure 11). In short, when the contrast with their surrounding is higher. Environments with many unique elements therefore make it harder for objects to stand out. Or, when a green light is blinking between other green lights, the contrast is too small. Making the light red, heightens the chance of being seen.

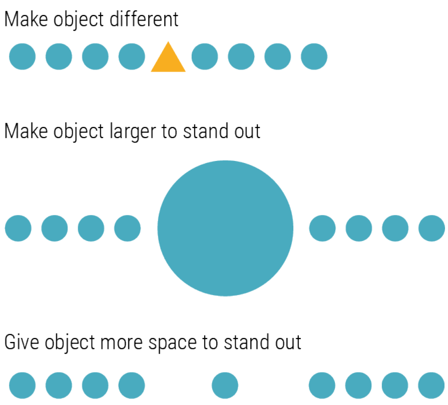


Figure 11: Crowding visualized.

Cueing can also guide our attention. Cues can be voluntarily followed, like arrows. Contextual cueing is the environment that pushes your attention towards a certain direction.

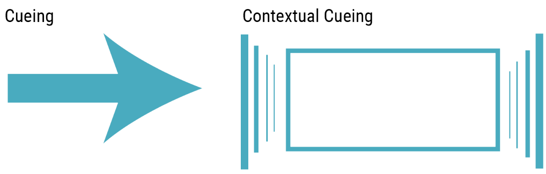


Figure 12: Example of cueing and contextual cue.

One thing that is interesting to note is that in the western world our brain works from left to right (Figure 13). Most people's mental timeline goes from left to right. So, when people look for a beginning they tend to look left.

Figure 13: Western thoughts direction.

These guidelines have to do with how our brain works (Figure 14). Van der Stegchel explains that the image is recorded in the brain and the idea and details are especially well recorded in the fovea. In the brain these signals are analysed through filters. These filters are activated when specific details are seen. For example; colour, orientation and shape. It is important to know that these information elements are not linked to each other. So, when you have a blue triangle and a red square, the brain won't know what object has what colour, only that there is a triangle and square with the colours blue and red. It will have to look at an object in detail to know exactly what colour that specific object has.

All this information is passed on to other parts of the brain. Van der Stegchel argues that the brain subconsciously analyses the information without our consciousness necessarily being aware of this. Semantics and meaning, for example, are registered by the brain without us being aware of an object. This allows for "priming". Sending the brain subconscious messages, steering it to do certain things.

However, the brain is also aware of certain other states and will try it's best to take these into consideration. For example, trying to make someone drink a soft-beverage will only work when that person is in fact thirsty. Some of the states and considerations van der Stegchel names are memories, instructions, personals goals, fears and faces. Past experiences influence where we point our attention. When you instruct someone to look for something, they tend to find it faster. But when a person is afraid of something, they are also more likely to notice it. The same goes for faces. We have a natural tendency to notice faces. More specifically, if someone looks a certain

Building Blocks and Attention

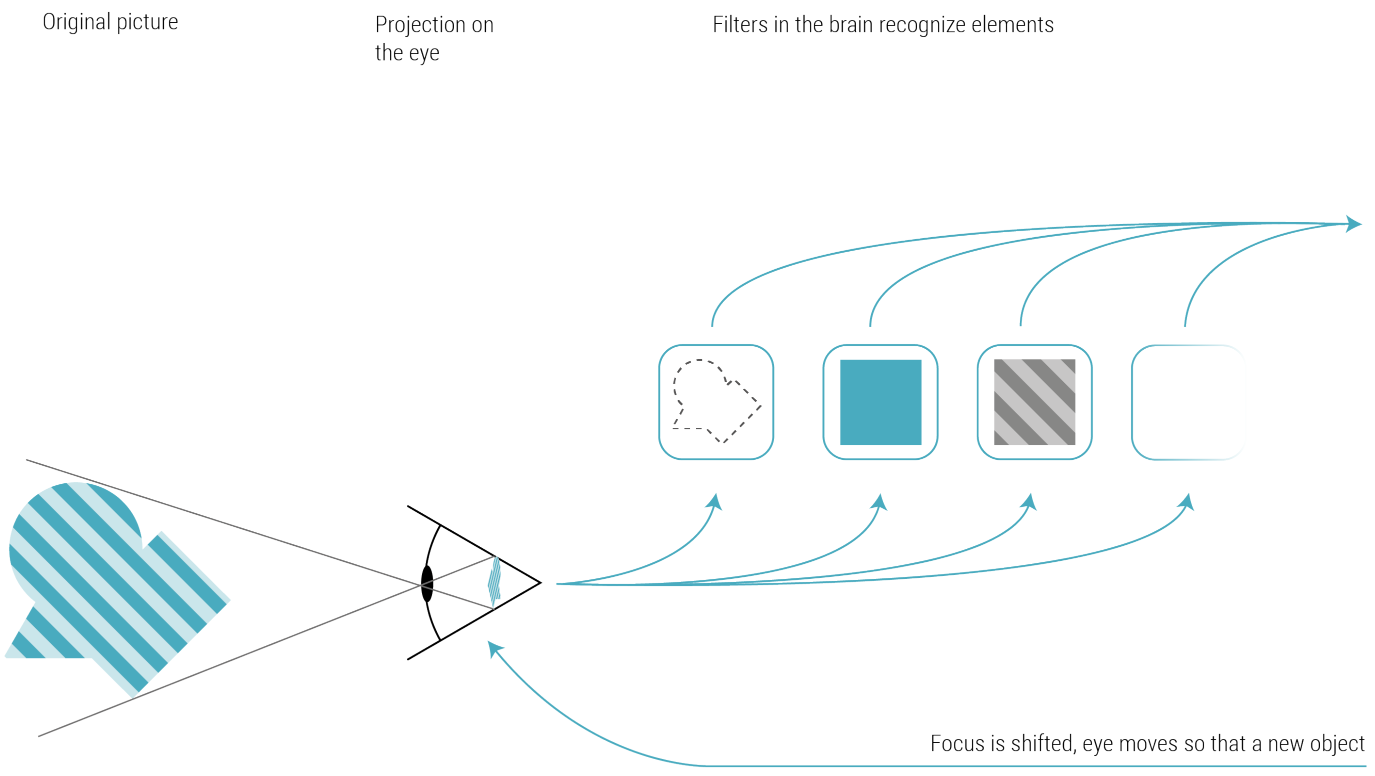


Figure 14: A model on how the brain works based on the work of Stegchel.

direction, we tend to move our attention to where the person is looking.

These elements are also used to decide whether the visual object is communicated to the visual cortex, the conscious part, making us aware of what we are seeing. The brain decides for us where our attention goes. However, we can consciously decide to “disengage” with the object.

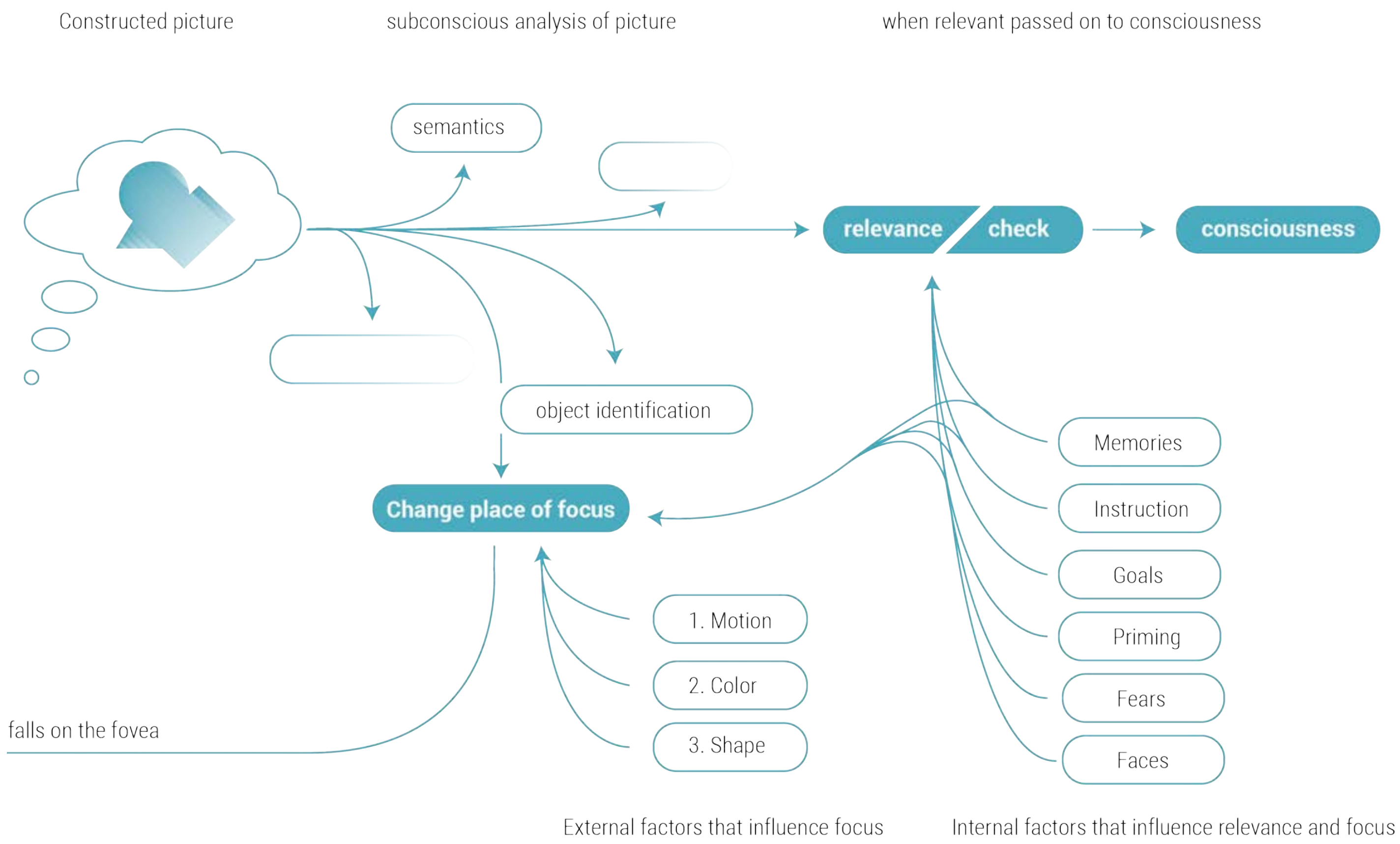
The subconscious, focusing part of our brain is also prone to motion, colour and shape. In that order. So, a weird shape will grab the attention, unless there is a unique colour, but motion will almost always grab our focus.

Van der Stigchel believes that the subconscious part of the brain has a more robust and larger memory. If you teach people something unconsciously, there is a higher chance they will remember it longer.

Many of these principles can be used to design environments in VR and allow the designer to make the discovery of certain elements more likely.

Even more interesting is the fact that many of these principles are already applied to 2D interface designs. Since these designs work on basic principles, they should still work in VR. Perhaps there are more possibilities in VR, but there seems to be no reason to assume that they won’t work in VR.

These principles for design also remind of the Gestalt principles which have been developed over the years (Wagemans et al, 2012). Gestalt principles (Figure 15) allow humans to recognize patterns and order. This, in turn allows a person to steer his or her attention to possible meaningful visualisations. Here some of the well-known will be presented. These can be used to group certain kinds of elements



together so that when an immersant understands one element he or she can easily find the others.

Other principles and ideas for guiding attention can be found in guides which will be introduced in the next section.

4.4 CURRENT METHODS OF ATTRACTING ATTENTION

Throughout the research several methods of attracting and guiding attention were observed. It is possible to fit these in one of three categories; tools, place and properties. Tools are extra aspects linked, or close to, an interactive object that aren't necessarily an inherent part of that object. Place are where the objects reside and have to do with the geometrical location of the object. Properties have to do with the dimensions and the characteristics of the object.

Further distinctions are made within these groups. Some seem to fit with tools that give overview. Others have characteristics of some sort of physics. Cues and Human are inspired by Stigchel (2016) his work and hold tools that are either pure cues or tend to speak to our human nature.

Finally, Fujibayashi et al (2017), explained the game dynamics of the Zelda game "Breath of the Wild" at the Game Developers Conference in 2017. Besides a physics engine, "Breath of the Wild" also features a "chemistry engine" that allows objects to change state in a way that users understand. So "chemistry" was added to properties.

Many more principles and ideas for guiding attention can be found in specific guides for

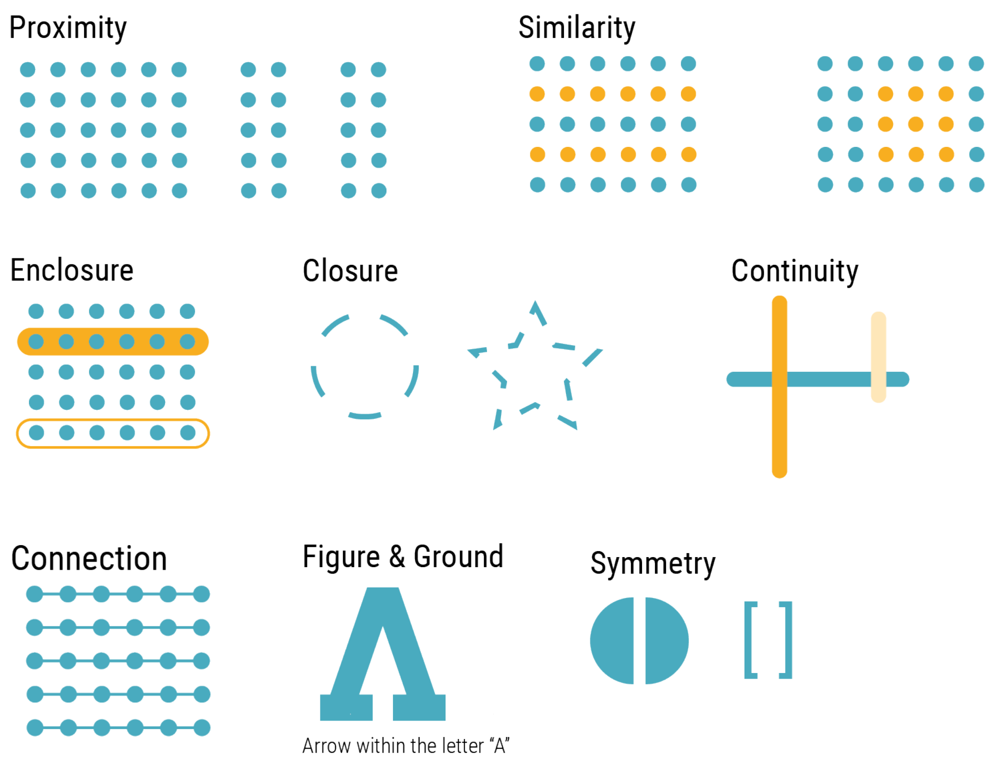


Figure 15: Some of the Gestalt Principles visualized.

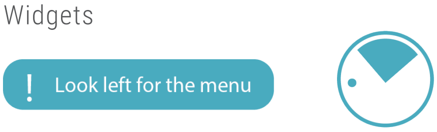
current interfaces designed for 2D displays. The work of Wouter Middendorf (2012), who wrote 60 principles for perceptual persuasion for the design agency Fabrique, and Susan Weinschenk (2015), a behavioral scientist who has her own 100 insights into what motivates people's behaviour, were used. In this report, a specific look is taken at tools that are specifically used in VR.

Tools

Here a summary of all the tools that can be used to guide attention, which were taken from the studied sources mentioned before, is presented. Each one is accompanied with a simple visualization to get an idea of what the tool encompasses.

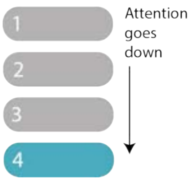
Overview

Widgets



Bars

Navigation



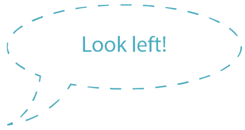
Human

Personification

Eye-contact

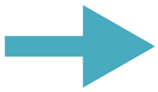
Gaze

Spoken commands

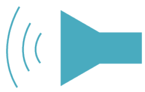


Cues

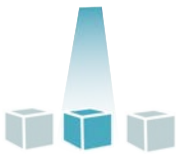
Arrows



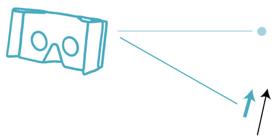
Sound cues



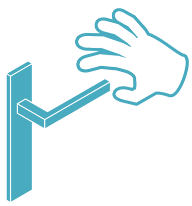
Lighting



Changing reticle

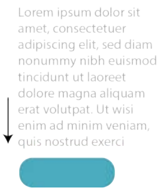


Affordances (handles, buttons)

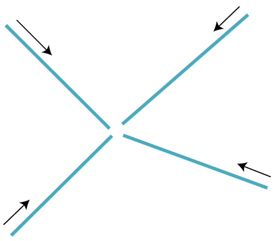


Visual complexity

Text that ends at an element

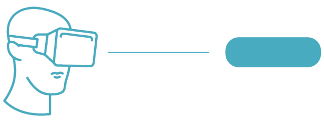


Converging lines

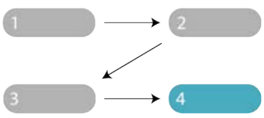


Place

Close, in front, eye-level

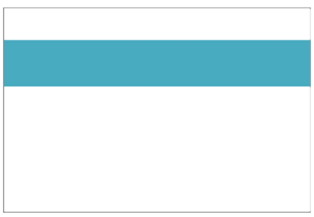


Z-figure pattern

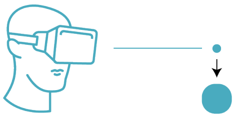


On the right

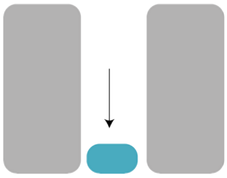
Page wide



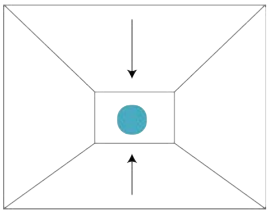
Close to gaze position



At the end of white space

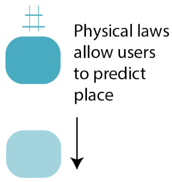


At vanishing points

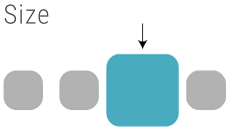


Properties

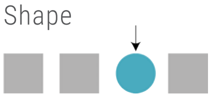
Physics



Size

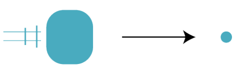


Shape



Animation

Movement towards point



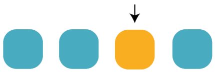
Movement at the point

Movement at point

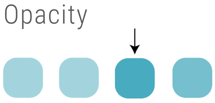
Blinking

Chemistry/State

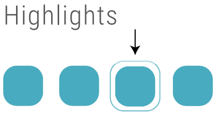
Colour



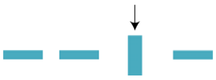
Opacity



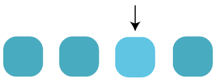
Highlights



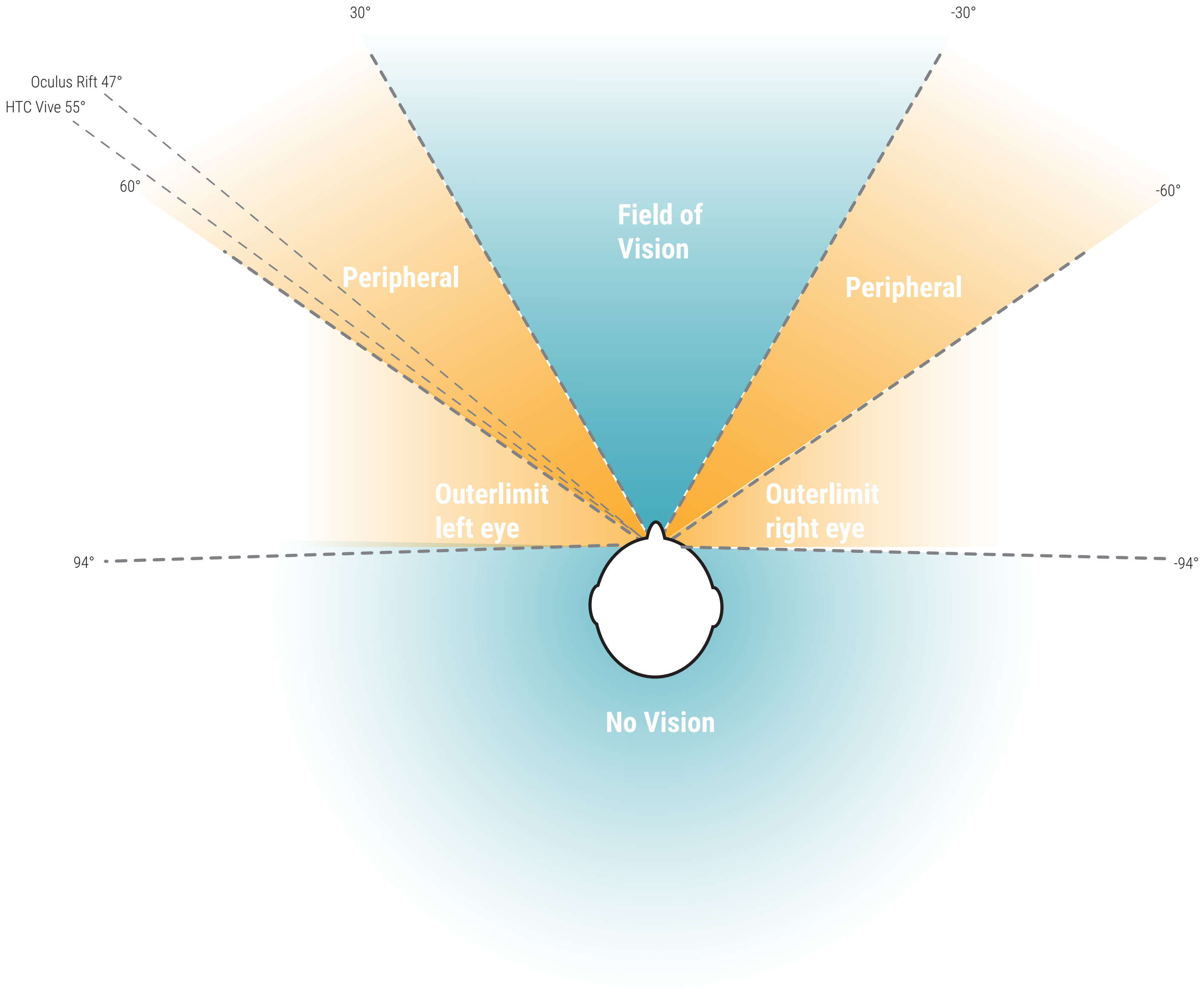
Contrast



Brightness



The aspects in the properties that are about the object but can also be applied in reverse; on the world. E.g. by lowering the contrast and brightness of the environment, objects can pop-out.



Oculus Rift, HTC Vive FOV from Davies, 2016
Human FOV from Dreyfuss, 1960

Figure 16: The fields of view of humans and the ones offered by the HTC Vive and Oculus Rift.

5. GUIDING ATTENTION: TOOLS

5.1 HIDDEN ELEMENTS

With tools to guide attention you can draw an immersant's focus towards certain objects. These object can be "hidden" in three ways:

1. Elements hidden behind other objects
2. Interactive elements hidden between non-interactive objects
3. Elements hidden outside the Field of View

For each of these three points there are several solutions and the decision was made to further investigate the elements hidden outside the field of view. Many solutions can be found for objects to stand-out. Therefore, the second option seems less interesting. Elements hidden behind other objects is also something that already happens (think of windows in front of other windows on your computer screen, or the ability to drag the notification screen down on your smartphone) and is therefore also less interesting. However, objects hidden out of sight that can be discovered by rotating your head seem to be native to VR and therefore the most intruiging. This also reduces the possible solutions for grabbing attention to those that persuade users to look around.

5.2 TOOLS

Selection of Tools
A lot of the tools work effective but have a specific application. Some tools work well when other stimuli are lacking; audio cues work well when there's no overwhelming sound, light cues work well when there are nog large light changes. Other tools can grab the attention because they are placed in front of the eyes. Since tools work in specific applications, it is necessary to pick a specific application.

Stegchel covered the theory behind visual cues that are outside the fovea. With a narrower field of view on the current Head Mounted Displays (Figure 16), it would be interesting to know how tools work that are placed outside this area of focus. Furthermore, normally objects are all visible on a screen, but with the ability to look around, immersants have the possibility to look away from objects. When you change aspects of these objects, like color, highlights or opacity, it won't matter because the image is not rendered on the display of the HMD. For this reason tools were chosen on the fact that they are not applied to the object outside the FOV of the HMD and chosen for their ability to guide attention to this object.

Appendix C.1 details the considerations for each tool. It is decided to focus the research on three tools and to focus on visual tools since audio will not always be used in VR and since the theoretical background of this research concerns visual, not auditory, information. Finally, it is decided to focus on more simple tools as these are more attainable to complete and test within the set time-frame. This also makes it easier for other designers to use these tools and change them to fit their goals.

Since it is possible to combine certain tools, it is decided to do so, as it allowed more tools to be tested within the same time. This all results in the following tools being tested:

1. Animation: Movement at the point (moves into FOV)
2. Changing reticle (combination with Arrow)
3. Converging lines

The first two are contrived from the work of Stegchel while the latter was found in a guide for website design and is also found in photography composition to guide a viewers attention (Krages, 2016).

These tools differ in their position and activeness. The arrow "attached" to the HMD and follows the user looking around while the converging lines and animation happen inside the virtual world, independent of where the user is looking. Furthermore, the animation is active, while the arrow and converging lines are passive.

These tools differ in their position and activeness. The arrow "attached" to the HMD and follows the user looking around while the converging lines and animation happen inside the virtual world, independent of where the user is looking. Furthermore, the animation is active, while the arrow and converging lines are passive.

Through iterations these were developed and resulted in the following tools (Figure 17):

1. Moving Ball
2. Swirl
3. Gaze Arrow

Moving Ball

The moving ball is grey, 25 cm in diameter, placed at eye-level and about three meters away from the user. It moves from its position left or right of the user, forward into the peripheral vision. It slows when it is close to the video and then reverses its speed and continues to make a "jabbing" motion at the place where the attention needs to be, as to say; "there it is". This motion takes three seconds.

During an early test, someone suggested to move the ball "around" an immersant, instead of having a straight line. The straight

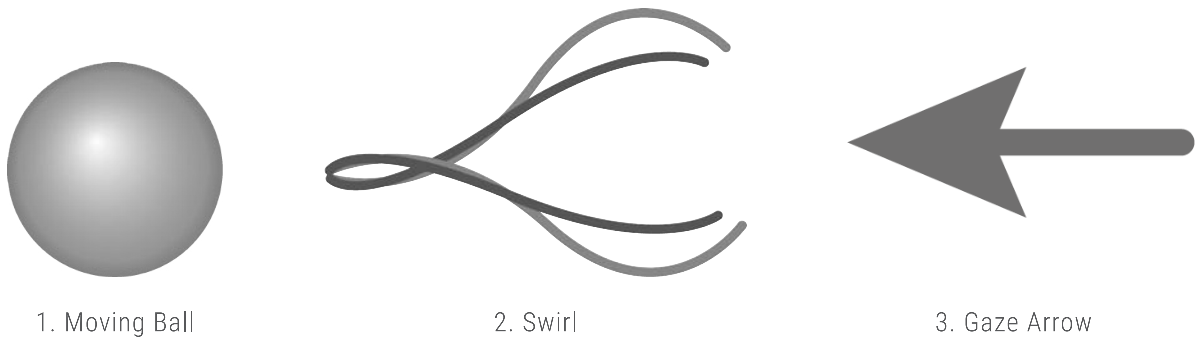


Figure 17: The three tools that were developed to guide attention to a certain point.

movement is experienced as a projectile coming towards you, while the circling movement around an immersant invites more to follow it.

Swirl

The swirl started as organic lines in the background as organic shapes are more attractive (Weinschenk, 2015). Someone suggested arrows and these were tested. It was then suggested to animate arrows since the arrows weren't obvious and felt like "part of the environment". The animated arrows were quite effective. However, the ball is already animated and the arrow is already featured with the "Gaze Arrow", so eventually the design was reverted to the swirl. This was made grey as well and placed on both sides of the screen, otherwise, being only on the left or the right could already suggest a direction. The lines would start large on one side and converge towards the other side at a certain point. It was decided to fade in the lines so that it wasn't always visible. At first it faded in and out within one second, but this motion was deemed to fast causing it to grab to much attention. In line with the other animations it was set to fade in and out within 3 seconds.

Gaze Arrow

The gaze arrow was a blue arrow situated in the middle of the vision, where normally the gaze reticle would be. Through iterations it was decided to remove the colour and turned grey. The arrow features a white border line so that the contrast is large enough with the surrounding and the arrow could be clearly distinguished. During initial tests it was mentioned that the arrow should be moved to the side so it doesn't occlude the main video. This also places the arrow in the peripheral vision, which is more interesting for this research as it is more subtle.

Figure 18: Picture of the HTC Vive used for development at UNITiD.

6. GUIDING ATTENTION: TEST

The selection produces multiple abstract tools that can help guide attention. But how effective are they, what would be a successful implementation and how and where should they be used?

6.1 RESEARCH QUESTION

This results in the following research question:

How is an immersant helped by being made aware of a specific object that is out of sight in VR through the guidance of his or her attention?

This question covers what tools can be used and how these tools should be implemented so that a user feels helped and not forced.

6.2 METHOD

With the theoretical framework and the evinced tools, assumptions can be made about what tools would work well for this situation.

Participants

The goal of this test is to generate insights in how the tools work and are perceived by immersants, therefore it is a qualitative study. Faulkner (2003) suggests user tests can find 80% of problems with 10 participants. The more diverse this group is, the more diverse the insights should be. This should also increase the chance of receiving more unique user feedback.

Differences in the experience level of participants with VR could lead to unique results. While experienced users in VR might already be accustomed to the device, controls and interaction patterns, a novice user might be overwhelmed with the possibilities and have a larger cognitive load causedby the new sensory input.

Men and women could generate different results. To exclude the possibility that certain observations won't occur, both men and women are included.

In short, the participants should differ on gender and their experience with VR. The participants were recruited from the university as they are more easy available time and location wise. The participants details can be seen in Table 1

Gender	Male	Male	Female	Female	Female	Male	Female	Male	Female	Male	Male	Male	Male
Age	22	18	24	24	24	23	23	20	23	24	19	20	23
Experience	Tried it once	Never tried it before	Never tried it before	Tried it once	Tried it a few times	Tried it once	Tried it a few times	Never tried it before	Tried it a few times	Tried it a few times	Never tried it before	Tried it once	Never tried it before

Table 1: Participants for the first test in order of participation.

Task

The participants are tasked with watching a video and are stressed to pay attention. They are told that afterwards questions concerning the video's content and build-up will be asked. This should motivate the participant to pay attention to the video.

The utilized video is about an Industrial Design Engineering alumni working at KLM and was chosen because the information density is high and the shots generally switch every three seconds and should give enough visual information to keep the attention of the participants at the video. The video's do not contain bright colors, flashes or other images or sounds that could over-stimulate the participant. Furthermore, the producer of the video has generously granted permission for the usage of the video in this research.

Walkthrough of Test

Once the participant enters they will be asked to sign an agreement in which they agree for their information to be used anonymously in this research and that they maintain the right to stop with the test at any time they wish (Appendix C.2). It is also explained that they will be recorded on video and that the data gathered in the research will be handled with care, stored online and anonymously published.

After age and gender are registered, the participant is located towards the VR environment and helped with putting on the VR headset, headphones, controllers and oriented in the right direction (where the video will appear). At this moment, the participant is stressed to pay attention as questions about it will be asked afterwards.

It is purposely left out that objects around them could be interactive to prevent them from looking around. The controllers are handed over to them though, because this would normally also happen and subtly communicate that interactions with the environment should be possible.

The participant will be shown the video. During the test, each tool will be used once with at least twenty seconds in between each usage. It will then be noted how the participant reacts. Each tool has different configurations and each of these configurations is assigned to a key. That way, tools can easily be used in different ways and in different orders each time.

In the case that participants not only react, but also act on the tool, a text box is placed each time at a location outside the FOV. The text reads "please say it out loud when you read this". This way it could be observed in what degree the participants focus was affected. After each tool, the text box was removed and the next one was set up for the next tool, during the test.

Once all three tools have been executed and the reactions have been registered the video playback is stopped. Each tool is then shown again and the participant is then asked whether the shown tool was observed by him or her during the video to double check the observations about tools being noticed. It is also shown so that participants can answer questions about each specific tool afterwards.

The HMD, controllers and headphones are taken from the participants and he or she is explained the goal of the test being about guiding attention. They are then requested to take a seat and answer questions concerning each tool.

Finally, the participant is then asked to share any ideas or suggestions to improve the tools and will then be thanked and receive a small chocolate as reward.

Schedule

1. Entry – signing participant agreement
2. Registering age, experience and gender of participant
3. Explaining VR system
4. Start video recording
5. Start video playback in VR
6. *Activate text in VR*
7. *Apply one tool*
8. *Activate text in VR*
9. *Apply another tool*
10. *Activate text in VR*
11. *Apply remaining tool*
12. Questionnaire ranking the different tools
13. *AttrakDiff questions to evaluate the tools*
14. *Inquiring suggestions*
15. Hand over little gift

Survey

It was decided to combine the observation form and survey and build them using google forms as it is easy to use and automatically generates illustrations that speed up the analysis. The actual survey can be found in Appendix C.3.

The first part is for the observer who fills in the age, gender and experience. Once the test is started the observer also fills in how the participant reacted to each tool. The options are:

- Not noticed
- Noticed, but looked in wrong direction
- Noticed, looked in right direction
- Moved head all the way in the right direction
- Moved head all the way in the wrong direction

Below each multiple choice there is room for extra remarks and observations.

Then the next page is opened and the participant is asked to rank the tools from best to worst in whatever way they see fit. Then they are asked to explain their answer. This should trigger participants to think about what they value and let them express their own priorities, instead of priorities indirectly suggested by the test itself.

The following three pages ask the participant to rate each tool on different scales, which are taken from AttrakDiff (Appendix C.4). AttrakDiff (Hassenzahl, Burmester, & Koller, 2003), asks participants to indicate their preference between two opposing word pairs on a scale with seven steps. These word pairs give insight in how participants appreciate a certain product, in this case what connotations people have with the three different tools. The word pairs order is randomized for every tool and every test. Word pairs are added so that the effectiveness, comfortability and intrusiveness could also be measured. When certain connotations are extreme, the observer asks why the participant felt that, to gain insight into the answers. These are then written in the next two questions.

These next two questions ask the participant why he or she thinks the tool works and what could be improved. This should give insight in what parts are effective with people and gives input for improvements.

The final page asks for any remarks or suggestions. Here the observer will talk with the participant and motivate him or her to really think deep and express any point not covered yet. Once discussed, the participant is asked to write this down. This way, the answer is quickly recorded (without the need of transcoding) in the way that the participant meant it.

Environment

The test is conducted in VR using the HTC Vive. Building a test environment in VR resembles the actual environment in which these attention guiding tools will be used much closer. It also allows for a greater amount of control since everything in VR is programmed.

With the use of Unity, a game developer platform, environments can be built and programmed and instantly tested with the HTC Vive. This allowed for an iterative design process in which the tools are be immediately tested. It also allows participants to make small suggestions that can be instantly tested. The HTC Vive supports an extra window that shows what the immersant is seeing (Figure 27). This helps in interpreting participants reactions and feedback as the observer can take note what the participant is talking about. Furthermore, Unity offers many fully developed examples off VR for the HTC Vive which can easily be repurposed to fit the research goals.

To test the tools on their effectiveness it was decided to eliminate almost all the surrounding elements in the virtual world. A grey floor plane was created on which the immersant could stand. The standard skybox provided in Unity was used. This skybox provides a globe around the immersant, starting with a dark blue on the bottom to a light blue for the sky and some effect to indicate the horizon. This helps with creating a sense of space. Otherwise there would almost be no indication that the user is seeing depth, or be in a VR environment.

A video screen was placed about 3 meters away from the user with a width of about 3 meter and 2 meters high (Figure 20). This distance is close enough to be comfortable. Furthermore, someone

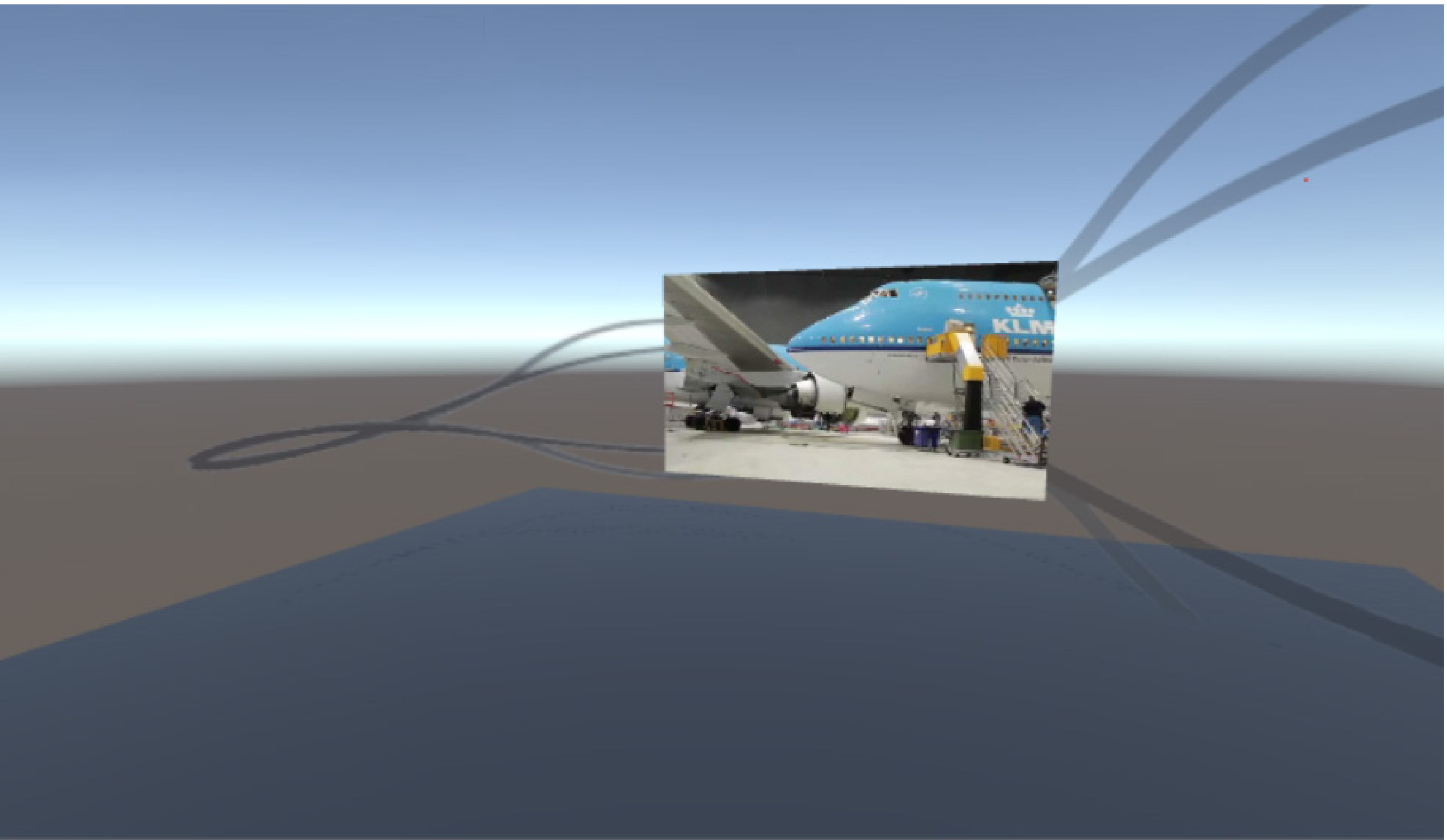


Figure 19: The swirls with the video in the VR environment.

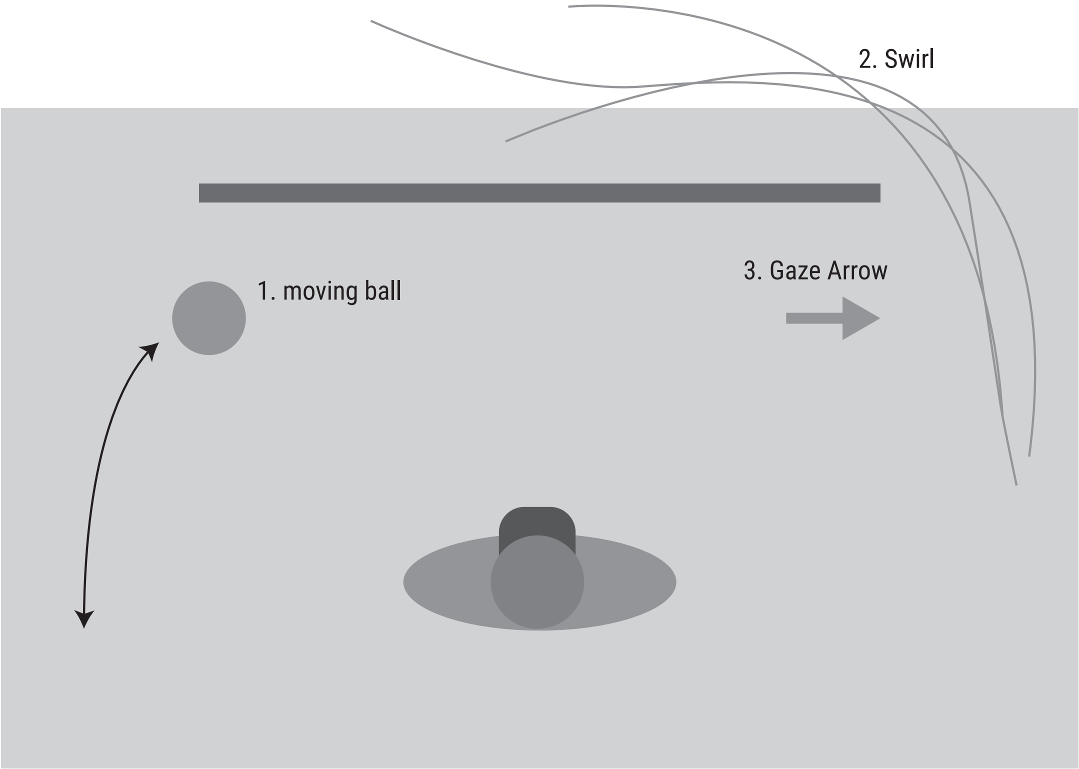


Figure 20: A top down view of the test environment.

Figure 21: The moving ball together with the video in the VR environment.

expressed that when the display was more to the back, he felt it was more part of the environment, not something intended to have all his attention.

A script is written that can be used to instantiate objects into the environment with an assigned button. Elements were created and animations were assigned to these objects. Combined with the script they are called into the world at any moment and they appear either on a preprogrammed position, or a certain distance away from a users' head (it would stay in the center, even when the head was moved).

A video of the environment can be found here: https://youtu.be/azyNaZ-ugew

Introduction of Tools

How do you introduce an object unnoticed, while the effect of the object should be noticed? For example, when there are converging shapes, are these already part of the environment, or are they introduced at a certain point in time? Especially when the environment is empty, introducing these converging shapes will likely already grab attention. For this reason it was decided to fade in and out within three seconds. The gradual movement is a lot less noticeable than when it happens within a second.

Figure 22: QR code to the video showing the test set-up and tools in action.

Figure 23: The gaze arrow together with the video in the VR environment.

6.3 RESULTS

Effectiveness

Figure 25 shows how participants responded to the tools. When the tools are placed in order of effectiveness the following list is created:

1. Moving Ball
2. Gaze Arrow
3. Swirl

Preference

The Moving Ball was the preferred choice, the Gaze arrow came second and the swirl last (Figure 24). The reason participants gave for this were that they did not see the swirl or interpreted it wrong as it was quite big and the lines opening could mean that there is something in the encapsulated area.

Semantics

The indication for each word pair were averaged and compared and can be seen in the jagged profile on the next page (Figure 26).

The participants written input was analyzed and a structured summary of quotes can be found in Appendix C.5.

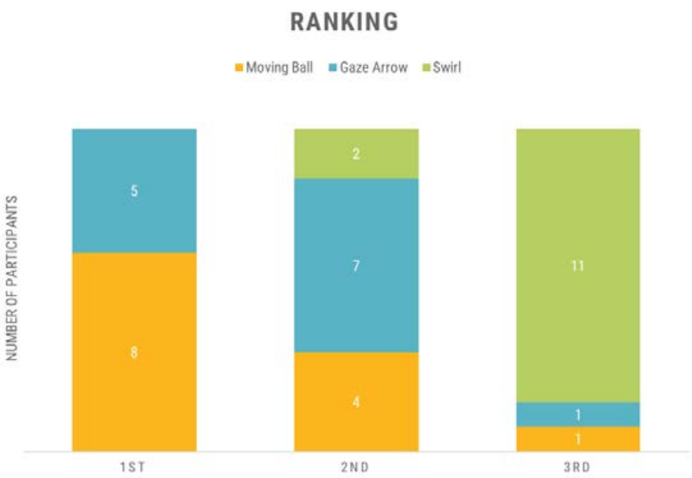


Figure 24: The distribution of 1st, 2nd and 3rd place for each tool.

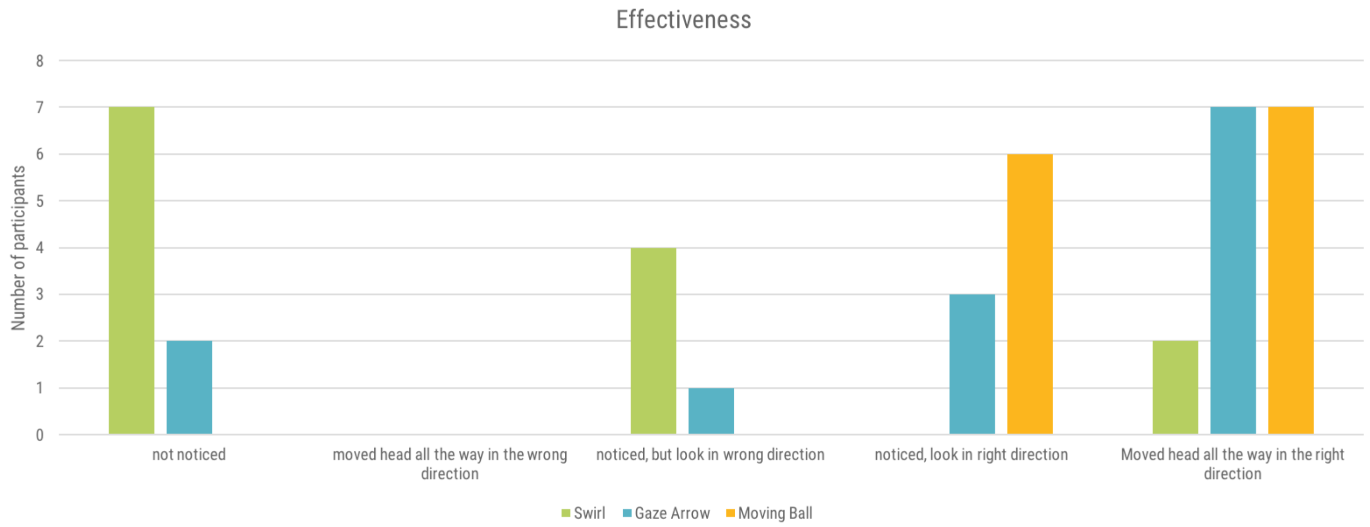


Figure 25: The effectivenes of each tool shown by how often each tool was marked in a certain "effectivenes" category.

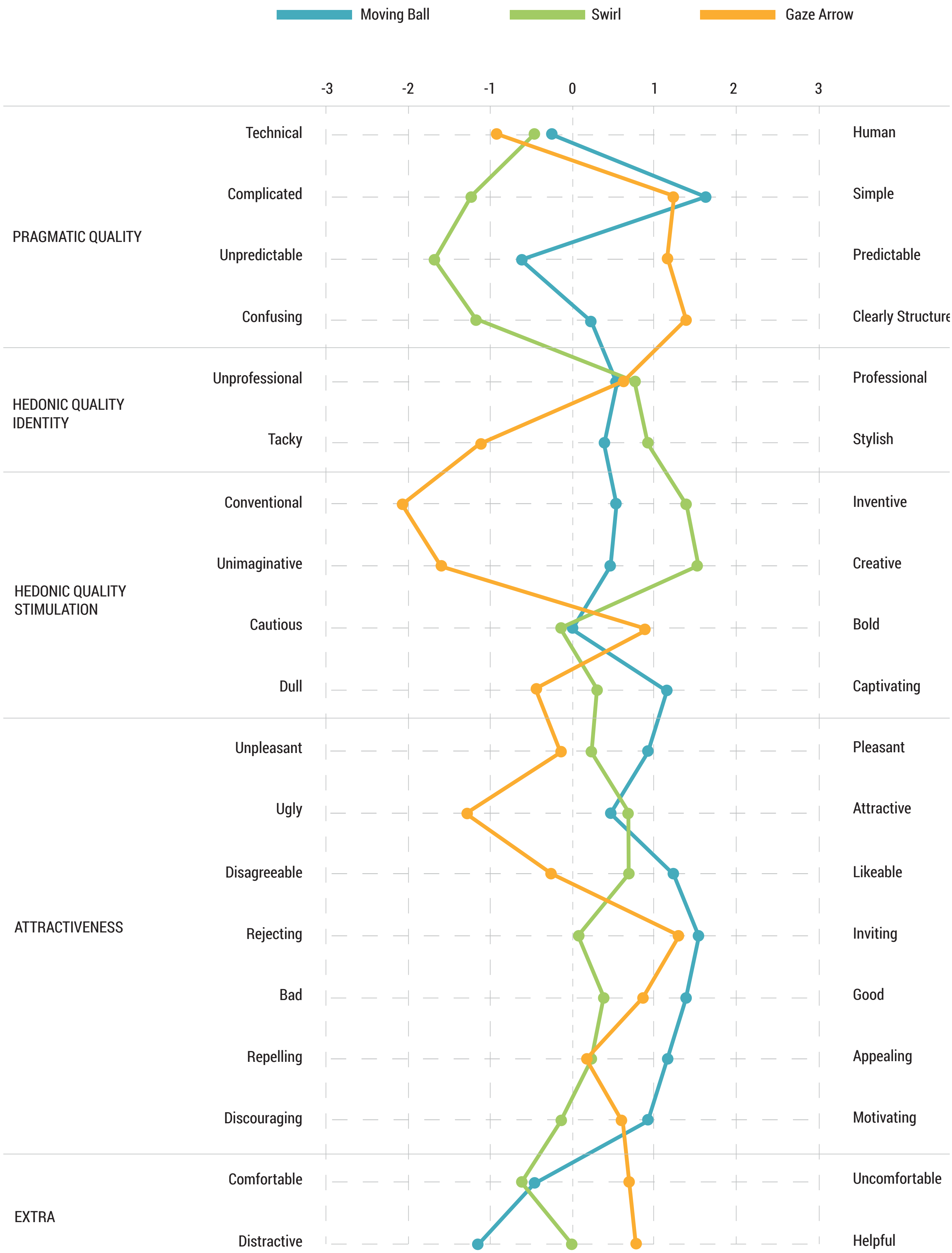


Figure 26: The jagged profile showing the average score given to the AttrakDiff questions in test 1.

Qualitative Data

Word Pairs

From the word pairs, much could be learned about how participants view the tools and what context is most appropriate. The following conclusions were drawn:

Moving Ball

Compared to the other tools the moving ball is most captivating. Although users found it quite pragmatic, it wasn't necessarily helpful; more distractive from the task they are doing than the other tools. However, participants did find it intuitive and overall attractive (as in pleasant, likeable, good, appealing and motivating).

Swirl

From the AttrakDiff word pairs it can be learned that the swirl is the least predictable of all the three tools. Participants also found it to be the most confusing one. It scores better than other tools on inventiveness, creativity and the hedonic quality stimulation, which means participants identify with it more. Finally, it is regarded the most comfortable.

Gaze Arrow

The Gaze Arrow scores highest at being clearly structured and predictability, making it the most pragmatic tool. Despite its effectiveness, it is regarded the most tacky, conventional, ugly and uncomfortable off all three of the tools. Neither does it score high in the stimulation part, meaning it is less supportive of the human need to move forward. Participants also identified the least with this tool.

Participants Reactions

Appendix C.5 holds a list with all the reactions of participants that are deemed relevant. Remarks that are already listed, or are worded better by other participants are skipped. These remarks are then grouped and the groups are given subject names. These subject names will be repeated here as they summarize quite well what the overall observations are.

Moving Ball

According to the participants the moving ball worked because of its motion, this automatically invited to follow the movement and the movement was sometimes seen as playful. It was stated that it is a subtle effect, but that it can also be somewhat vague. It is not clear that the ball is a cue to look somewhere. It was suggested to add an extra animation to catch attention and make the shape better fit its context.

Swirl

Most users appreciated the subtleness and aesthetics of the swirl. However, it often went unnoticed or its purpose was misunderstood and once noticed and understood correctly, the direction was also hard to interpret. It was suggested to make it smaller, more inviting and combine it with other elements like animation and fades.

Gaze Arrow

The arrow was deemed as something that all people clearly understand and are familiar with. It catches the attention a little less than the moving ball and it was suggested to add motion and make the arrow dynamic and react to the user. Some users felt it was somewhat forcing.

Other Remarks

It was mentioned that if you really want attention, you should place it in the middle of your vision. Other suggestions were faded lights on the side, making the video screen move in a certain direction and to make it react to the user's gaze. Finally, someone remarked he is less aware of his surroundings and therefore of these subtle cues.

6.4 DISCUSSION

Because the environment is entirely empty, anything added to it will most likely automatically attract attention. In this sense, attracting attention is not so much proven with these concepts. This is however not the sole purpose of the test, it is about guiding the attention towards a certain point. In this aspect, improvements could be made. Attention can be forced to go somewhere, for example by desaturating everything except for the piece in question. But then the user is interrupted and functions are blocked. Therefore, the focus is much more on the quality of the tools than the effectiveness.

It would have been better when the different tools would have had even less differences between them so that it could've been clearer what is causing the different results between the tools. In the current execution, the distance, size, animation, depth and color contrast within the tools differed.

However, by having tools that differ on more aspects, and having a qualitative test set-up, more information is gathered about the different aspects than what is possible with only minor differences between the tools.

The gaze arrow would have been interesting to test with objects other than an arrow. It is assumed that this would also attract attention, but this has not been validated through a test.

Initially the gaze reticle should change to an arrow. This iterated into a version in which the arrow was no longer placed on the reticle, but on the side of the vision field. The reticle changing, therefore has not been properly tested either. However, since participants expressed that the arrow is a clear indication to look in a certain direction, it can be assumed that the reticle changing to an arrow will also be effective, though this has not been validated in a test.

Finally, the converging lines most likely find their origin in photography and have much more to do with flat pictures that contain 3D construction in which a vanishing point is apparent. A more literal translation to VR would then be to place objects at the end of alleys, streets or paths, instead of lines that flow organically and vanish at a certain point. In short, the theoretical backing for the swirl is marginal. Nonetheless, it helped in the creation of a new tool with its own qualities.

6.5 CONCLUSION

To answer the initial research question, "How is an immersant helped by being made aware of a specific object that is out of sight in VR through the guidance of his or her attention?"
it can be concluded that a moving object is most fitting and natural in a virtual world, where it is part of the elements and helps users shift the focus of their attention through movement. Implementation is enhanced when the shape of the object fits with the context.

The arrow in the peripheral vision is a very clear instruction to move a certain direction. Although effective and professional, participants felt somewhat forced by it. It also doesn't blend in as nice with the environments as the moving object though and seems more appropriate for use with Flat User Interfaces.

Lastly, elements in the background can be used to steer attention in a subtle and comfortable way. It should, however, not be too big and stand out from the background. Animating parts of the element could help with this and more clearly steer attention.

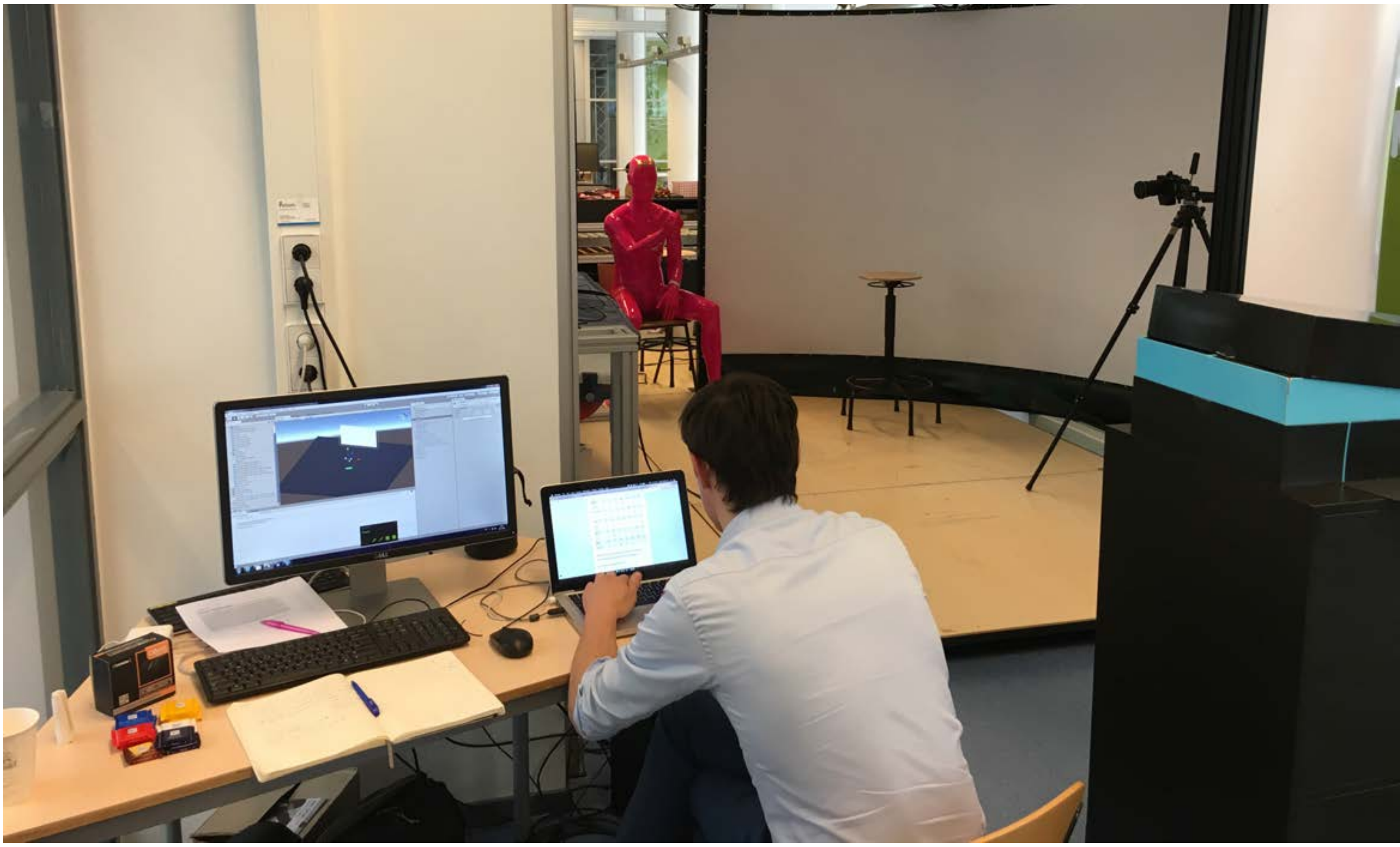


Figure 27: A picture of the physical test set-up with in the foreground a monitoring showing what the participant saw and on the right a particpant filling in the questionnaire.

Figure 28: A screenshot of Google Earth in VR.

7. SEE MORE: TOOLS

7.1 VISIBILITY

The tools previously tested are supposed to attract attention to a single object that is outside the field of view. The goal of the tool is to push the immersant to look in a certain direction. But would it be possible to allow the immersant to decide for him or herself in a certain direction? Another problem with the tested tools is that only allow a designer to guide the attention to one object; it doesn't allow the immersant to perceive several objects of interest outside his field of view. So, another method of catching the attention towards the object could be the reverse; first making the object visible and then let the object itself catch attention. The focus will be specifically on enlarging the visibility in VR and for this, several tools were developed and evaluated.

7.2 DEVELOPMENT OF TOOLS

Five tools to be more aware of your environment are lighting effects, a radar, a mirror ball, sideview mirrors and a birds-eye view. Their origin, selection and development for the test are described here.

Lighting

The idea is that brighter lights can grab the attention towards them. When everything is black, a bright light on one side should attract the attention (Figure 30). However, this idea is discarded. The presence of lights is only noticeable in dark environments whereas bright environments don't make the immersant aware of light sources (Figure 32). Lights also need something to shine on; surfaces, smoke, the environment.

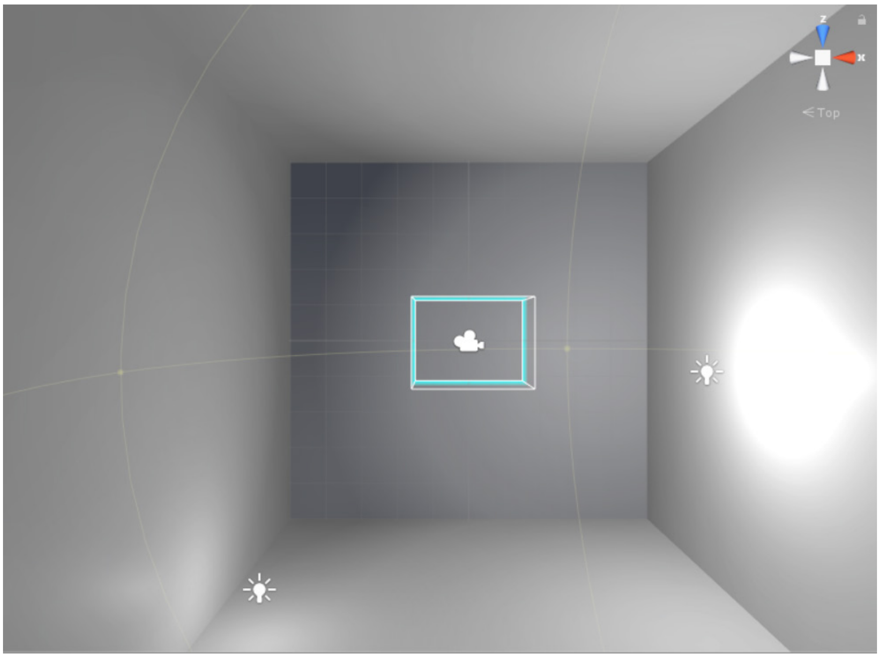


Figure 29: A top down view of the inside of a white cube. The blue rectangle with the camera shows where the immersant is placed. Two light sources are indiciated with light bulbs.

Through primary tests it became clear that they did not necessarily catch the attention of participants. The lights are either too subtle or deemed to be part of the environment (Figure 31). Especially when two lights are introduced (one brighter indicating more interesting elements, while the other less bright, indicating less interesting elements) they will blend in with the environment. To really catch attention, they would need to blink. This, however is deemed to not help with creating a sense of what is happening around a person. Only that attention urgently is needed (this tool would be more appropriate with guiding attention).

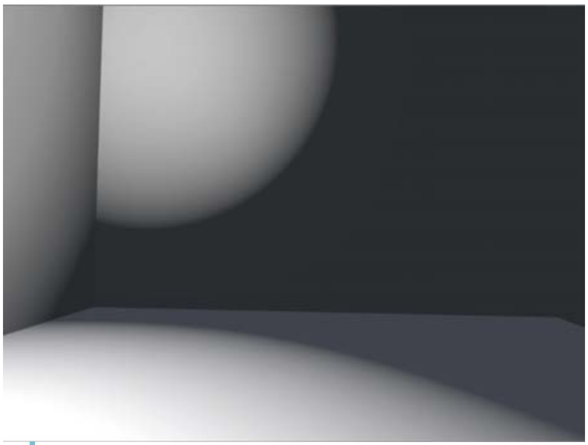


Figure 30: The camera is looking at a corner and the light coming from a source in the back left shining on the corner.

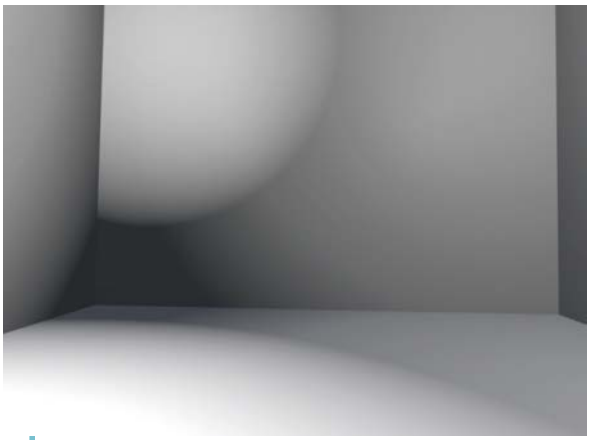


Figure 31:The camera is looking at a corner and the light coming from a source in the back left shining on the corner and a more ambient light is in the back right.

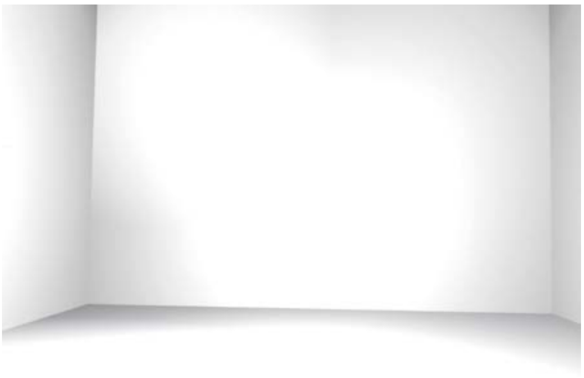


Figure 32:The camera is looking at a corner and the light coming from a source in the back left shining on the corner and a more ambient light is in the back right. A third, ambient light is added.

Radar
The radar is listed in the tools for grabbing attention featured in Appendix C.1. The radar allows an immersant to orient himself and see where he's looking at and how far he or she should turn to see something of possible interest.

In the test set-up, the radar consists of a triangle representing the field of view which the immersant can see and a circle and dots around the circle that represent objects of interest. The entire radar is paired with the head so that the radar always appears in front of the immersant, no matter where he walks or which direction he is looking at. The triangle's orientation is paired with the HMD though, while the circle with dots' orientation is paired with the virtual world so that the points of interest are always correctly aligned with the actual objects in the virtual world.

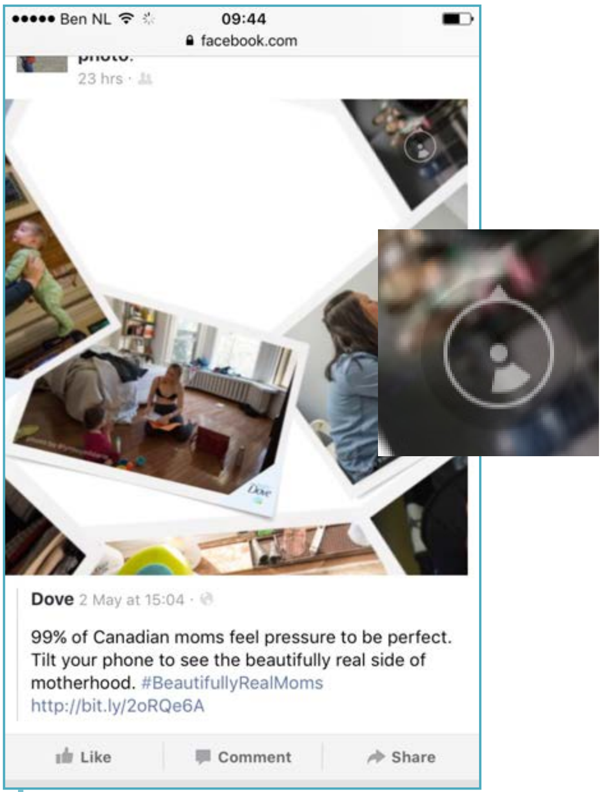


Figure 33:This DOVE commercial displayed on the facebook website on an iphone features a globe of pictures than can be discovered by rotating your smartphone. The radar in the top right shows where you are looking at and where the "front" is through the use of a triangle.

Figure 34:The radar in blue. The blue dot is indicating the white capsule.

Mirror Ball

To render reflections on digital objects, sphere mapping or environment mapping can be used (Kitagawa, n.d.); a spherical ball that perfectly reflects its surroundings. This inspired the creation of the mirror ball. The reflective ball is placed in front of the user, below eye-level so that it is visible but not in the way. Since the body is not rendered in VR, the surroundings are captured in the reflection of the ball. This can be used to see what is around the immersant. It is somewhat comparable to convex mirrors used in traffic to spot oncoming traffic that can't otherwise be seen. It should help drivers navigate their car through difficult areas. The mirror ball should help immersants in the same way to navigate the VR world.

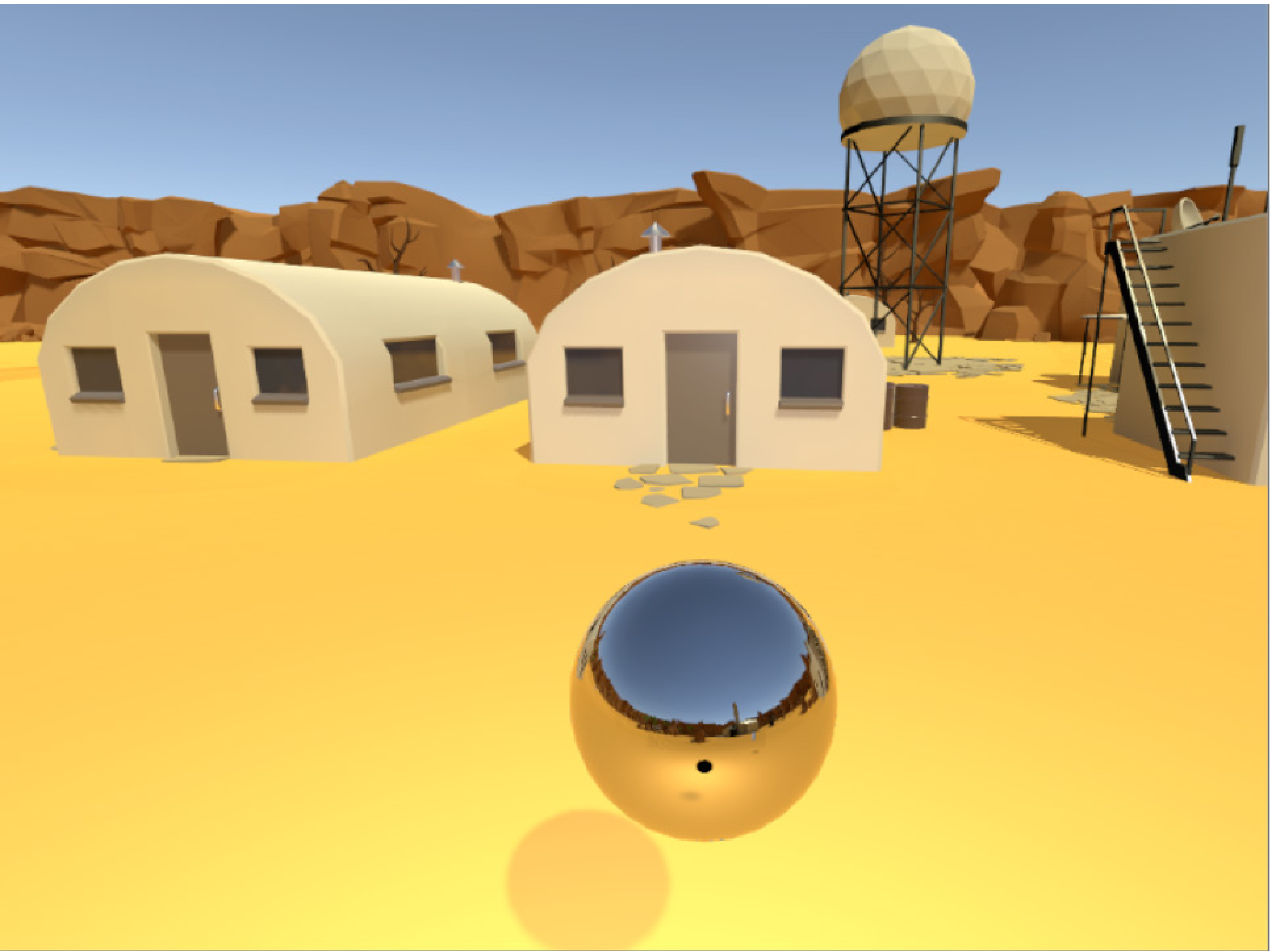


Figure 35: The mirror ball showing its surrounding environment. Note that there is no avatar, so there is no reflection of the immersant.

Sideview Mirrors

Inspired by cars that use sideview mirrors so that a driver can see what is happening behind him, two mirrors on the side are created. Initially these were square, but this made reflections in Unity to narrow. Then a cylindrical mirror was used, but not enough of the floor and ground could be seen. In the end, squashed balls were used as mirrors. However, it is decided to not further develop and test them. The reflections are too small and placed too much to the side to work effectively. If it would be bigger and more in view, it would greatly resemble the mirror ball.

Figure 36: The sideview mirrors, which are convex in shape. They closely resemble the mirror ball.

Birds-Eye View

On Mac OS X you have mission control (Apple, 2016) to get a "birds-eye" overview of all the windows and applications that are open and running. All open windows are reduced in size and presented on the monitor. The same can be done in VR in which the entire environment is reduced in size so that one looks down on all that there is. This is achieved by allowing the immersant to press a button which instantly sets the users location 25 meters higher and 25 meters to the back. Because you then look forward, the immersant is tilted 45 degree so that he looks at the area he was looking at.

While developing and testing it became clear that this created some anxiety as the participants feel they are high up in the sky, with the possibility of falling down. To prevent this feeling, a platform was added below the (not visible) feet and the immersant was not tilted.

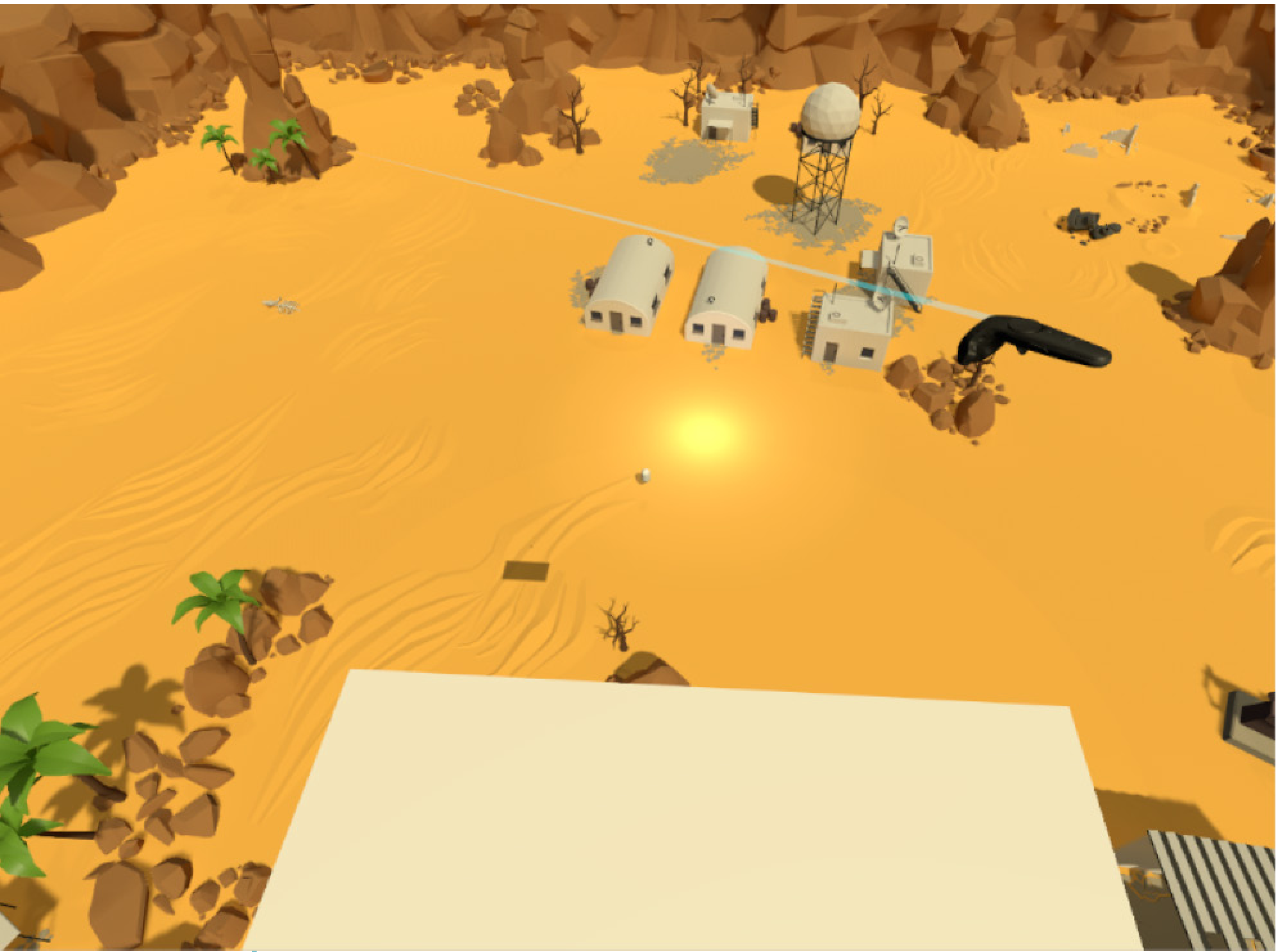


Figure 37: The birds-eye view. 25 meters up in the air and 25 meters to the back. A littel platform should make the immersant feel more safe.

Figure 38: A top view of the testing environment.

8. SEE MORE: TEST

Next to acquiring the associations and qualities of the newly developed tools, it is also interesting to learn how they score compared to the previous three tools that were tested to guide attention to one specific place. This test should therefore not only gauge the qualities of each "visibility" tool but also compare its effectiveness to the other tools for guiding attention.

8.1 RESEARCH QUESTION

A similar question as the one asked in the first test is posed. This time, however, the focus is on tools that allow immersants to see more of their surroundings.

How is an immersant helped by being made aware of a specific object that is out of sight in VR through 'the expansion of the visible'?

8.2 METHOD

The test set-up has some familiarities with the previous test, as the test is also done in a VR environment build with the help of Unity and it also evaluates the tools with the help of an online questionnaire. Therefore, some parts of the test method are not described here as they are already described in the previous test.

Participants

Table 2 presents an overview of the gender, age and experience of the participants. 14 participants, ranging in the age 22 to 59, took part in the test. Their experience with VR differed, but most had little experience being immersed in a virtual world. The distribution between males and females was equal.

Environment

The three new tools should help in making objects around the immersant visible. In a first test-setup it became clear that a sterile and empty environment, as used in the first test, was not appropriate since the object that needed attention would clearly stand out. It would therefore be hard to know whether the tool is effective, or whether it is because the environment is deprived of any distractions. For this reason, a more complex environment, a virtual desert world (Figure 38), provided in a Unity tutorial to build a tank game, is used. With this virtual world, testing the helpfulness of the visibility tools would become more realistic and therefore valuable.

Gender	Male	Female	Male	Male	Female	Male	Male	Male	Female	Female	Female	Female	Female	Male
Age	26	24	22	28	59	22	24	23	24	23	24	24	30	25
Experience	Tried it a few times	Tried it once	Never tried it before	Regular user	Tried it once	Tried it once	Never tried it before	Tried it once	Tried it a few times	Tried it once	Tried it a few times	Never tried it before	Never tried it before	Tried it once

Table 2: Participants for the second test in order of participation.

A white capsule, 0.5m tall, is used as the object that needs to be found. Its simple shape and white colour contrasts well with the environment. All capsules are placed 5 meters away from the participant at eye-level. It is either placed on the left or right side, but never entirely behind the immersant so that the time needed to rotate the head is about the same for each capsule.

A video of the environment with the tools is here: https://youtu.be/iBrmlHUTQFY

Task

The test-participants are allowed to explore the virtual world so that they are familiar with the surroundings. This is also done since the last test showed that participants are very curious and cannot always constrain themselves from looking around. Once they have seen enough they are asked to look forward and they are shown what the capsule they must look for, looks like. Then, in random order, tools are initiated one after the other and the participant is required to find each white capsule as fast as possible with the help of the tool. Once the capsule is found, the participant must notify the observer of this so that the time can be registered and the next tool can be initiated.

In Unity, each tool is programmed to a certain button. The corresponding capsule that needs to be found is programmed to the same button. This way, with the press of a button a tool is initialized and with the use of a physical stopwatch the response time can be registered. Each tool and capsule disappear after 15 seconds. The guiding attention tools are programmed in the same way as in the first test; they only appear for three seconds(Figure 39, Figure 40, Figure 41).

Figure 42: QR code to the video showing the test set-up and tools in action.

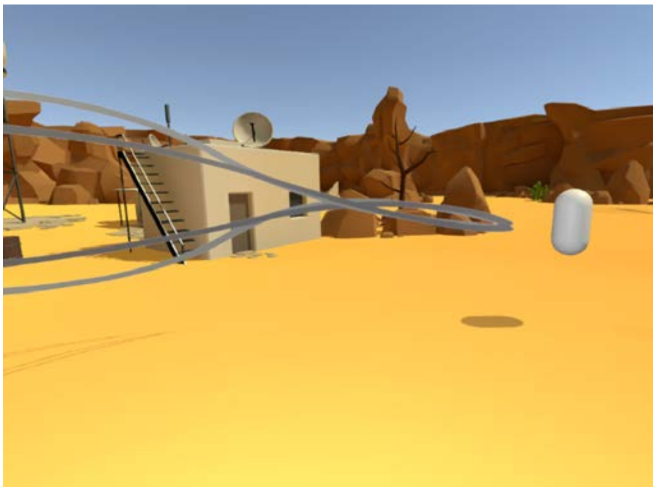


Figure 39: A screenshot from the test with the swirl pointing towards a capsule.

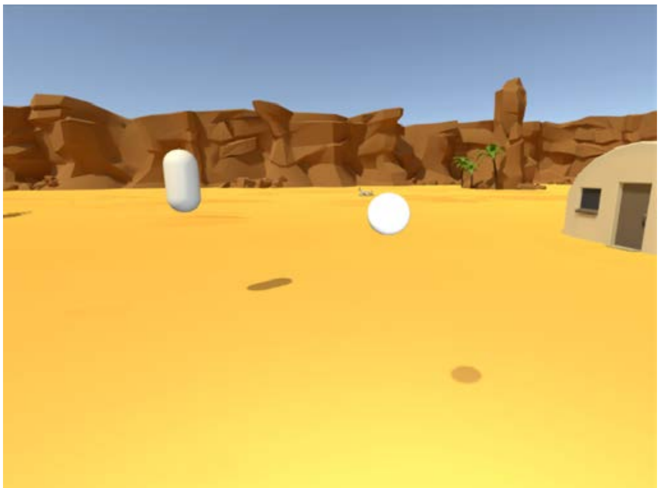


Figure 40: A screenshot from the test with the ball animated towards a capsule on the left.

Figure 41: A screenshot from the test with the arrow in the peripheral vision aiming towards a capsule on the left.

Comparing Tools

With this setup, the time to find the capsules can be recorded and compared to obtain a sense of the relative effectiveness of the tools. By adding the tools that guide attention to this set-up, a comparison can be made between the effectiveness of tools that guide attention and tools that enable visibility of objects outside the FOV. Participants could become more fluent in the task of finding the capsules, which could affect the final results. To reduce this, the order of the tools, for each participant, are randomized.

Evaluation Form

Just like the first evaluation form, this form (Appendix D.1) first has a section only for the observer in which he records age, gender, experience and the time needed with each tool for each capsule to be found.

In the same way as the first test, the participant is asked to rate all tools, including both guiding tools and visibility tools. Since this test is about finding the capsule, the option "nothing" is added in case participants prefer no tool or prefer just looking around.

To compare the results of the qualities of the first three tools to guide attention, the same AttrakDiff word pairs and evaluation will be used for each of the visibility tools. These can then be compared with the ones recorded in the first test.

To further compare the two methods of making an immersant aware of an object, a question is added that asks for the preference of the participant concerning tools that guide attention and tools that make objects outside the FOV visible. They are also asked for their reasoning.

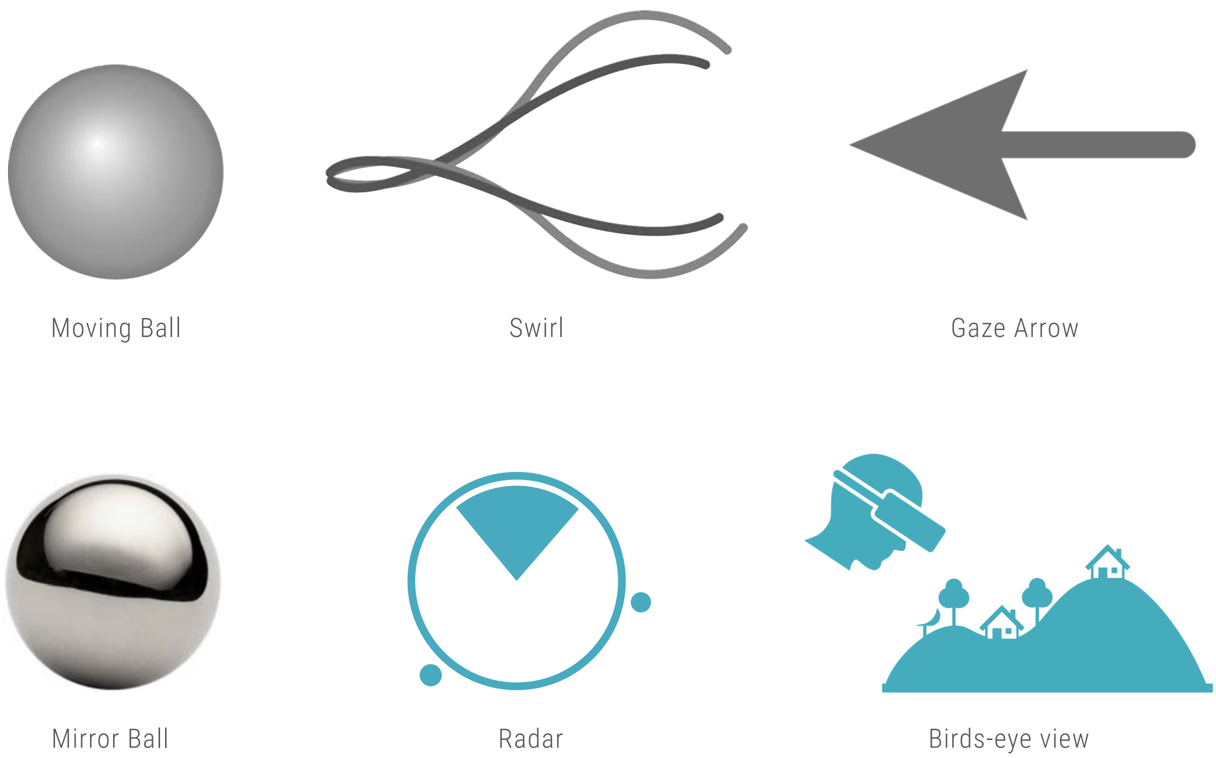


Figure 43: All the tools that are used in the second test.

Schedule
The test is run according to the following schedule:

1. Entry – signing participant agreement
2. Registering age, experience and gender of participant
3. Explaining VR system
4. Explaining the visibility tools
5. Place participant in the VR environment
6. *Use 1st tool*
7. *Note time from button press to finding*
8. *Use 2nd tool*
9. *Note time from button press to finding*
10. *Use 3rd tool*
11. *Note time from button press to finding*
12. *Use 4th tool*
13. *Note time from button press to finding*
14. *Use 5th tool*
15. *Note time from button press to finding*
16. *Use 6th tool*
17. *Note time from button press to finding*
18. Questionnaire ranking the different tools
19. *AttrakDiff questions to evaluate the tools*
20. *Inquiring suggestions*
21. Hand over little gift

8.3 RESULTS

The information from the evaluation form is analysed and discussed here.

Effectiveness
The orange dots in Figure 44 represent the average time needed for each capsule, and respectively each tool, to be found. However, as one can see in the boxplot, the time with the same tool and capsule differed for each participant. All the tools, with the exception of the moving ball, produced finding times below three seconds.

The birds-eye view is clearly the fastest. However, the moving ball has an introduction in which the ball moves into the field of view. It takes 1.5 seconds before the ball changes direction towards the capsule. Taking this into consideration, it would score better than the swirl. The mirror ball is the least effective as it has both the highest mean and median.

Off all the visibility tools, the birds-eye view tool resulted in much faster times than the radar and mirror Ball. This might have to do with the fact that many participants needed some time to interpret the radar and mirror ball. Or, one could say the birds-eye view took the least time to interpet.

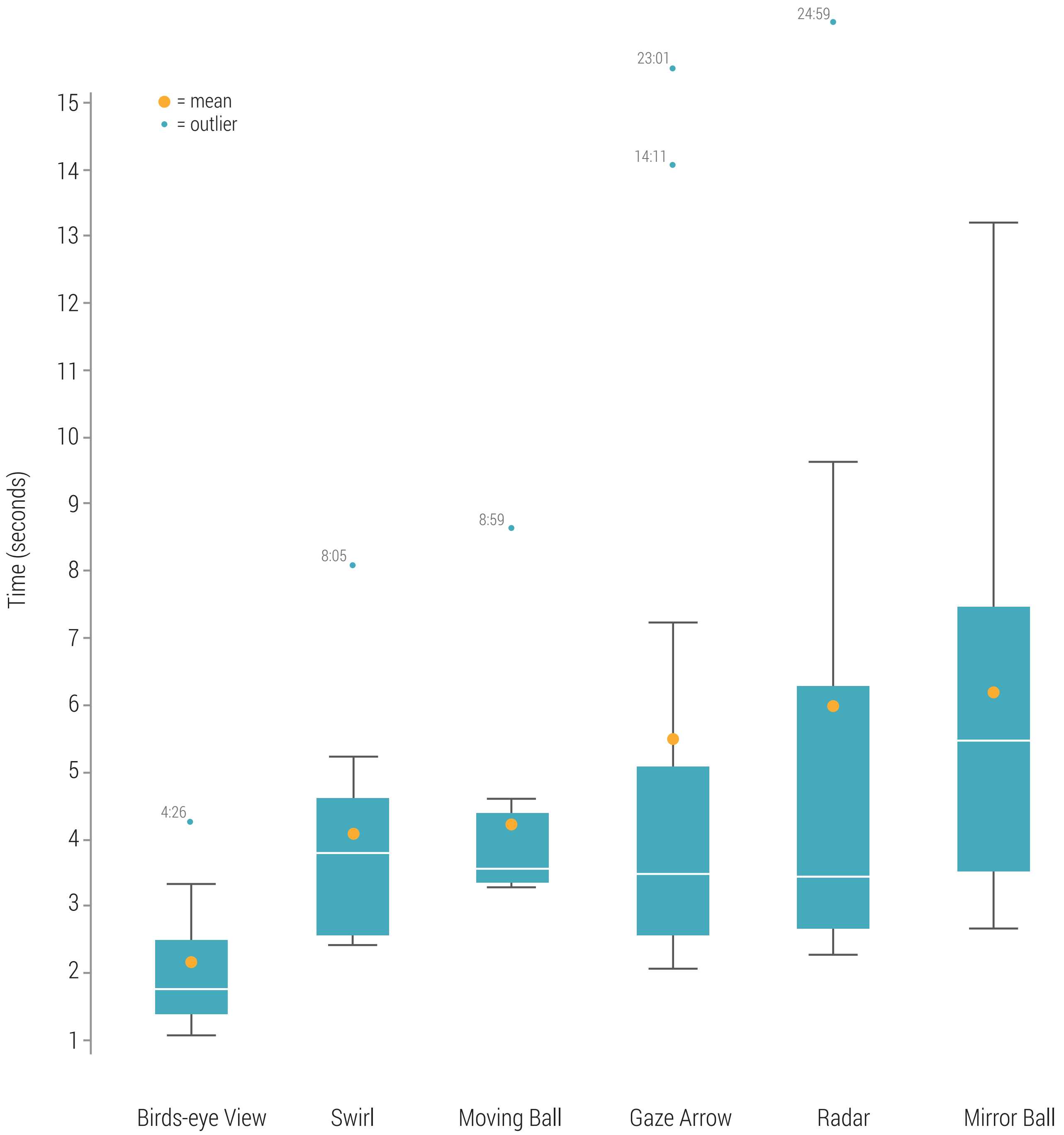


Figure 44: A boxplot of the measured times for each tool. The white bar is the median while the orange dot is the average time. The outliers were also used for the average times.

Preference

Figure 46 shows the distribution of votes for each tool. The first thing that is striking is the fact that there is no clear winner. When each vote, starting with 1st place, is multiplied with 7 to 1 respectively, Figure 45 can be drawn. Here it becomes especially clear that, on average, participants do not have a clear preference and that no tool is notably better than the others.

It seems that most participants favoured any tool over having no tool. In addition, of all the tools, the mirror ball was distinctly preferred less than the other tools.

Semantics

The results of the word pairs were averaged and turned into a jagged profile ().

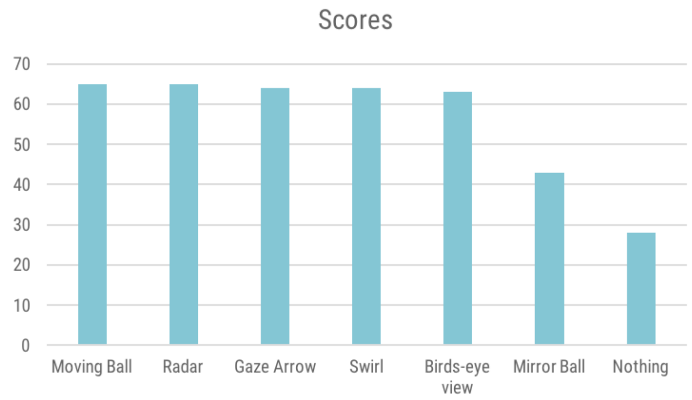


Figure 45: Each tool had its ranking multiplied by 7 to 1 and these numbers were added and created the seen scores.

Figure 46: The distribution of each tool over the several rankings. There is not one tool that received about the same ranking from the participants.

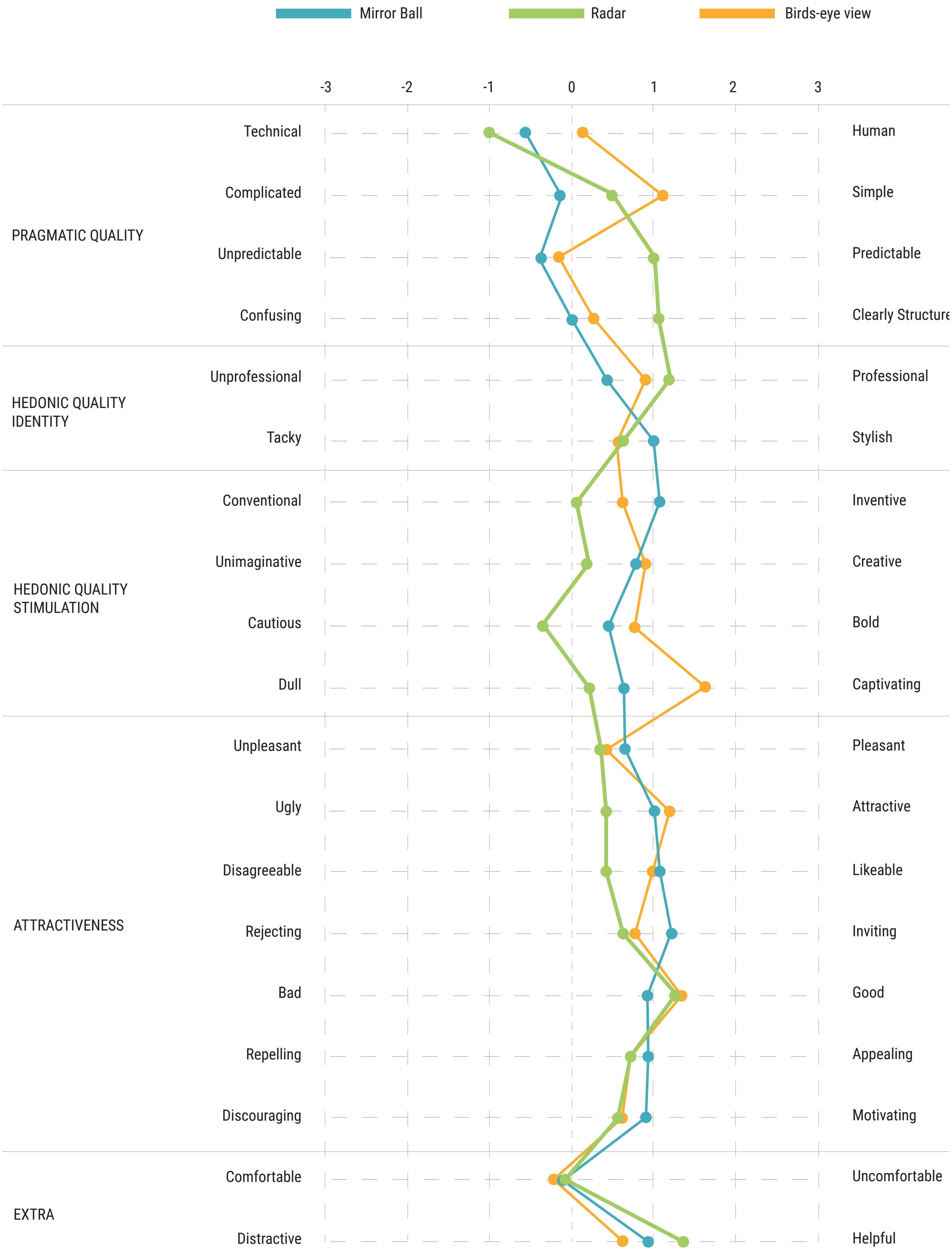


Figure 47: The jagged profile showing the average score given to the AttrakDiff questions in test 2.

Qualitative Data
Participants were asked to explain their choices and add their arguments. These written answers are analysed and structured (Appendix D.2). The themes and structures that occurred are used to do a qualitative analysis.

In general, participants explained that the visibility tools required more thinking as the tool had to be understood and interpreted. They also expressed that it was hard to order the tools from best to worst since they were all quite useful. Some mentioned that the tools with familiar elements are easier to use. Furthermore, someone mentioned that the larger objects are more obtrusive to the view.

Mirror Ball
From the AttrakDiff jagged profile it can be learned that the mirror ball is less pragmatic than the other tools. Participants did find it stylish and inventive and it scored good on attractiveness.

In the clarifications of their quantitative data, participants explained that it took them time to understand how the mirror ball works. Details were quite small and they suggested to try different shapes and sizes. However, participants did appreciate the ability to instantly see all around them.

Radar
The radar is the most pragmatic tool, according to the jagged Atrakdiff profile. Participants found it the most predictable and clearly structured. It is also deemed the most professional and the most helpful. However, it inspired participants the least as its hedonic quality stimulation scored below the others. Participants neither found it the most visually attractive.

Participants explained that they appreciated the filtering function of the radar in that it isolated key points of interest. It helped them to orient themselves in the virtual world. Some participants expressed that they found the radar familiar as they have seen it in other games and applications. However, just like with the mirror ball, participants explained they needed time to understand the radar.

One participant noted that it helps to find the right orientation to find an object, but that it doesn’t give you any sense of distance to that object.

Finally, some suggested to change the design of the radar; changing the colours and moving the dots inside the circle.

Birds-Eye View
Although simple, the Birds-eye view is rated as the least stylish of all three tools in the AttrakDiff form. It is also rated as the least helpful of all three tools, which is interesting because it did score the fastest times with finding the capsule. It was neither the most or least attractive tool.

It was expressed that it creates a good overview of the entire environment, but that it was harder to reorient oneself once back down. The suggestion was made to create an avatar so that participants could better understand their orientation.

Participants also expressed that details were small and too many and that perhaps a filter could help in distinguishing important objects from other objects. It was also suggested to have different steps of zooming out and making the transition smoother.

Many participants expressed that the sudden position high in the air could be somewhat scary and suggested measurements to make it feel safer.

Finally, one participant expressed that this tool kept the participant in control.

8.4 DISCUSSION

The test was focused on finding one single object. This works perfect with the guiding attention tools that guided the participants' attention directly to the capsule. However, the visibility tools were optimized to find multiple objects, not just one. In this sense, they were at a disadvantage on the guiding attention tools. Furthermore, the guiding attention tools didn't need any instruction to be understood. The visibility tools would likely have scored better when participants were more accustomed to using them. This skewed the timing results.

The time needed for finding the capsule with the birds-eye view was the fastest on average. It should be noted though, that often participants found the capsule while in the birds-eye view. The observer did not interrupt and instruct participants to go back to their original position and then find the capsule again. If this would have been the case, the participants would have most likely needed more time to re-orient and find the capsule.

Finally, when participants were asked to order the tools, the option of "no tool" was included. Participants, however, were not challenged to find a capsule without the help of a tool. No baseline measurement was taken because the recorded times were intended to compare the tools relative to one another. In hindsight though, it would have been valuable to gather this data so that the tools could have been compared to a situation without tools.

8.5 CONCLUSION

From this test can be learned that all the tools are deemed useful, with the exception of the mirror ball. With the ability to show more comes also the need to filter this extra information. When there is only one object, it would be better to use a tool that guides attention. When the user needs to be given more control or requires an overview, the visibility tools seem more appropriate.

The mirror ball is a nice idea, but it needs to be larger, which would make it impractical. Filtering information could help in finding objects of interest faster. However, the distortions and small details seem to be a hurdle for many immersants.

The radar did filter information, which was greatly appreciated, but took a moment to understand. It helped participants to orient themselves but doesn't give an indication of distance. Changing it more into an actual radar or combining it with a map could help orient immersants even more.

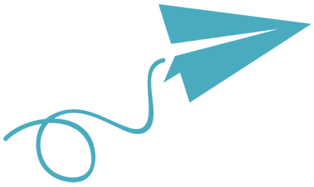
The birds-eye view created a fast to understand overview but had an overload of information. The sudden height immersants are placed at, is neither appreciated. To circumvent this, a miniature world could be used wherein the virtual world is shrunk so that the immersant can see the entire world. The difference between relocating the immersant and shrinking the world is the depth perception; in a miniature world, the immersant does not get the feeling of being high up in the air. This miniature world could also accentuate certain features. Finally, it would be good to add an avatar so that immersant can better orient themselves and link what they see in the overview with what they see back in their original location.

Inspiration should be taken from current navigation software, like Google Maps navigation or the TomTom, where they combine directions, simplified maps and an avatar together with a birds-eye view to help users find their way.

The answer to the question “How is an immersant helped by being made aware of a specific object that is out of sight in VR through ‘the expansion of the visible’?” would be that it helps to create an overview, preferably with the use of a radar or a miniature world. An immersant is helped even more when the information is filtered. When he or she is looking for a specific object it is more helpful to guide attention then to make more of the surroundings visible.

Figure 48: Screenshot of the first person view in the playstation VR game *Robinson: the Journey.*

Figure 49: Screenshot of the same area as in Figure 48, however this is a miniature representation of the entire area which the gamer can activate.



Animated Object

guide attention

- Most Effective
- Specific Point
- Integrates Well
- Captivating
- Intuitive
- Playful

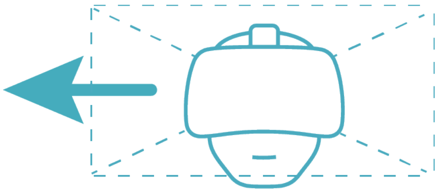
- Distractive

Converging Lines

guide attention

- Most Subtle
- Specific Point
- Creative

- Easily Missed
- Needs Animation



Gaze Arrow

guide attention

- Most familiar
- General Direction
- Professional
- Clear

- Ugly
- Forceful

Mirror Ball

create overview

- Take time to interpret
- Aesthetically interesting
- Instant overview

- Least favored

Radar

create overview

- Takes time to interpret
- Most pragmatic
- Clearly structured
- Helps with orientation

Miniature World

create overview

- Creates overview
- Instantly clear
- Gives control to user

Figure 50: The tools in their final iteration, together with the findings from the tests.

9. CONCLUSION

This report contains a small set of interaction patterns that are already employed in VR applications. Six tools that should aid people in VR worlds are formed and tested and can be added to the interaction pattern guide. In Figure 50, the six tools and their results are summarised. This summary shows the value each tool has and where they can best be implemented. These values are embodied in a short scenario that should help the reader imagine how the tools can be implemented.

9.1 EXAMPLE SCENARIO

To elucidate on the application of the tools a scenario is presented in which each tool is featured and shows how they could be applied.

Imagine a training program in which an immersant is taken through a chemical lab and instructed on how to combine and treat chemicals to create a new chemical (Figure 51, Figure 52). The VR experiment should make the immersant familiar with the rules of the lab but also make him familiar with the room itself.

Animated Object
The lab-environment is loaded and the immersant can look around. After a set time, a paper-plane flies into his field of view. The immersant follows the paper-plane which lands at the beginning of a long table with all kinds of materials. Here the immersant finds a paper-note that explains that the immersant will create a new chemical.

Converging Lines
Behind the table large arrows start animating, indicating that the immersant should work from left to right. Two erlenmyer flasks are highlighted and start to pulse, indicating the immersant should start there.

Figure 51: A chemistry lab working table.

Figure 52: A picture to show what the chemistry lab simulation could look like.

Peripheral Arrow
The instructions read that a solution must be added. This solution can be found in the fridge under the table. An arrow in the peripheral vision appears that is pointing down. The immersant finds the fridge underneath the table and finds in it the needed solution. He proceeds to pour the solution in the flask and finishes this experiment.

Miniature World
After this the participant is free to walk around and check-on experiments that are running in the lab. Using the miniature world, the participants instantly sees what other experiments are running and what their state is. One experiment has a pan that is flooding with its bubbling solution. So, the immersant goes back to his normal view and walks towards the pan.

Radar
The immersant is notified that there are several instruments he can use to stop the pan from overflowing. A radar appears on which several points of interest are indicated. The immersant orients himself to face those points of interests and sees they indicated a pan-lid in the far corner and a fire-extinguisher on the other side. The immersant decides to go for the pan lid as the radar shows it is closer, and walks towards it. The radar removes itself once again from the immersants field of view.

Mirror Ball
While the immersant walks towards the pan, he can keep an eye on the experiment with the use of a mirror ball. This also allows him to check whether other experiments need his attention. When he is halfway, he spots a huge fireball in the mirror ball. Apparently the experiment released volatile gasses that caught fire. Still looking at the mirror-ball, the immersant can spot something else in the room that starts to blink. It is on his right side. Once he points his head there he sees the fire extinguisher. With this he extinguishes the fire and the simulation is ended.

9.2 RESEARCH QUESTIONS

After a multitude of interaction patterns were indexed, the direction towards guiding attention was taken. This led to the question how immersants could be made aware of objects outside their field of view. Answering this question helps with answering the initial question:

Research Question 2:

How can the use of Virtual Reality Applications be improved so that immersants can use Virtual Reality applications more efficiently and with more ease?

Based on the tools that were developed and the tests that were conducted it can be stated that virtual reality applications can be improved by using tools that guide attention of users towards objects outside their field of view, or the use of tools that allow an immersant to be more aware of his or her surroundings. Through these tools, immersants feel more in power and are enabled to use applications more efficiently and with greater ease as they are enabled to see more. The tools help them find out what is possible in the virtual world.

9.3 CRITICAL NOTES

Some critical notes must be stated concerning the findings and qualities of the tools. Firstly, the tools have been tested on a small group of participants, with only one nationality, at only one date. It is conceivable that people from other countries, or after some years, might react totally different. These results should therefore be taken as a starting point and implementations should be tested.

The same goes for the patterns found. These are found in a time that VR-developments are fast and a lot could change in the coming years.

Furthermore, the effectiveness of the tools has not been tested. The tests gauged the reactions of people on the tools and aimed to give more information on the implementation of the tools. However, some people could still ignore the tools, or prefer looking around on their own initiative. The positive results from the test could have been the result of the participants' willingness to help the researcher. On the other hand, the tools do create an extra motivation for the immersant to see more.

It is also imaginable that VR headsets will eventually have larger field of views. Then, immersants are able to see a lot more already without needing the help of these tools. Still, the tools can guide attention to objects behind immersants and allow more functionality like prioritizing and direct guidance to a certain spot.

Finally, it must be acknowledged that many of these tools are already present in some way. Many games, for example, already use radars and arrows to guide their users. The value of this report, consequently, is not so much in identifying these tools but much more in their application and evaluation in VR.

9.4 HELPING DESIGNERS

The six tools treated in this report can be added to the list of interaction patterns. The goal of this report is to help designers with designing interactions in VR and it is believed that alongside the succinct interaction pattern guide, these six tools should inspire and help designers to create VR applications that immersants will enjoy using.

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APPENDIX

APPENDIX A.0

Supporting Research Questions

Introductionary

- What is VR?
- What are the possibilities in VR? (Flying, moving, seeing, hearing, creating, navigating)
- Where can VR be implemented?

- What kind of input devices are there? (Remotes, leapmotion, trackers)
- What kind of input is used?
- How is input done?
    - How is input translated to action?

- What are current VR applications?
    - What are the possibilities in these applications?
    - How is the interaction shaped?
    - How is the interaction guided?
    - How is the interaction explained?

Interactions

- What interactions are there in VR?
    - Which interactions are copied from the real world?
    - Which interactions are native to the VR world?
- What are the elements of VR? (world, display, interaction, sound, visuals, controllers)
    - What is a good VR experience?
    - What are essential elements for successful VR?
    - Why are these elements important for success?
    - How are they integrated when they are successful?
    - What creates bad VR experiences?
- Which themes for patterns in interaction design in VR are there?
    - What are the patterns in these themes?
- How is attention guided in VR?
- How is the environment shaped?
- What is comfortable to look at?
- What are comfortable motions?
- What role do haptic, audio and visual feedback play?
    - In what way are haptic, audio and visual feedback given?

- What products are out there? (Daydream, Vive, Oculus Rift, Cardboard)

APPENDIX A.1

App testing setup

Besides the literature, articles and guidelines that exist, good interaction patterns also exist in current VR applications. Therefore, a selection of Virtual Reality apps have been selected to test and analyze. The goal is to find qualitative data; what interactions seem to work well. In a later stage the findings can be confirmed.

RESEARCH QUESTIONS

- What VR apps have good interactions?
    - What do these good interactions look like?
- What are bad interactions?
    - What do these bad interactions look like?
- How are these apps designed?

METHOD

Setup

Multiple virtual reality apps were tested on three platforms; Google Cardboard, Playstation VR and the HTC Vive.

These platforms respectively have an increasing level of possibilities. Apps were walked through three times; the first time to get familiar, the second to write down notes and the third time to collect screenshots and double check observations.

The observations were then collected. Observations that occurred frequently were noted. These observations were then added to the patterns list. If it was already there, the annotation "assessment tool" was added to indicate it was observed in actual apps.

Lastly, all the screenshots were printed, grouped and assigned to the themes of the patterns.

Assessment criteria

From the literature study, multiple patterns have been found. These have been clustered into subgroups and themes. The VR applications are analyzed with regard to each of these themes. The apps are also rated from 1-5 on their usability using the five dimensions that Nielsen (1994) uses to rate usability; Efficiency, Learnability,

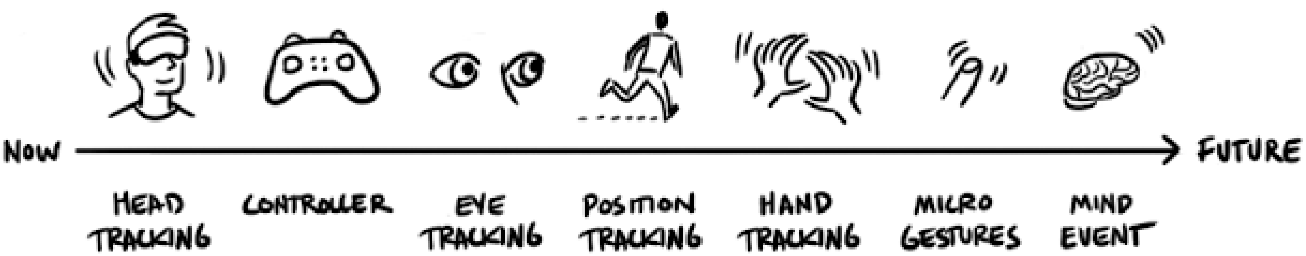


Figure 53:UXness - Virtual Reality – Timeline. A timeline to give an idea of the different levels of complexity.

Memorability, Errors and Subjective Satisfaction.

Beside this information the app name, a description of the app, the platform and notes, for important information that doesn't fit any of the other criteria, were recorded.

- Apps\Assesment criteria
- Description
- Platform
- Notes
- Efficiency
- Learnability
- Memorability
- error
- Subjective satisfaction
- Menus
- Object selection
- Object translation
- Object manipulation
- Controls
- Ergonomics
- Motion Sickness
- 2D interface
- 3D objects
- Locomotion
- Animation
- Audio

Apps

The selection has been based on a top 10 of VR applications by Friedman & Mullins (2016) a top 20 of cardboard applications by LeClair (2016) and the titles on Viveport (2011) with a tendency towards functional applications that are rated positive and use the controllers. Many of the applications were demos or free as they were easier to attain.

RESULTS

When grouping the screenshots two more themes were found: "tools" and "info". Tools were specific tools that could do a certain function (like warping, painting, shooting, grabbing, holding) and were assigned to a specific controller (e.g. the right hand controller). Screenshots grouped under info contained text that explained or gave extra information.
Other findings, that weren't found in the studied literature, were;
assistants that are embodied,
extreme head movements are uncomfortable,
extra information appears once a person looks at it,
properties change when you go over a selected object,
the use of a "pallete" with options and a "brush" with the tool which was dubbed "painter palette controls",
the use of dedicated home/menu buttons,
the use of vibrations for "interactive" elements and errors,
banners with extra info were linked to objects in VR,
content was often placed at eyelevel and came towards you when selected,
information should not be placed inside a button,
loading screens often stick to the head indicating that you are not yet in the VR environment,
movable objects sometimes are restriced in a degree(s) of freedom to help the immersant with placement,
menus are often opaque to still see depth in the background,
audio was used to reinforce "choices"

like going over objects, selecting them or activating them and finally that objects come towards the immersant and that the immersant often does not need to physically move towards the object.

The findings can be found in the table on the next page.

CONCLUSION

The Assesment tool allowed to find many examples of the patterns found in literature. The two main themes that weren't discovered in the literature phase where the use of tools, for example the "Painter's Palette" and the, in hindsight obvious, info screens.

Apps\Assesment criteria	Description	Platform	Notes	Efficiency	Learnability	memorability	error	subjective satis	Interaction Menus	Object selection	What works Object translation	what doesn't work Object manipulation
1 Youtube	Watch 360 video	Cardboard	Not clear how to get the UI	5	4	4	-	4	Appears with button press. Fades away after a while	Gaze, then touch a button	-	-
2 Jaunt VR	Cinematic VR experiences	Cardboard	You can't look everywhere because of the gaze, ability to reset orientation	4	5	4	3	4	3 parts, 1:1, more options show once something is selected	Gaze + fuse timer (different lengths)	-	-
3 Proton Pulse	Ping Pong using your head	Cardboard	Turn around to pause	4	4	5	-	4		Gaze + fuse timer (different lengths)	-	-
4 Cardboard crash	Autonomous cardboard driving car	Cardboard	Characters look back at you, get sick :(. Fuse is nice, but you can't "browse" other buttons	2	4	4	2	3	3 buttons	Gaze + fuse timer (different lengths)	-	-
5 Tuscany	Virtual world; villa in italy like surrounding	Cardboard	Not a lot of features, very smoothing, frustrating locomotion; you move constantly and the "switch" takes time	3	5	4	-	3	-	Gaze + Fuse timer. No indication where you are looking or when it is selected	-	-
6 Virtual Speech	Practice speaking in front of an audience	Cardboard	Doesn't explain how it works. Looking at an option automatically selects it, very annoying!	2	2	3	-	2	1:1 menu, low contrast between select and not selected.	No gaze dot, no visual fuse. Button press	-	-
7 InMind 2	Game and story, go through the brains and collect/select neurons	Cardboard	Very smooth, zoom in is too fast	4	3	4	4	4	Content high, buttons low, simple see through menu overlay	Gaze, fuse	-	-
8 Cardboard	VR market and demo	Cardboard		4	4	4	-	4	Flat menu, white icons	Gaze, button press	Instead of the reticle you have an object. You can place it by clicking the button	-
9 InMind	Shooting Neurons in the brain	Cardboard	Accelerations are anoying, fast precise movements require hands	4	4	4	-	4		Gaze, fuse	-	-
10 Gravity Pull VR	1st person puzzle game	Cardboard	Actually walking makes you move (very nice). Couldn't find in-game menu.	3	4	5	2	4	Flat panels with options. Buttons don't light up.	Gaze, button press	with the reticle select an object, grab it by pressing. Than you can walk it somewhere and let go or throw.	
11 tilt brush	Painting in 3D space	HTC Vive	Select what tool the controller is.	5	4	5	-	5	Menus set on both controllers. Radial menu around hand. The other hand is for action	embodied controller is used to select	Use two hands, grip and move/rotate	Use two hands to make it smaller.
12 dataviz VR	Make 3D graphs	HTC Vive	Text isn't readable	2	1	3	-	2	Menu 2D, 2 planes; controls and information. Selected menu can be scrolled through	Laser (ability to turn on or off), reticle, vibrate	point, grab with buttons, move	through menu on right controller
13 3D sunshine	build blocks	HTC Vive	Tools that you attach to your controller. It's weird they use touch pad for grabbing	4	4	3	-	5	a main menu and two "stands" on either side give immediate options	embodied controller is used to select. Far away menu is selected with laser	Move the controller while the object is grabbed. Move the controller to change the world	Button combination and moving controller. Two controllers for resizing.
14 The Body VR	take a tour through the veins and blood cells	HTC Vive	Jump cut within the same room, not nice!	4	4	4	-	4	Buttons change color once selected.	Laser, reticle		
15 Gnomes & Goblins	Discover the world of Goblins & Gnomes	HTC Vive	Characters look back at you (eyecontact) rich world	4	3	4	1	5		Embodied controller, Use trigger to pick up objects.	Move the controller while the object is grabbed.	
16 Rec Room	A sports community in a digital world	HTC Vive	Switching between hand and pointer is sometimes weird, needs adjusting, nice that you hear others. A lot more social.	4	5	3		4	Wrist menu 1:1 menu. Menu appears around you	Embodied controller or laser pointer. Trigger to pick up	Move the controller while the object is grabbed. Ability to glue object to hand.	
17 Paintlab	Painting program	HTC Vive	It's weird to have a camera hovering	2	2	4	2	2	Only on the controllers	Embodied controller is used to select	Move the controller while the object is grabbed with the trigger	Use both embodied controllers to grab with the trigger and then rotate, move or scale
18 Budget Cuts Demo	Find your way through a building past evil robots.	HTC Vive	You can go through objects, also with controls. No laser pointer for spraying is annoying	3	4	4			Small inventory in hand	Embodied controller, ability to change function of controller, not clear when you spray	Move the controller while you grab the object. It hovers	
19 Google Earth VR	Flying can be nauseating. Prefernce for moving to head fly instead of controller.	HTC Vive		4	4	4	4	5	1:1, horizontal scrolling, icons pop-up	Laserpointer, trigger to drag, grab to rotate	-	turn it
20 The Lab	Several smaller games	HTC Vive		3	4	4		5	Embodied menu: controller highlights with menu options, curved menu	Embodied controller, trigger to move, laser pointer	Move the controller while you hold the object	
21 Steam VR	Jumpboard to programs and settings	HTC Vive	How do you go up or down? Scroll, click or drag?									
22 PS4 VR Demo	Some Demo games	PS VR		4	5	5	-	4	Colorfull, pop-up once selected. Menu scrolls horizontal. See-through pop-up menu appears over environment.	Press x button		
23 Tumble VR Demo	Build blocks and crash towers	PS VR	out of sight, there is an embodied "assistant" who explains things. Objects are pulled toward you once selected	4	4	3	4	3	not curved. Reticle (gaze) appears and objects are animated if you can select them. A laser comes from the controller	Aims laster, pull trigger	Move the embodied controller around while holding the trigger	
24 Rez infinite	Shoot object while flying	PS VR	Feels like you can't use VR to it's potential, why gaze? Why not laserpointer?	4	3	4	-	3	Use arrow keys	Gaze	-	-
25 Eagle Flight	Fly around paris as a hawk	PS VR	Immersive and fun game! Very natural gestures	4	5	3	-	4	Menu panels are placed in a circle around you.	Gaze and reticle, press x to select. Fly towards 3D objects	-	-
26 Robinson: the journey	A boy needs to survive on a desolate world	PS VR	Personalized assitant (hovering globe).						(highlight and opacity to 100%). Use reticle to select menu option. More options appear once menu-option is selected	gaze, laser pointer or embodied controller then click to select	move around the avatar to move around the object. Tractor beam for smaller objects.	

Controls	Ergonomics	Motion Sickness	2D interface	3D objects	Locomotion	Animation	Audio	#
Gaze, button press	You can sit and stand	-	2buttons and sliding panel	-	On a rail or stationary	-	-	#Gaze pointer #use a white line divider to align the phone
Gaze, fuse and button press	touching isn't always nice	-	Wide. Content in de middle. Objects use shadow once selected	-	Use of buttons	pop to the front	Audio is used to reinforce selections	#1:1 menu #menus are walkthroughs #fuse to select #audio reinforce selection
Gaze, fuse	ok, good movement of head	-	Very large, you have to look around a lot	Shield is fused with the gaze	-	Shield moves with your head		# use the back to pause
Gaze, fuse	No possibility to reset view. You have to 180 twice	Sudden movements, very fast.	Use shadows to create depth	Not controllable	Slow on a track, uses a "cockpit"	Animation shows element is a button. Animation to guide users attention	Atmospheric sound, explain options of buttons	# Character looks at you #make description and selection separate buttons
Gaze	looking down is not superb	none	-	-	Constant movement. Look to the floor to stop or go.	Background animations	Atmospheric sound	# sound comes from sources
Gaze, fuse, button press			Places objects and buttons in environment	-		Buttons animate once you go over them.		# buttons part of environment #spatial enough room, spread over horizon
Gaze, fuse, button press	Only one direction to look at which is nice	Slightly when you zoom in.	Comfortable viewing distance (2,5m)	-	Rails, constant velocity	Zoom in animation; is disruptive	Use a narrator, use sound to confirm	#2,5m viewing distance # sound narrative #sound select confirmation #dynamic fuse time #content eyelevel #controls low #dedicated menu button
Gaze, button press, head gesture (tilt)	Sit, stand, look around, most content in front of you	-	Eye level	Reticle changes when options are possible. Objects rotate when you rotate with your head.	Rails, constant velocity	Pop towards you, colored		#keep content and mains all in the same direction #keep icons simple and white #make icons come towards you #reticle changes with options #menu on the floor #motion to guide attention #icon with motion to show new option #selected menu options change characteristics (color,size)
Gaze, fuse and head gesture (tilt)	looking around fast is tough	Acceleration makes you more sick, use a cockpit though	Flat, lower controls	-	Track	World coming towards you (less sickening than moving in a world)	Surround, reinforce selections	#titlt head to progress to room #making objects come to you is less nauseating than you flying towards objects
Gaze, walk (head motion), press button	Tiresome and annoying you need to hold HMD to press button. Walking backwards is disorienting and weird	Almost none because you actually walk	Flat, little to close, no feedback what you select, affordance shows what is possible (void where it needs to go)	Change color if you can change it.	Walking and head motion. Steering by looking.	Physics engine	nothing spectacular	#Always give the option for a menu and orienting #object can be pulled over pre-set track
2 controllers, grab, trigger buttton for "action", scroll through options	Pallette is under a weird angle, especially color picking	-	use of depth, white icons. Anchored to controller, use of banner to explain stuff	turn it around	physcially walk around	When selected, animation (depth, extra text)	sound to reinfoce action, menu, point and selection	#Vive Menu linked to vive button #use controllers embodiment to select #information appears once selected #"painter palette" controls, one hand palette, the other the brush #sound for aiming at object #sound for selecting #sound coming from tool #sound to switch between menu #explanation banner/label #menu anchored to hand
2 controllers, one pointer, one menu. "grab" button and "click" button, vibrate when interactive, scroll through options	-	-	text is too small. Menu sticks to controllers	one big object that can be rotated, smaller objects haptic feedback if interactible	physically walk around	Menus animate when selected	Audio reinforces selection	#grabbing controller grabs object #trigger is selecting/executing #animate menu when selected #vibrate when going over interactive object
Two controllers with various buttons	-	-	Anchored to world.	Opacity decreases when selected. Buttons stick out.	Grab the world and move it around	buttons change color		#2 controllers for resizing #menu anchored to environment #sound for selecting
Two controllers with various buttons, both pointer and trigger	Allow the user to sit and stand	Cockpit and constant velocity.	Slider, select where the slider needs to be. Important information in the front, less important on the side. Labels or		Physical walking, platform following a trail.	Objects appear by growing from nothing	Audio reinfoces pointing	#sound when pointing #slider, select where you want the point #change color of selected button #important info in the front #move "absorbed/discared" content/info to the side #explanation label/banner #possibility to sit and stand
Haptic vibration to catch attention	-	-	-	Physical laws apply, affordances	you can walk or instantly transport	Animated character, physics apply	Audio grabs attention	#embodied controller for selection #use trigger to grab something #sound cues to guide attention #Natural Physics #character eye contact
Two controllers with various buttons, both pointer and trigger. Vibrates when going over objects.	selecting items on your wrist watch is not that comfortable	Automatic rotation is slightly nauseating	Button in depth. Selected options animate.	You can grab everything. Shape tells what you can do with it. Highlighted objects and those that	you can walk or port.	Natural physics	Spatialized audio	#wrist menu #spatialized audio #embodied controllers for selection #change color of selected button #1:1 menu #interactionable objects are highlighted #vibration indicates interactionability #change function of controller # natural physics #label #vibrate when touching #move object towards yourself to apply to yourself
Embodied controller with overlay menu. Controller vibrates with error	-	-	-		walk	none		#"painter pallet"
Embodied controller and use of a hand		-	2D labels	highlight when you can touch them. 3D buttons.	Throw a ball, preview a globe than you can pull over yourself	Natural phsyics.		#highlight when interactionable #natural physics #hand menu #embodied controller with hover ability
Vibrating for error	Can be weird to change tilt	When going forward and backward fast it's nauseating	2D labels	-	Fly through the environment using the controller als mini	Icons coming towards you	Use audio reinforcement for selection	#use controller for flying direction #icons pop-up #1:1 menu #Laserpointer #error vibration #embodied controller #achnored labels
Controller, take over different uses, controller vibrates with action		-	2D labels anchored to objects	Move objects toward you to change your environment	Walk around, port	Animate selection to show what happens	sound to confirm actionable object	# move object on yourself to apply them #port #animation when pointed at #Sound to confirm action #vibration to reinforce pointing at certain object #Embodied controller #2D anchored labels #Curved menu #reticular #make objects come toward you #natural physics
								#Highlight, put to front, fill with color (opacity 100% when selecting menu)
PS controller. Joystick to select buttons.	Displays to close	-	A little to close for comfort (1-1,5m).	-	-	Menus are animated		#animated menu #Make icons come toward you #horizontal scrolling #see-through master menu #controller labels #loading screen stuck to head
PS controller. Laser or gaze to select. Buttons to click.	-	-	On the background. Extra information is displayed on controller/embodied	Are highlighted if you can move them	-	Natural physics, menu is animated and changes brightness	spatialized audio from assistant	#Menu circles around you #Cockpit #Personal assistant #laserpointer #gaze #Trigger to grab #move embodied controller #anchor info to VR world # Natural physics #interactionable 3Dobjects highlight #tractor beam for objects
Gaze and ps controller, buttons to click.	-	Little, flying while looking around intensely. Almost no acceleration	Text to wide and too large, almost hurts eyes	-	Rails		Set to music	
Gaze and moving head to fly around (yaw, tilt, rotate)	-	Use of a cockpit and white dot.	labels are tracking objects	-	Use gaze to fly around, constant speed	menus are animated	spatial sound	#Menu panels placed on cricle #gaze #icons come toward you once selected #labels on objects #Cockpit #Gaze for navigation
Reset orientation button		Slow movement, no acceleration	2D lables anchored to objects	Interactionable objects are highlighted	minitiure map. Climbing uses head and gripping.	Natural physics	spatioal, sound when gazing at something	#Menu animates #white icons #gaze #show extra menu options once gazed at #sound reinforces gaze #levitate large objects #tractor beam for small objects

APPENDIX A.2

Summary Virtual (R)evolution & Dutch VR awards 2017

To deepen the information found in literature and to help decide what should be researched more in depth concerning interactions, contact was sought with developers. This was done by visiting the Virtual (R)evolution 2017 trade fair. In the afternoon of Thursday, march the ninth, the Dutch VR awards 2017 were also held here.

The visit had the following goals:

- Get in contact with developers and retrieve their contact information
- Find out what problems developers run into concerning interaction. What information do they need.
- Be inspired by talks, projects and people.

CONTACTS

A number of dutch companies working on VR projects showcased their products. Some of the we're for training purposes, some for the health field and a few for showcasing "to-be" products and entertainment.

At the conference it was learned that Nijmegen holds a VR incubator; VR Labs. This company provides other companies with a space and tools to develop for VR. It would be interesting to contact them in the future as several developers can be quickly contacted within the same building.

INSPIRATION

Throughout the day several developers and talks were visited, which was inspiring as they talked about their own perspective and ideas.

According to dr. ir. Erik Vullings (Senior Scientist at TNO) VR is quite individualistic. During his presentation about the future of VR he explained that AR allows much more interaction with the people and the environment around you. It allows you to see what others see. Mixed Reality allows users to collaborate. One of the challenges would be gestures and the lack of a "gesture library". According to dr. ir. Vullings people can save money with VR and that's where the money can be made.

Detlef La Grand, the founder of VRMaster, stated that on cardboard vibration works well for giving feedback. However, VR is not common yet, so he thinks training is a good market to start.

Marjo NieuwenHuijse, developer at SERIOUS-VR, also creates training in VR. According to her, with manuals, you have practical stuff you need to do. This is made abstract and changed into a written manual. Often, this manual is then translated to VR. However, VR allows you to take the practical steps and directly design them into VR. So, many practices in training needed to be unlearned. Because the training is in VR, much data is also recorded. The question is how you can use that data to evaluate. Finally she stated that audio can be very strong in VR, but it is often forgotten. Trying out their training it was observed that it is not always easy to guide the attention of the trainee and allow him to do the proper thing.

One startup, MIND MANSION, used VR to handle claustrophobia. While doing exercises the room shrinks. They mentioned that videogame controllers are often hard to understand for novice users as they are unfamiliar with all the buttons. They therefore believe in using the hands and gestures. They state that the LEAP-MOTION is not yet reliable enough and use gloves developed by Manus VR.

INMOTIONVR uses gamification and the sensors to improves the posture of people.

Carlo de Heer, from the goldviz company that makes realtime interactive visualisations, stated that a challenge is how to explain interactions in VR. How do you explain what is possible?

One could summarize that VR was active in the education, medical, gaming and engineering fields.

DUTCH VR AWARDS

The first time ever held, the Dutch VR awards 2017 awarded prices in six categories to developers of VR applications and experiences. Here are the categories with their winning submissions and developers;

Category 1 – Immersive VR 360 Video productions
Ashes to ashes - Submarine Channel

Category 2 – Games & Apps for VR & AR headsets
Landfall - Force Field

Category 3 – VR & AR innovations
Corpus VR – InMotion VR

Category 4 – VR & AR marketing campagnes
The Audi A4 Experience – DigitasLBI Amsterdam

Category 5 – VR & AR studentprojects
ToyBoxing – Koen Damen

Category 6 – Trade colleagues
VR Data visualization for cancer research – DEMCON nymus 3D

At the end of the VR awards there was a panel discussion with the winners. The roles of technology, business and creativity were discussed. Digitas LBI Amsterdam explained that the more expensive the HMD, the larger the possibilities and experience. However the reach is smaller. Cardboard sets are a large group, but the experience is less. So their take on this is that the experience for Cardboard needs to be improved.

The panel agreed in the end that the most important aspect now is creativity. VR needs to be used for it’s strengths, not as a gimmick. It is now up to companies to find the strengths of VR and design apps specifically for VR, else it will remain a gimmick.

PROBLEMS

Through talking to developers and trying their products the following several problems we’re indexed. Tracking of the user still needs to be perfectioned. Measurements and standards for children are not yet common knowledge.

Three problems or themes that could use further research emerged;

- Audio. How do you design and employ audio in VR?
- Guiding Attention. How can you guide the attention of the user to certain parts? How do you explain them you can interact with an object.
- VR native menus. The real world has interfaces, the 2D world has interfaces, and both are applied to VR. But what UI is native to VR?

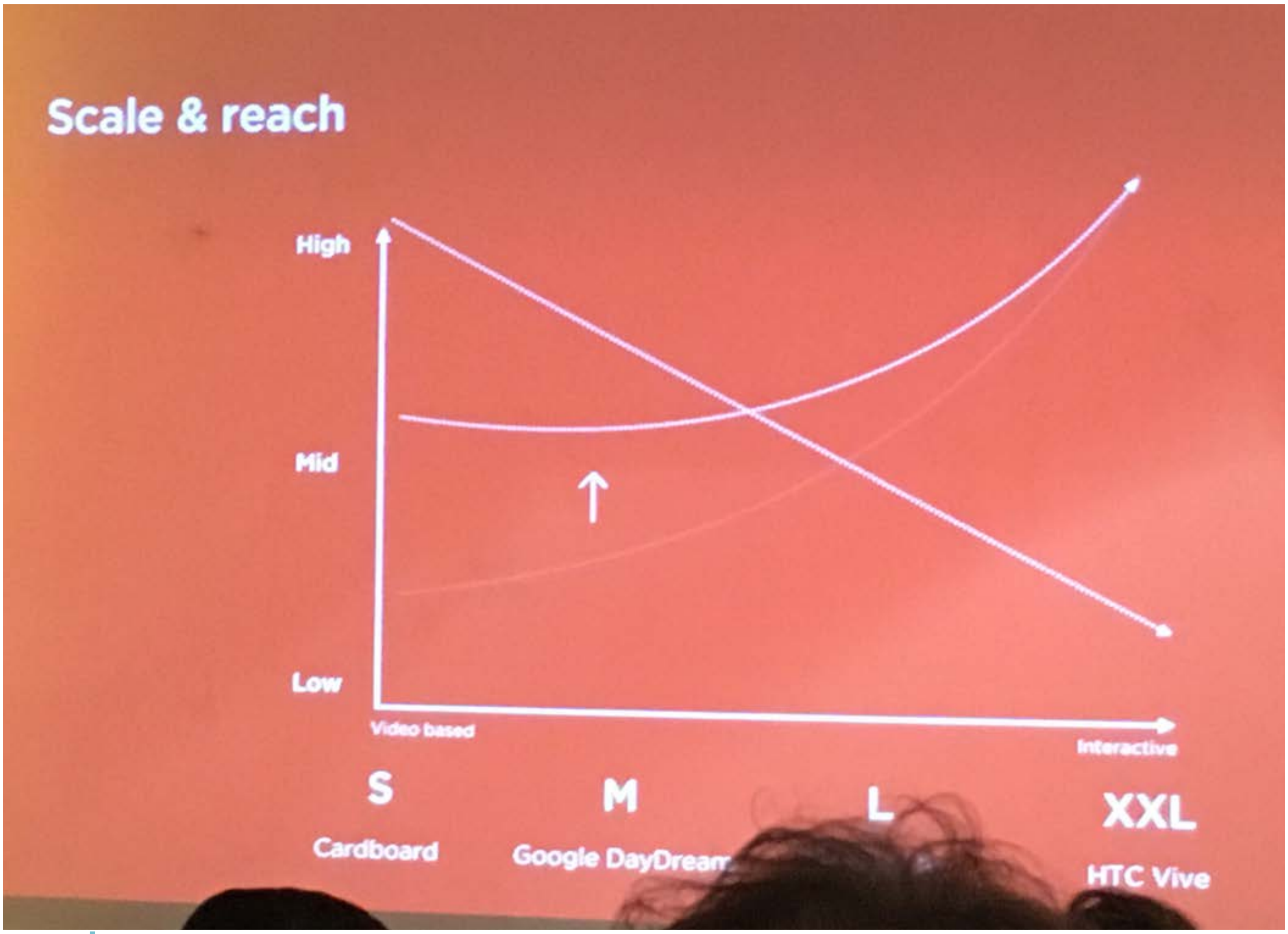


Figure 54:Cardboard has great reach but the experience is less. Improving this experience could target a great audience.

APPENDIX A.3

Interview Jonatan Bijl - VR Developer

28th of February, 2016

Jonatan Bijl developed two Virtual Reality experiences related to container terminals. It seemed appropriate to interview a VR developer as they have practical experience.

Summary of interview

The port of Rotterdam uses automated terminals. The driving happens behind fences so that people are not hit. However, sometimes an engineer will have to access a car. Several safety protocols are used for this, which need to be trained. Training, however, costs a lot of money since activity on parts of the port need to be halted.

The company, TBA, develops the control of the cars. Jonatan developed a system that uses the same control for the cars, but allows a user to virtually be in this world and interact with the fences and the cars. This way people can be trained and get familiar with the port without having to interrupt activites.

Personnel use the oculus rift and an Xbox controller to move inside the world. With the joystick the user can move through the world. Buttons are highlighted to show you can interact with them. With the joystick users can select a button and activate it with the A button on the Xbox controller. The Xbox controller was used as it was more intuitive than a keyboard.

Error screens and information was shown on panels that are stuck to objects or the avatar. Panels stuck to the avatar still allow the user to look away to prevent disorientation, but the panel does move with the person once he walks around.

Jonatan developed the game in Unity. Objects were imported from other programs, but the layout was done in Unity using prefabs. This allowed him to use the same object multiple time. Within Unity he could then change certain aspects of the applied prefab.

He also developed a VR experience for an exhibition so that visitors could see two vehicles. Again users would need an Xbox controller to move around. Accelerations were slow to prevent motion sickness and users could sit in a chair. In fact, there were two chairs and both visitors could see each other in the vitual world.

He noted that you need to be careful with real world objects that you could bump into. People who would want to look over a reel bumped their head on the table.

The company wanted more interactive elements so red big dots with an "I" were added. Using gaze and a fuse timer, where the red dot would turn, pop-up screens would appear with more information. Once the user looked away from the screen for a certain time, it would disappear again.

Jonatan used some guidelines from Oculus and those he found on forums but also followed his intuition and did some experiments with users.

APPENDIX A.4

List of all the interactions patterns and their sources

Nr.	Group	Theme	*subthemes*	Pattern	Source
A	1	**General guidelines**			
				Don't tell narrative, let the user create his own narrative	Laurel, 2016
				Designs tend to become complicated, keep them simple.	Zhou et al, 2008
				The world is an interface!	Zhou et al, 2008
				"Design Sound, visual touch and proprioception in tandem"	Serafin, 2016
				"Create a sense of presence"	Serafin, 2016
				Make the experience social	Serafin, 2016
				"Maintain VR immersion from start to finish"	Oculus, n.d. -a
		Natural interactions			
				Embody content or audio with the use of a personal assistant who gives the tips and information	Assesment Tool
				Virtual Characters eye contact makes the experience more immersive	Assesment Tool
				users are likely to have an expectation that they will be able to interact with that virtual world in the same ways they do outside of it	Oculus, n.d. -a
				People are used to convey information through text and pictures, less through experiences	Zhou et al, 2008
				People's minds are square. They think in boxes and lines.	[Vision VR/AR Summit], 2016
				Go for natural, but above all simple!	Hürst & van Wezel, 2012
				"Consider both natural and magical interactions"	Serafin, 2016
				Intuitive and phsycially appropiate	Höysniemi et al, 2005
				Stay away from gestures that need to be memorized	Davis, 2016
				Humans are naturally attracted to looking at faces and eyes.	Hunter, 2016
				Moderate eye contact can increase immersiveness positively	Hunter, 2016
		Guiding attention			
				Use the direction of the animation to point the users attention	Oculus, 2015 | Assesment Tool
				Place objects just in the field of view to catch the attention of users	Google, 2015
				Consider scaffolding guidance so "users know where they, who they are and what they're supposed to do next"	Hunter, 2016
				Use lights to guide the user. E.g. put light on objects or entrances users should go to.	Google, 2015
				design cues and affordances that encourage the participant to make dramatically interesting choices	Laurel, 2016
				If not all objects are interactive, hint at which objects are interactive. E.g. change shading or make a sound.	Ravasz, 2016
				Use sound to move the attention to the desired position.	Hunter, 2016
				use the gaze of other virtual characaters to direct attention	Hunter, 2016
		Physcial Ergonomics			[Vision VR/AR Summit], 2016
				Preferably don't use extreme head movements	Assesment Tool
				Hights can be uncomfortable	Google, 2015
				Sharp objects can be uncomfortable	Google, 2015
				Objects coming toward you can be uncomfortable	Google, 2015
				"Design environments and interactions to minimize the need for strafing, back-stepping, or spinning, which can be uncomfortable in VR"	Oculus, n.d. -a
				Standing increases immersion but can become more tiresome.	Assesment Tool
				"Allow users to set the origin point based on a comfortable position for them with guidance for initially positioning themselves."	Oculus, n.d. -a | Assesment Tool
				"there must be minimal motion to avoid fatigue"	Alger, 2015
				Users don't always want to stand so allow the option to sit.	Alger, 2015
		Virtual Reality Sickness			
				Keep the horizon straight	Google, 2015

Nr.	Group	Theme	*subthemes*	Pattern	Source
				Take care of the pseudo coriolos effect	Dichgans & Brandt, 1973
				"Do not use “head bobbing” camera effects. They create a series of small but uncomfortable accelerations."	Oculus, n.d. -a
				"Avoid visuals that upset the user’s sense of stability in their environment. Rotating or moving the horizon line or other large components of the user’s environment in conflict with the user’s real-world self-motion (or lack thereof) can be discomforting."	Oculus, n.d. -a
				Strafing and backwards walking an cause motion sickness	Oculus, n.d. -a
				Prevent latency, it's one of the biggest contributors to motion sickness	Kolasinski, 1995
				Prevent or limit cybersickness.	Serafin, 2016
				Add a horizion	Amini, 2017
				Build a cage or cockpit	Amini, 2017 | Alger, 2015
				Use a vignette	Alger, 2015
		Testing			
				Fitts law	Teather & Stuerzlinger, 2011
				WOz practices	Höysniemi et al, 2005
				No single practice for analysing HCI	Höysniemi et al, 2005
				Learnability, efficiency, memorability, error and subjective satisfaction	Zhou, 2008
				"Test your content with a variety of un-biased users to ensure it is comfortable to a broader audience."	Oculus, n.d. -a
				Test with first time VR users; they can offer a new perspective.	Hunter, 2016
				Greyboxing; primitive polygon shapes to test placement and size	Chu, 2014
B	**1 Pointing/Targeting**				Teather & Stuerzlinger, 2011
				Use a reticle to show the user what he looks at and how it is tracked	Assesment Tool
				Provide dynamic feedback about the actions the interface is tracking	Davis, 2016
				Probing with hands or controller is slower, but more immersive. Probing with a pointer is a lot faster but less immersive.	Teather & Stuerzlinger, 2011
				"Paint reticles directly onto target rather than a fixed depth plane"	Oculus, n.d. -a
				Can be intuitive and user-friendly as long as there is a clear targeting cursor adquate visual feedback.	Oculus, n.d. -a
				Make the reticle go over the objects, not a virtual globe	Google, n.d.
				items should be large and well-spaced enough for users to accurately target them	Oculus, n.d. -a
				When Idle, the reticle should be as small as possible	Ravasz, 2016
				When the user looks at a place that is approachable, the reticle should transform into a larger pointer.	Ravasz, 2016
				When the reticle goes over an interactive object, the reticle should react accordingly.	Ravasz, 2016 | Assesment Tool
				Adapt the reticles color in order to stay visible in all lighting conditions.	Ravasz, 2016
				Replace the reticle with a specific 3D item to make for an easy cue for interaction.	Ravasz, 2016
				Animate objects that are targeted to show interactionability	Hunter, 2016
				Show extra information once a person aims/looks at a certain elements	Assesment Tool
		Gaze			
				Light up elements you look at	Google, 2015
				Use a visual reticle to aid with looking at a certain object.	Google, n.d. | Assesment Tool
		Wand			
				Design for the fact that people push through objects	Davis, 2016
				Vibrate when going over a selectable element	Assesment Tool
	2 Select/Activate/Confirm				
				Use a physical button	Google, n.d.

Nr.	Group	Theme	*subthemes*	Pattern	Source
				Place visuel feedback of selections within the immediate interaction area	Fröjdman, 2016 | Assesment Tool
				Change the properties of a selected item: color, opacity, highlight, size, distance	Assesment Tool
		Gaze			
				"orientation, acceleration, and position can all be leveraged for unique control schemes, such as gaze- and head-/torso-controlled movement."	Oculus, n.d. -a
				Use a button or a timer (where a user focuses on a button for a set time) to select	Google, n.d. | Assesment Tool
				Use a timer: "create virtual buttons that leverage a timer, or fuse, which trigger after the user has focused on them for a certain amount of time" Visually represent the countdown, don't puse "fuse buttons" to close to one another	Google, n.d. | Assesment Tool
				Use dwell times of various lengths	Fröjdman, 2016 | Assesment Tool
		Wand			
				Make object come to the user.	Alger, 2015
				Use haptic feedback to make the interaction with objects more immersive. Think of vibration when touching or going through elements	Google, n.d.
				Motion controllers can track movement and give haptic feedback	Alger, 2015
				Allow users to initially visually orient themselves on their controller	Oculus, n.d. -a
				Apply selection by moving them on an object or the user.	Assesment Tool
3	**Translate**				
		Gaze			
		Wand			
4	**Manipulate**				
				"Once the user understands the basic concept, the interactions tend to be smooth and fluid. But it's the first step that's the hardest. For this reason, we strongly encourage including tutorials, text cues, and other guides when developing with these modes."	[Leap Motion], n.d.
				the "thumbs up" is consistently used around the world to mean "OK."	[Leap Motion], n.d.
				"start with simple physical interactions that don't require much physical or mental effort. From there, build on the user's understanding and elevate to more challenging interactions."	[Leap Motion], n.d.
				Use two hands/controllers for resizing, orienting and positiong 3D objects	Assesment Tool
5	**Controller design**				
		General			
				Make use of "Painter Palette" controls. One controller for the menu/options, the other with the tool/selector.	Assesment Tool
				Visualize the controller in VR	Assesment Tool
				Use a dedicated "Home"/"Menu" button	Assesment Tool
				"Tooltips" can be usefull to provide extra information about the controller. But users might miss the information.	Hunter, 2016 | Assesment Tool
				"No traditional input method is ideal for VR, but gamepads are currently our best option"	Oculus, n.d. -a
				"Consider the representation of player's body"	Serafin, 2016
				"Your hands always occupy the foreground"	[Leap Motion], n.d.
				"Make the user's hand semi-transparent when near UI elements."	[Leap Motion], n.d.
				"grab" the controller to grab objects. The trigger button is often used for this.	Assesment Tool
				The trigger button is often used to confirm/activate selection.	Assesment Tool
				Animate when the controller changes function and/or allow the user to manually change the function	Assesment Tool
		Haptic feedback			
				Controller vibrates when it touches an object to give haptic feedback	Assesment Tool
				Vibrate when there is an error	Assesment Tool
				Use haptic feedback to make the interaction with objects more immersive. Think of vibration when touching or going through elements	Google, n.d.

Nr.	Group	Theme	*subthemes*	Pattern	Source
				Motion controllers can track movement and give haptic feedback	Alger, 2015
		Tools			
				Consider switching the applied tools of a controller. E.g. a brush and a Gum	Assesment Tool
C	**1 2D interfaces**				
		Spatial dimensions			
			Depth		
			Size		
				Don't make letters too small (because of the resolution)	Assesment Tool
				Don't make screens to wide. Keep it 1:1	Oculus, 2015 | Assesment Tool
				Ideally, your UI should fit inside the middle 1/3rd of the user's viewing area.	Oculus, n.d. -a
				Make menus resize automatically and try different languages to see how they adapt (e.g. german has longer words).	Oculus, 2015
			Place		
				Banners with information anchored to objects, menus and controllers are an ituitive way to provide extra information	Assesment Tool
				Place interfaces in an arc around the user. "Our bodies tend to move in arcs, rather than straight lines, so it's important to compensate by allowing for arcs in 3D space"	[Leap Motion], n.d. | Assesment To
				Place menus and content at eye level	Assesment Tool
				Anchor menus to the hand	[Leap Motion], n.d. | Assesment To
				Allow the user to call up or move the menu	Hunter, 2016
				Text floating in the environment can easily be missed	Hunter, 2016
				Use the idea of "front, middle and back" to stage screens, important information is closer to the user	Alger, 2015 | Assesment Tool
				Place the UI so it is comfortable to explore and interact with	Alger, 2015
				Think of ways to incorporate the interface into actual in-world object; e.g. a book or on the arm.	Oculus, n.d. -a | Assesment Tool
				Text and infoscreens are anchored to the VR world. Loading screens and important notifications can stick to the users head.	Assesment Tool
				Place the main content and objects consistently in front of the user	Assesment Tool
			Distance		
				The selected element should be closer to the user than the rest	Assesment Tool
				Don't place two surfaces too far apart. That way eyes don't have to change focus too much.	Oculus, 2015
				Elements that can be selected should be linearly distanced from the user, not sporadically.	Assesment Tool
				Don't position objects too close to the eyes, but not too far either because of the resolution.	Assesment Tool
				sit approximately 2-3 meters away from the viewer	Oculus, n.d. -a
		Menus			
			Buttons		
				Separate information and buttons. Prevent users from accidentally pressing a button when they want more information.	Assesment Tool
				"a dimensional button indicates to the user to interact with the affordance by pushing it in (just like a real world button). If the button moves expectedly inward when the user presses the button, the user knows they have successfully completed the interaction."	[Leap Motion], n.d.
				Shadows indicate depth and that you can press a button.	Alger, 2015
				"a circle appears that changes color as you approach. When you press the button, it compresses and bounces back, with a color state change suggesting that it's now active. At the same time, a satisfying "click" sound signals that the interaction was a success."	[Leap Motion], n.d.
				It's better to not make actual buttons vertically	Alger, 2015
				Consider actual buttons that are part of the environment	Hunter, 2016 | Assesment Tool
			Content		

Nr.	Group	Theme	*subthemes*	Pattern	Source
				Move away the old content and replace it with the "requested" content, leave the button in place though	Oculus, 2015 | Assesment Tool
				Keep information dense areas interaction-free	Fröjdman, 2016
				Scroll by section (or chunks)	Oculus, 2015
				In a big menu, the selected option should go to the middle.	Assesment Tool
			Navigation		
				Scroll from left to right (horizontal instead of vertical)	Oculus, 2015 | Assesment Tool
				Make menus dynamic	Assesment Tool
				"users have the ability to move the content directly instead of attempting to target a small, mouse-style scrollbar"	[Leap Motion], n.d.
				Allows the user to navigate spatially between different tasks, instead of virtually.	Colgan, 2015
				Design a radial menu around a hand, they can be accessed quickly and with muscle memory.	Alger, 2015
				"Provide dynamic feedback about the actions the interface is tracking to make clear which elements are being activated and which actions the user can take"	Davis, 2016
				If you use one hand for the menu, use the other for selection.	Assesment Tool
		Special screens			
				"The display should respond to the user's movements at all times, without exception. Even in menus, when the game is paused, or during cut scenes, users should be able to look around."	Oculus, n.d. -a
				With cardboard, use a white line divider so a user can line up his phone correctly.	Assesment Tool
			Text		
				Text is hard to read due to resolution and angle. So "limit the angular range of text to be close to the center of the user's field of view."	[Leap Motion], n.d. | Assesment Too
			Loading screen		
				Loading screen is often stuck to the head and doesn't track the orientation of the head	Assesment Tool
			Notification		
				Avoid using time-limited information	Fröjdman, 2016
				"physical input devices can be combined with the enhanced display possibilities provided by virtual image overlays."	Zhou, 2008
				Consider using audio notifications as visual information is already quite rich	Google, n.d.
			Error		
				"Provide the user with warnings as they approach (but well before they reach) the edges of the position camera's tracking volume as well as feedback for how they can re-position themselves to avoid losing tracking."	Oculus, n.d. -a
				"We recommend you do not leave the virtual environment displayed on the Rift screen if the user leaves the camera's tracking volume, where positional tracking is disabled. It is far less discomforting to have the scene fade to black or otherwise attenuate the image (such as dropping brightness and/or contrast) before tracking is lost. Be sure to provide the user with feedback that indicates what has happened and how to fix it."	Oculus, n.d. -a
			HUD		
				"Oculus discourages the use of traditional HUDs. Instead, we encourage developers to embed that information into the environment."	Oculus, n.d. -a
			Info		
2	**3D Objects**				
				If not all objects are interactive, hint at which objects are interactive. E.g. change shading or make a sound.	Ravasz, 2016
		Spatial dimensions			
			Size		
				"Use human scale"	Colgan, 2015
				"one meter in the real world corresponds roughly to one unit of distance in Unity"	Oculus, n.d. -a
				Size and depth can communicates importance	Alger, 2015
				Consider Children	Hunter, 2016

Nr.	Group	Theme	*subthemes*	Pattern	Source
				"Small object will feel cute and toy-like, easy to pick up with your hands"	Hunter, 2016
				"Bigger objects will make users feel fenced-in, as if they to lean or walk around them"	Hunter, 2016
				Size and depth can communicates importance	Alger, 2015
			Place		
				Use the idea of "front, middle and back" to stage objects	Alger, 2015
				Object have some relation to physical environment	Hürst & van Wezel, 2012
				Make the object facing towards the user	Hunter, 2016
			Distance		
				The optics of the Rift make it most comfortable to view objects that fall within a range of 0.75 to 3.5 meters from the user's eyes.	Oculus, n.d. -a
				Consider users who are sitting	Hunter, 2016
				"one meter in the real world corresponds roughly to one unit of distance in Unity"	Oculus, n.d. -a
		Affordances			
				"The size of an object or its constituent parts can suggest what kinds of physical interactions will work with it."	[Leap Motion], n.d.
				" You might want to include negative affordances that guide users away from certain interactions."	[Leap Motion], n.d.
				"push bars have wide surfaces made for pressing against"	[Leap Motion], n.d.
				"For inspiration, look for real-world affordances that you can reflect in your own projects. "	[Leap Motion], n.d.
				Demonstrate possibilities with a virtual character	[Leap Motion], n.d.
				Direct interactions can be implied and continually reinforced through the use of affordance in physical design… Higher level interactions …may need to be introduced and reinforced"	[Leap Motion], n.d.
				"Using physics as a foundation for your interaction design can provide realistic physical qualities to virtual objects."	Hunter, 2016 | Assesment Tool
				"If an object looks like it can be picked up, knocked over, or pushed, users will try to do so"	Hunter, 2016
				Provide objects with animations if they have an action	Hunter, 2016
				Provide visual hints on the object	Zhou, 2008
				Higlight objects to indicate an action is possible	Hunter, 2016 | Assesment Tool
				Use color to indicate which object can be used together	Hunter, 2016
				If not all objects are interactive, hint at which objects are interactive. E.g. change shading or make a sound.	Ravasz, 2016
				Vibrate controllers to indicate certain object properties (like maximum stretch)	Hunter, 2016 | Assesment Tool
				Set objects to an invisible rail so they move the way you want them to and it allows the user to use less precise movements	Assesment Tool
		Limitations			
				When people go through an object, show the x-ray.	[Vision VR/AR Summit], 2016
				When you collide a surface with an object, let the object go of the virtual hand.	(北京奇天大胜网络科技有限公司
				Consider your approach to culling and backface rendering, and so on.	Oculus, n.d. -a
D	1 Visuals				
				Lower the opacity of menus and objects when appropiate so you can keep seeing depth and the environment	Assesment Tool
				"Lighting cues, shadows, blurring the background, and other tricks from the cinema trade can help reinforce the sense of 3D space."	Colgan, 2015
				"Visuals can replace the feeling of touch"	Colgan, 2015
				"Bright images, particularly in the periphery, can create noticeable display flicker for sensitive users; if possible, use darker colors to prevent discomfort."	Oculus, n.d. -a
				Don't make the contrast to high. When using white on black, bring the brightness down.	Oculus, n.d. -a
				"Be mindful of sudden changes in brightness."	Google, n.d.
				Use simple and white icons	Google, 2015 | Assesment Tool
	2 Audio				

Nr.	Group	Theme	*subthemes*	Pattern	Source
				Audio can replace the feeling of touch	Colgan, 2015
				"make sure in-game sounds appear to emanate from the correct locations by accounting for head position relative to the output device."	Oculus, n.d. -a
				"sounds should get louder as the user leans towards their source, even if the avatar is otherwise stationary."	Oculus, n.d. -a
				Consider using sound for instructions so that the user can focus on the controls and the environment	Google, n.d. | Assesment Tool
				"Use directional audio in 3D space"	Hunter, 2016 | Assesment Tool
				Use audio to reinforce the fact that the user goes over an interactive object/button with his reticle/pointer	Assesment Tool
				Use audio to reinforce activating or selecting an element.	Assesment Tool
3	**Animations**				
				Use animations for every change!	Assesment Tool
				Make icons and selected items come toward you	Assesment Tool
				Make objects come toward you instead of moving the user to the objects	Assesment Tool

APPENDIX A.5

Screenshots of VR applications matched with the Interaction Pattern Themes

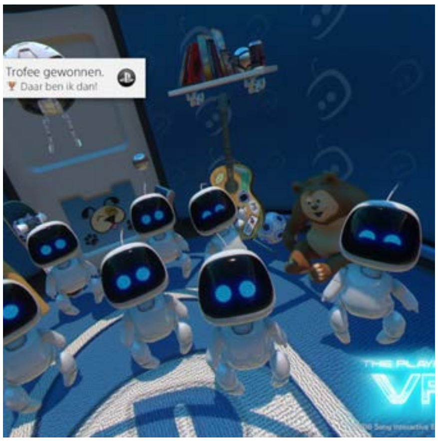
A1 General Guidelines

Natural Interaction

General Guidelines

4. Cardboard Crash-01.png

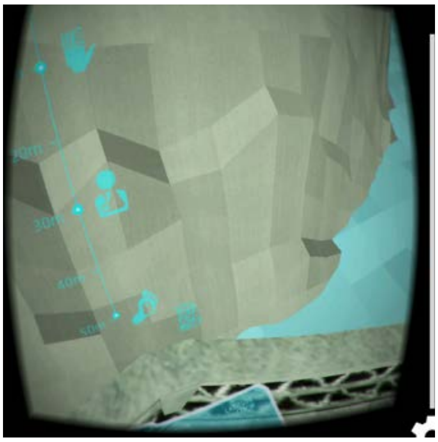

15. Gnomes & Goblins-02.png

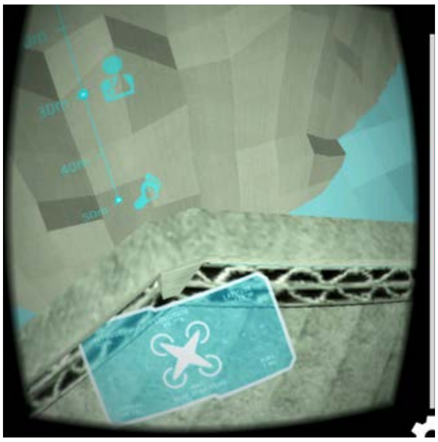


23. THE PLAYROOM VR-02.jpg

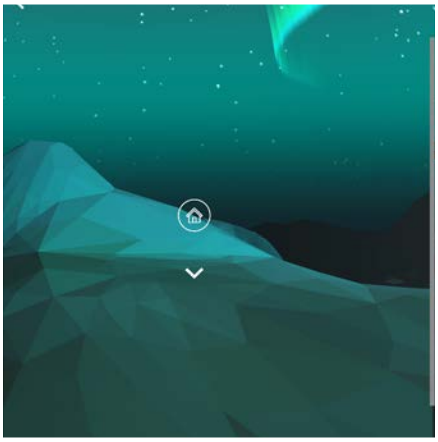
Guiding Attention

General Guidelines


4. Cardboard Crash-07.png


4. Cardboard Crash-08.png


4. Cardboard Crash-09.png

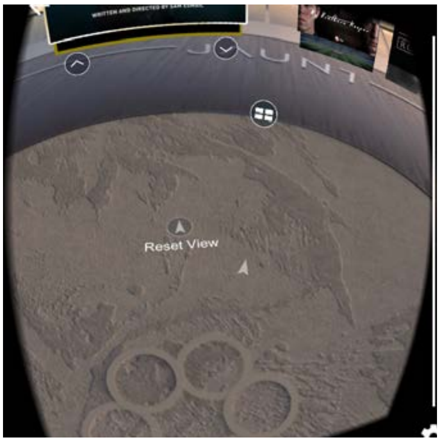

8. Cardboard-20.png


8. Cardboard-21.png


25. Eagle Flight-08.jpg

Ergonomics

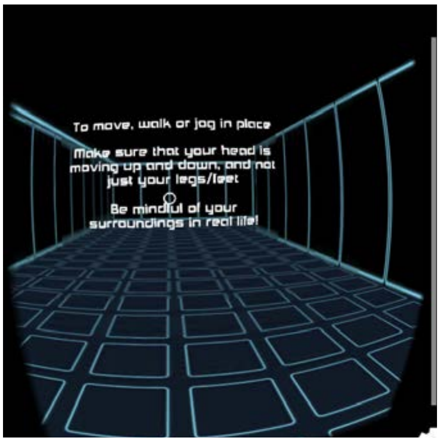
General Guidelines



2. Jaunt VR-08.png

8. Cardboard-03.png

9. InMind-01.png



10. Gravity Pull VR-02.png

26. Robison_The Journey-05.jpg

26. Robison_The Journey-22.jpg

Virtual Reality Sickness

General Guidelines

9. InMind-04.png

25. Eagle Flight-10.jpg

Testing

General Guidelines

B1 Pointing/Targeting

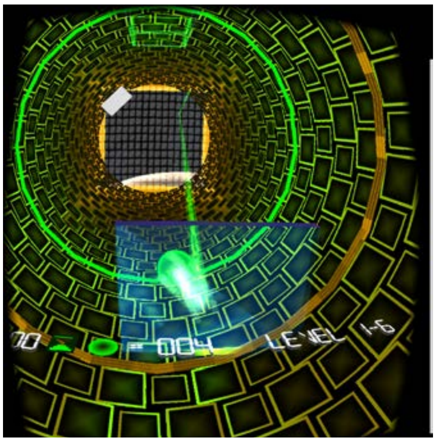
Gaze

Pointing/Targeting

1. Youtube app-02.png

1. Youtube app-03.png

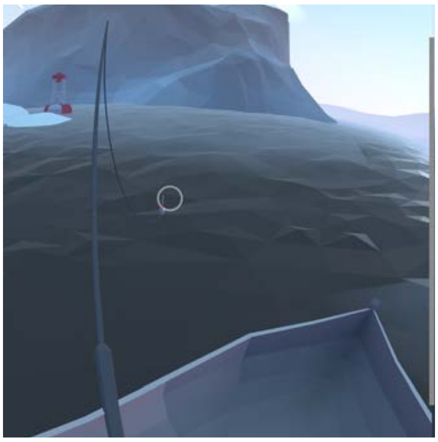
2. Jaunt VR-06.png



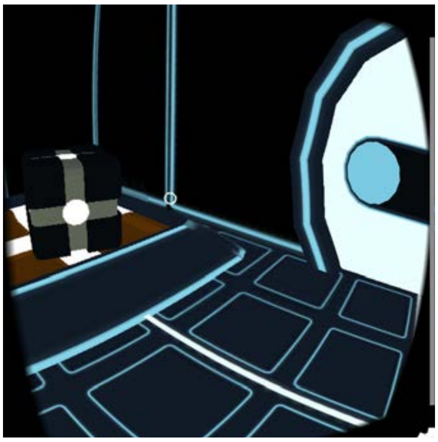
3. Proton Pulse-01.png

8. Cardboard-01.png

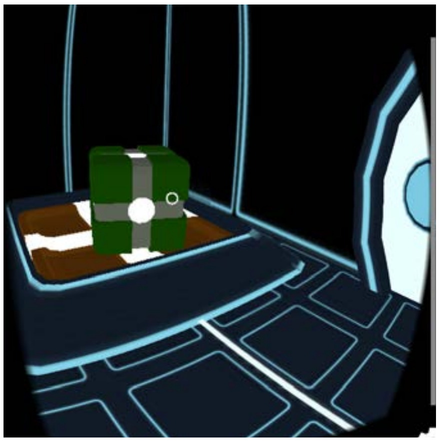
8. Cardboard-02.png



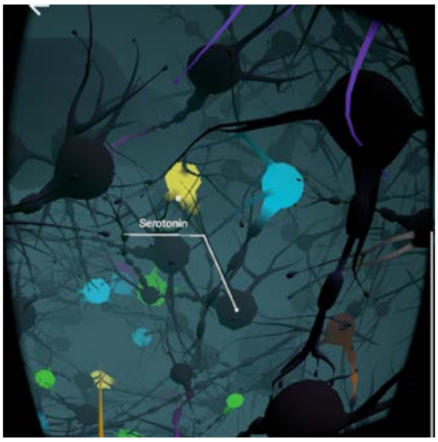
8. Cardboard-13.png



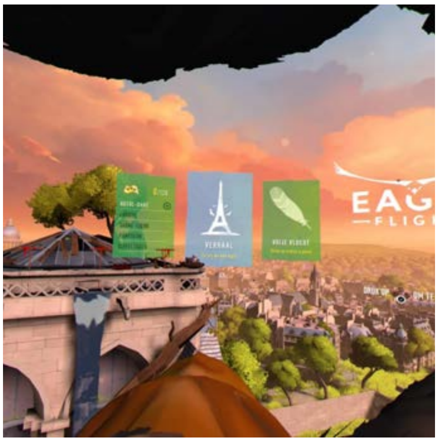
10. Gravity Pull VR-10.png



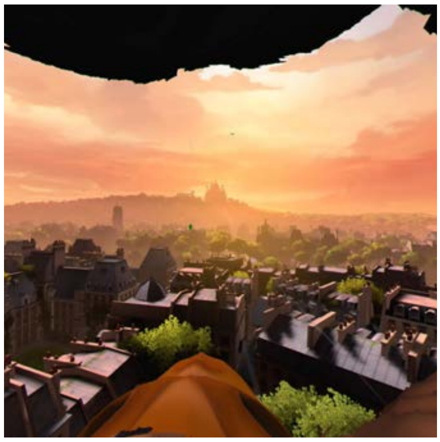
10. Gravity Pull VR-11.png



7. InMind 2-08.png



25. Eagle Flight-03.jpg



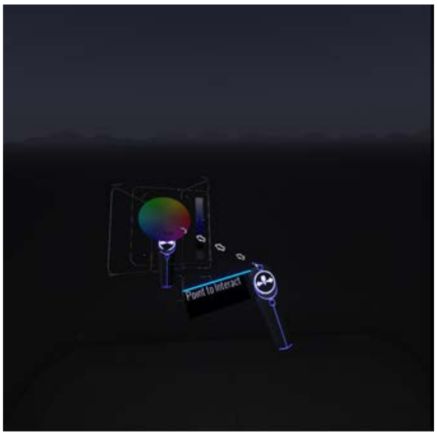
25. Eagle Flight-05.jpg

26. Robison_The Journey-09.jpg

Wand

Pointing/Targeting

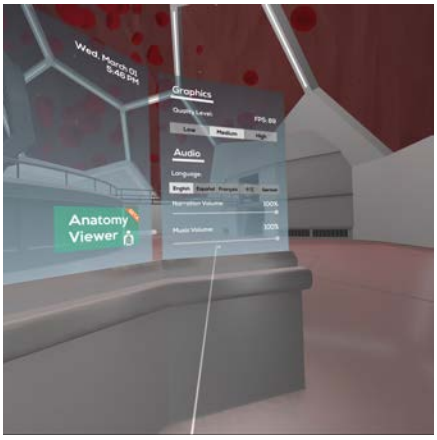
11. Tilt Brush-07.png



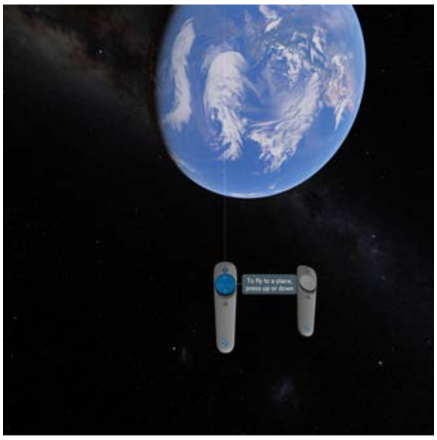
11. Tilt Brush-09.png

16. Rec Room-42.png

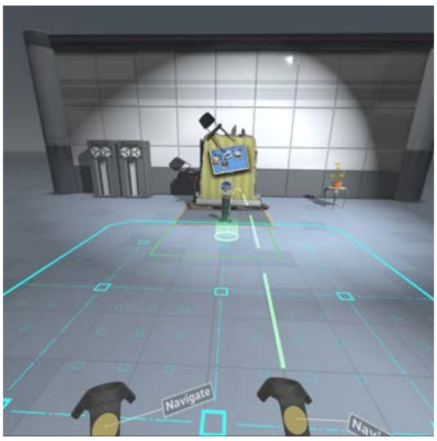
17. PaintLab-06.png



14. The Body VR-04.png



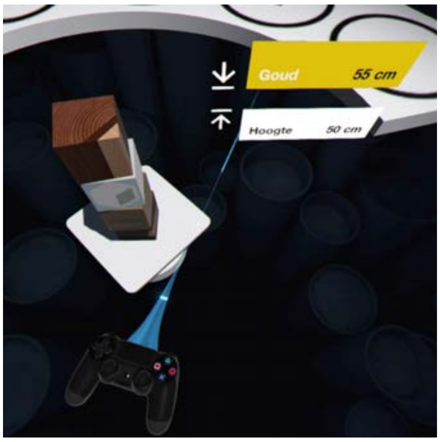
19. Google Earth VR-12.png



20. The Lab-08.png

20. The Lab-28.png

20. The Lab-30.png



22. PlayStation®VR Demo Disc-08.jpg

22. PlayStation®VR Demo Disc-13.jpg

B2 Activate/Confirm

Gaze
Select/Activate/Confirm

2. Jaunt VR-04.png

4. Cardboard Crash-02.png

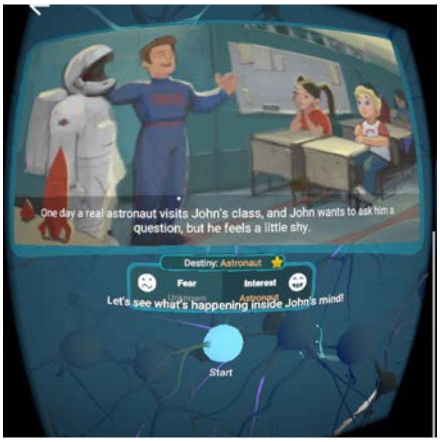
4. Cardboard Crash-03.png

5. Tuscany-01.png

5. Tuscany-02.png

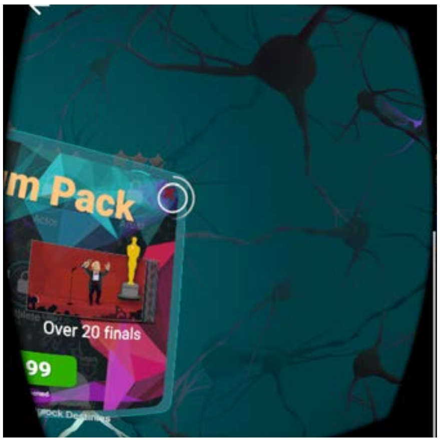
6. Virtual Speech-02.png

6. Virtual Speech-07.png



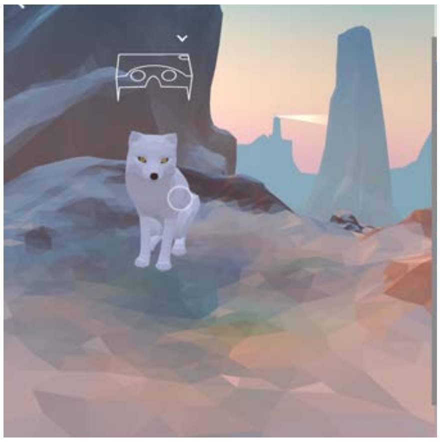
7. InMind 2-01.png

7. InMind 2-02.png

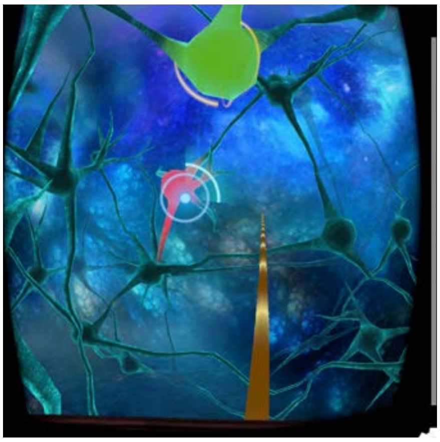


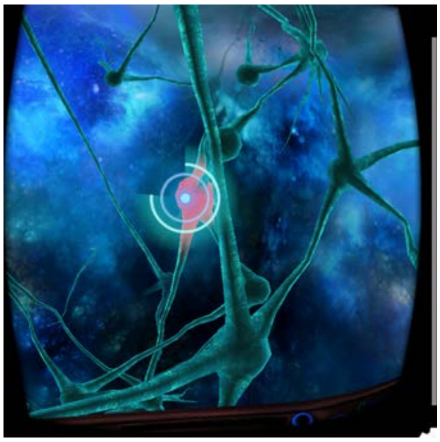
7. InMind 2-11.png


8. Cardboard-09.png


8. Cardboard-10.png

9. InMind-02.png


9. InMind-05.png


9. InMind-06.png

Wand

Select/Activate/Confirm

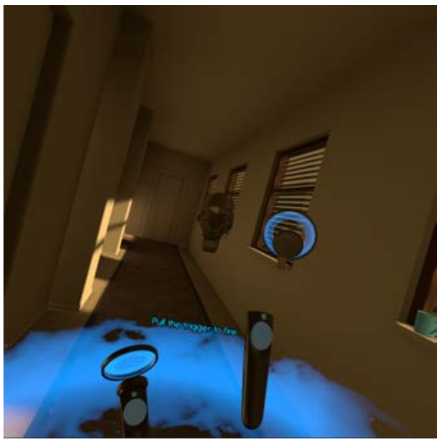
11. Tilt Brush-05.png

16. Rec Room-14.png

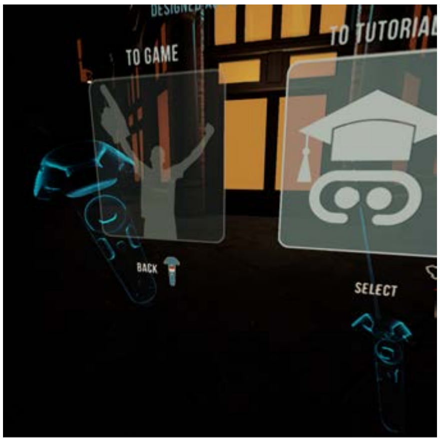

16. Rec Room-26.png


16. Rec Room-28.png

16. Rec Room-46.png


18. Budget Cuts Demo-10.png

Screenshot_Fri_Mar_03_16-15-58_2017.png



Screenshot_Fri_Mar_03_16-16-05_2017.png

B3 Translate

Gaze

Translate

1. Youtube app-04.png

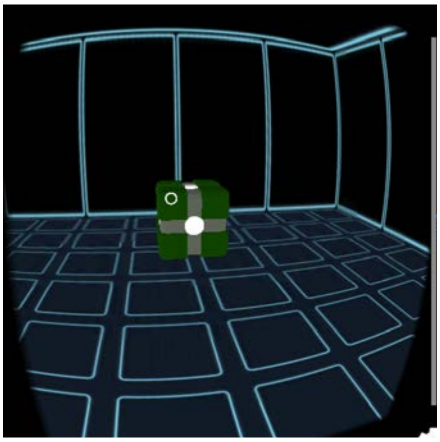
1. Youtube app-05.png

8. Cardboard-16.png

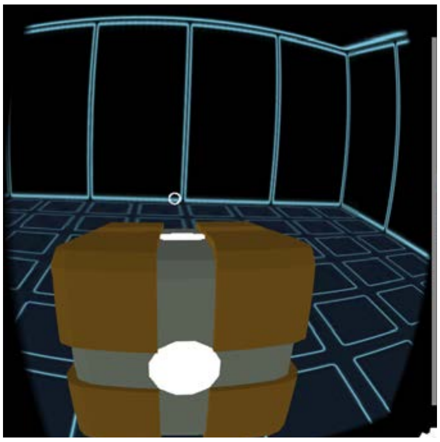
10. Gravity Pull VR-08.png

10. Gravity Pull VR-09.png

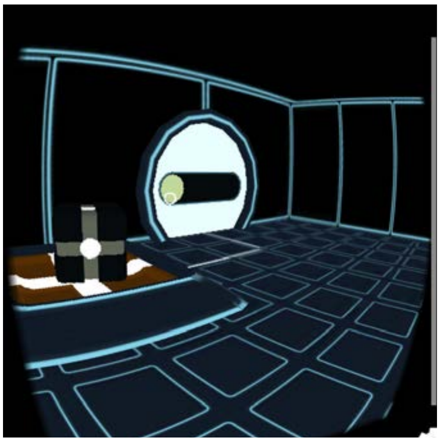
8. Cardboard-17.png



10. Gravity Pull VR-05.png

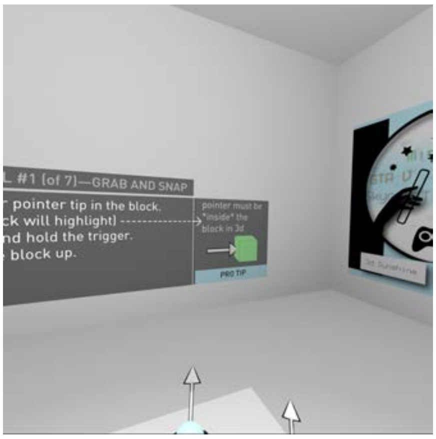


10. Gravity Pull VR-06.png



10. Gravity Pull VR-07.png

Wand
Translate

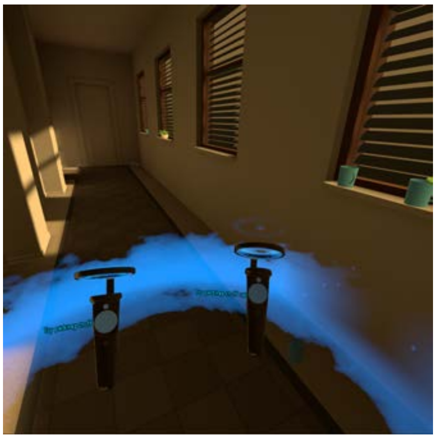

13. 3D Sunshine-06.png

13. 3D Sunshine-18.png

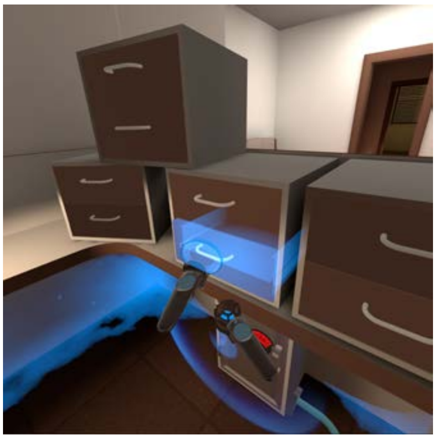

13. 3D Sunshine-24.png

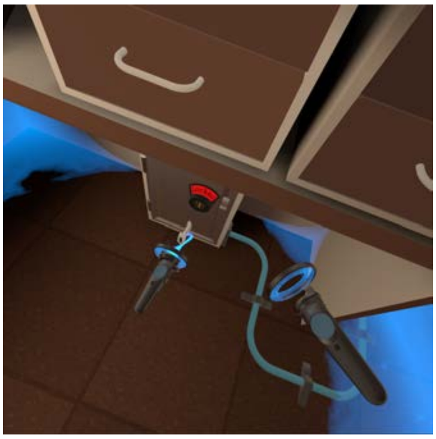

15. Gnomes & Goblins-08.png

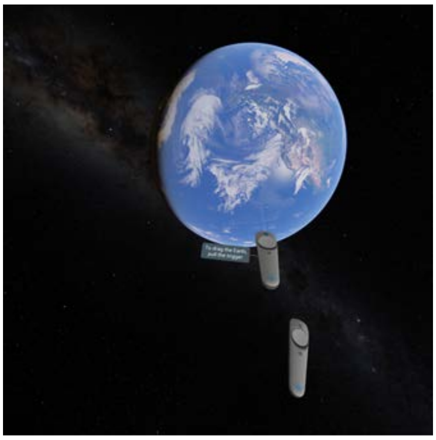
16. Rec Room-30.png

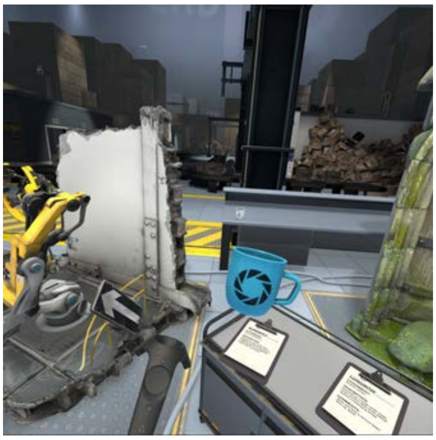

18. Budget Cuts Demo-02.png


18. Budget Cuts Demo-06.png


18. Budget Cuts Demo-20.png


18. Budget Cuts Demo-22.png


19. Google Earth VR-10.png


20. The Lab-22.png

22. PlayStation®VR Demo Disc-05.jpg

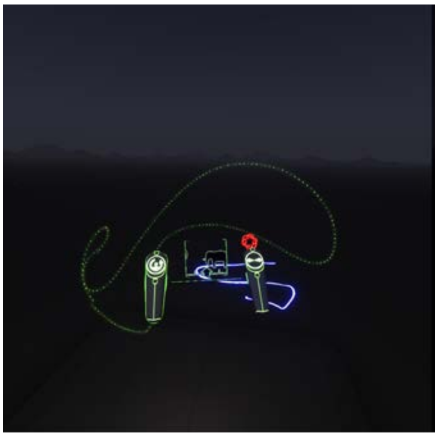
26. Robison_The Journey-18.jpg

26. Robison_The Journey-19.jpg

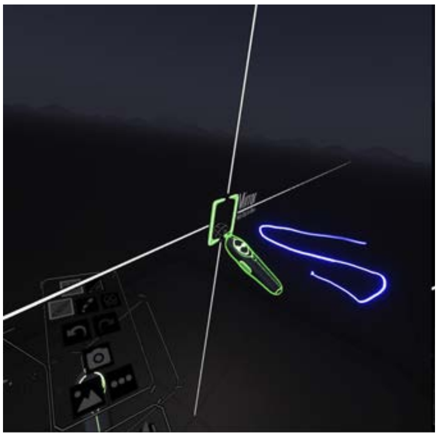
B4 Manipulate

11. Tilt Brush-15.png

11. Tilt Brush-17.png

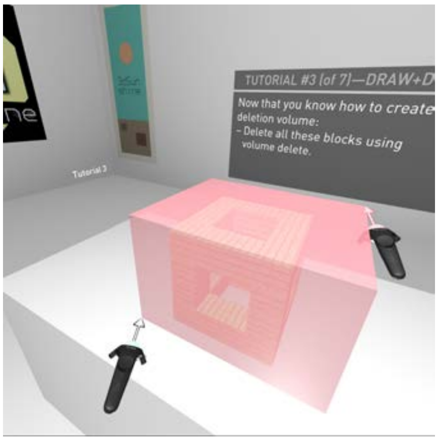


11. Tilt Brush-19.png

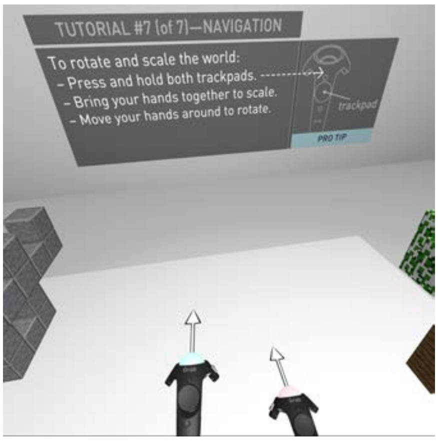


11. Tilt Brush-21.png

11. Tilt Brush-23.png



13. 3D Sunshine-12.png



13. 3D Sunshine-28.png

16. Rec Room-48.png

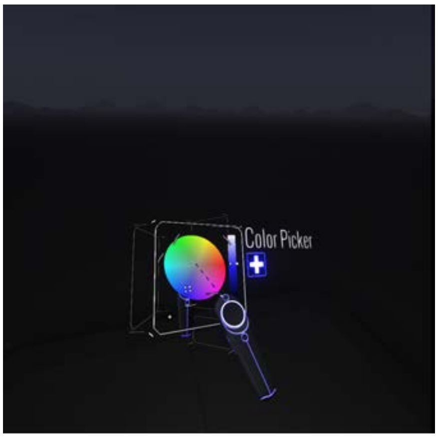
16. Rec Room-50.png

19. Google Earth VR-18.png

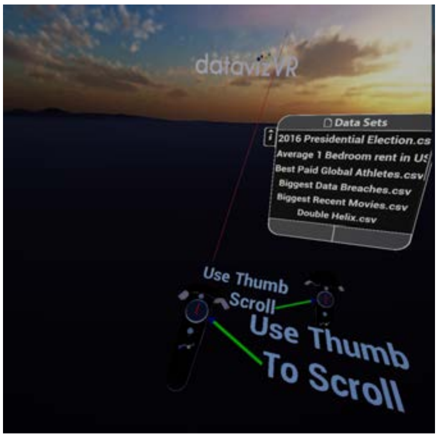
B5 Controller Design

General

Controller Design



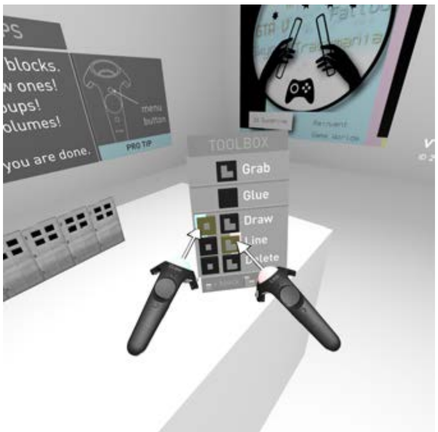
11. Tilt Brush-11.png



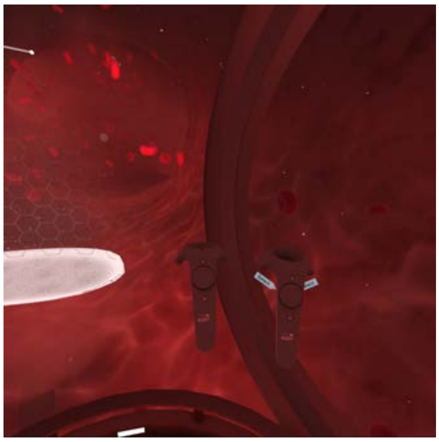
12. Data Visualizer-05.png

12. Data Visualizer-11.png

13. 3D Sunshine-02.png



13. 3D Sunshine-26.png



14. The Body VR-06.png

15. Gnomes & Goblins-06.png

16. Rec Room-04.png

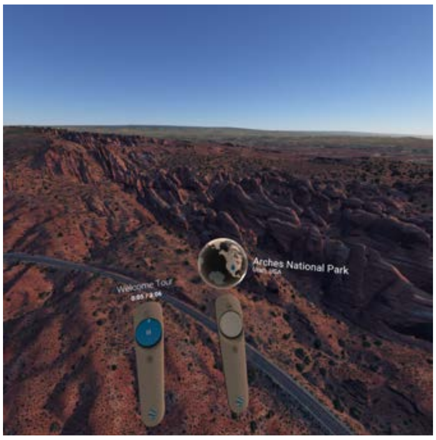
16. Rec Room-34.png

16. Rec Room-40.png

17. PaintLab-02.png

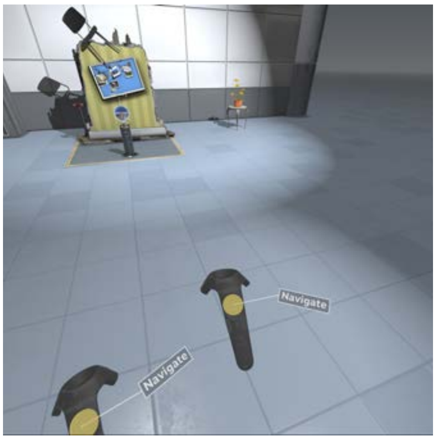
18. Budget Cuts Demo-18.png

19. Google Earth VR-02.png



19. Google Earth VR-04.png

20. The Lab-02.png



20. The Lab-06.png

26. Robison_The Journey-11.jpg

Haptic Feedback

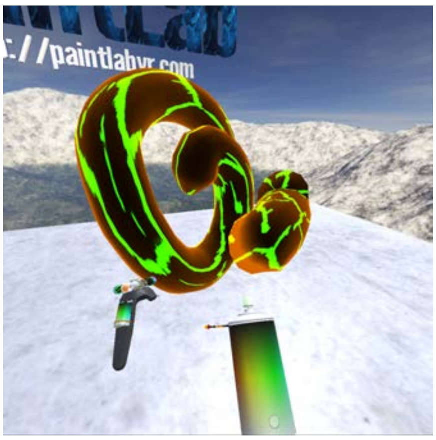
Controller Design

Tools

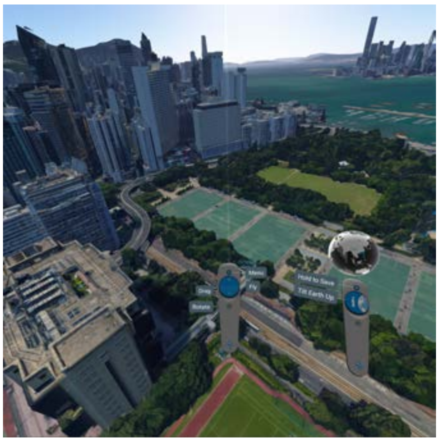
Controller Design

16. Rec Room-56.png

17. PaintLab-08.png

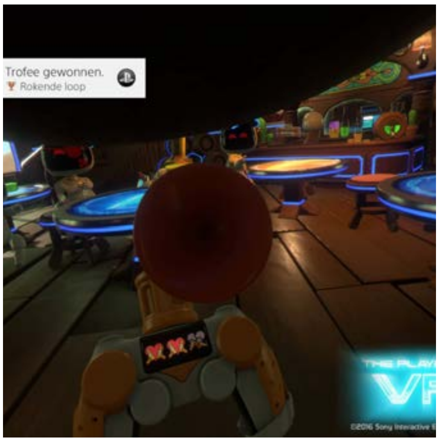


17. PaintLab-10.png


19. Google Earth VR-16.png


20. The Lab-24.png


20. The Lab-26.png



23. THE PLAYROOM VR-05.jpg

Screenshot_Fri_Mar_03_16-17-00_2017.png

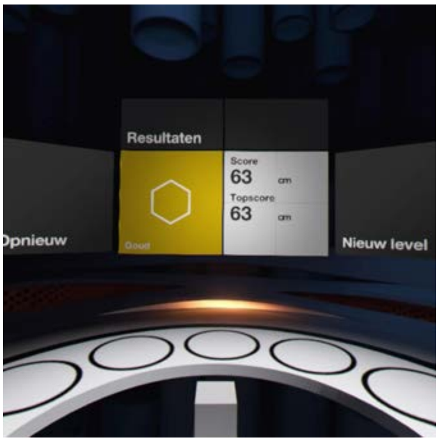
C1 2D Interface

Spatial Dimensions
Depth

Size
Spatial Dimensions

6. Virtual Speech-05.png


16. Rec Room-44.png

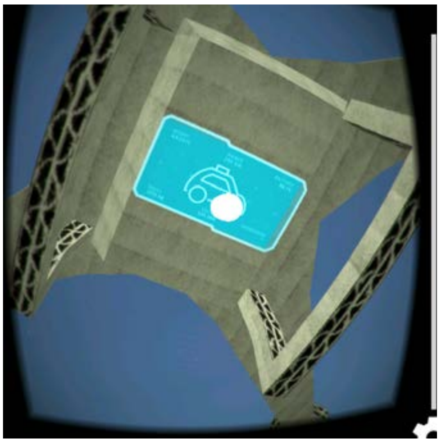


22. PlayStation®VR Demo Disc-09.jpg

26. Robison_The Journey-15.jpg

Place

Spatial Dimensions

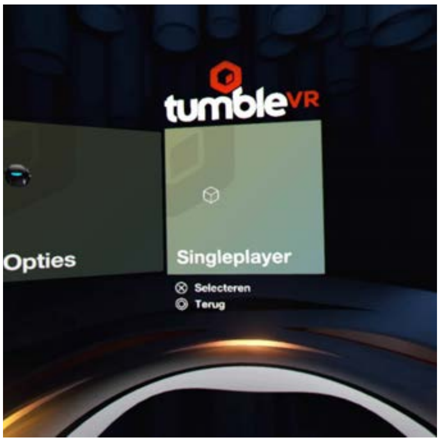


4. Cardboard Crash-10.png

14. The Body VR-02.png

16. Rec Room-16.png

16. Rec Room-68.png



22. PlayStation®VR Demo Disc-01.jpg

26. Robison_The Journey-16.jpg

Screenshot_Fri_Mar_03_16-16-35_2017.png

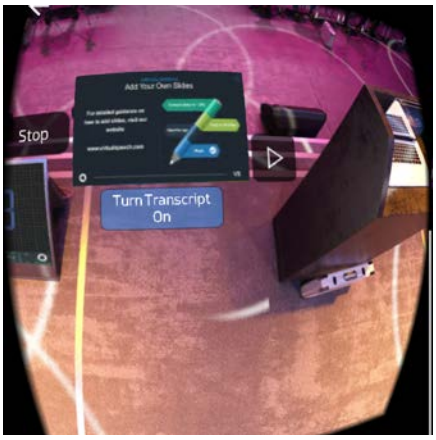
Menus

2D interfaces

2. Jaunt VR-02.png

2. Jaunt VR-03.png

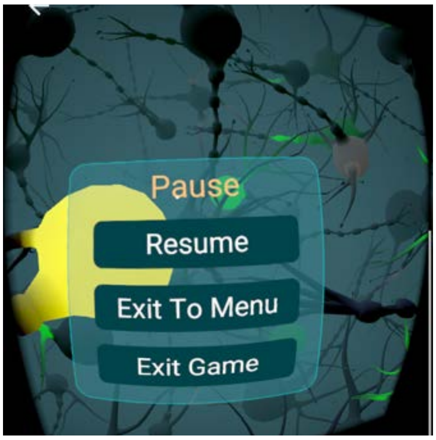
3. Proton Pulse-02.png



6. Virtual Speech-04.png

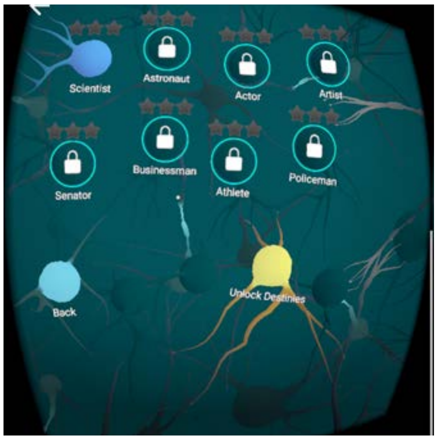
6. Virtual Speech-06.png

10. Gravity Pull VR-03.png



7. InMind 2-03.png

7. InMind 2-04.png

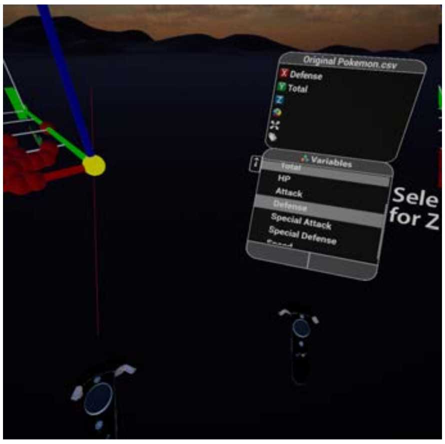


7. InMind 2-10.png

8. Cardboard-06.png

8. Cardboard-07.png

8. Cardboard-08.png

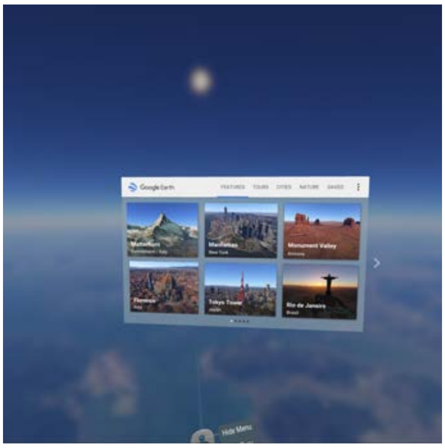


12. Data Visualizer-17.png

13. 3D Sunshine-14.png

13. 3D Sunshine-16.png

13. 3D Sunshine-32.png


19. Google Earth VR-20.png

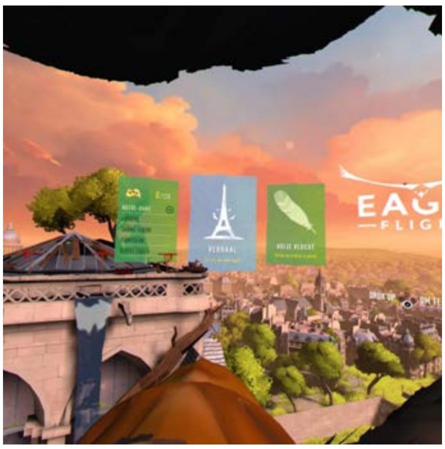
19. Google Earth VR-22.png

20. The Lab-04.png


23. THE PLAYROOM VR-09.jpg

24. Rez Infinite-03.jpg

25. Eagle Flight-02.jpg


25. Eagle Flight-03.jpg

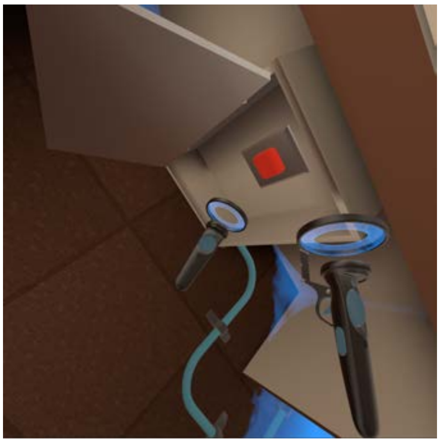

26. Robison_The Journey-06.jpg

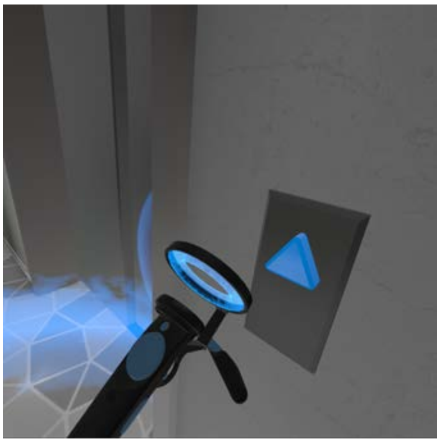
Menus
Buttons

4. Cardboard Crash-03.png

6. Virtual Speech-07.png

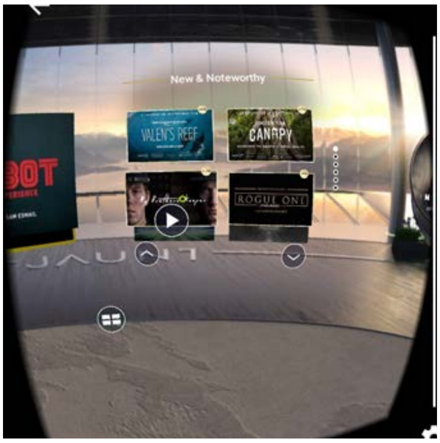
7. InMind 2-02.png


18. Budget Cuts Demo-24.png


18. Budget Cuts Demo-26.png

Content
Menus

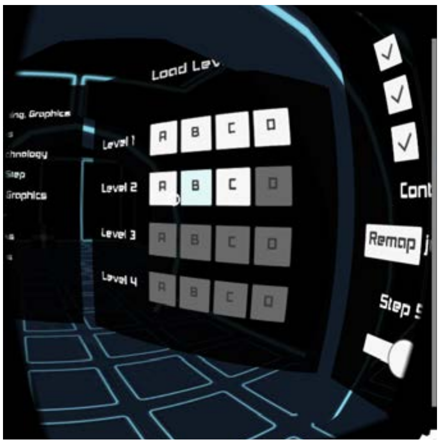

1. Youtube app-01.png



2. Jaunt VR-07.png


4. Cardboard Crash-06.png

6. Virtual Speech-01.png



10. Gravity Pull VR-04.png

11. Tilt Brush-13.png

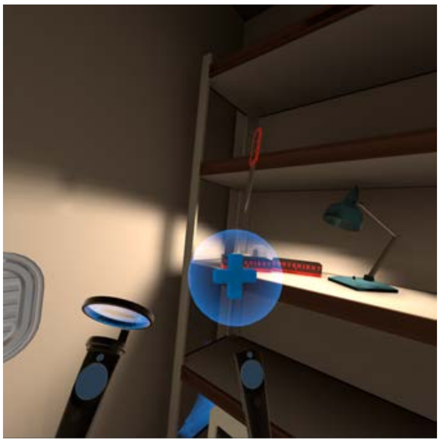
12. Data Visualizer-07.png

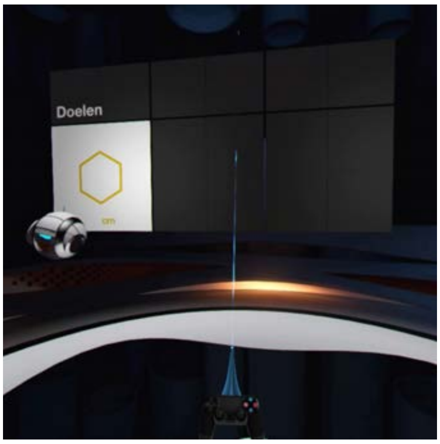
12. Data Visualizer-09.png

12. Data Visualizer-13.png

13. 3D Sunshine-20.png


16. Rec Room-20.png


18. Budget Cuts Demo-34.png



22. PlayStation®VR Demo Disc-02.jpg

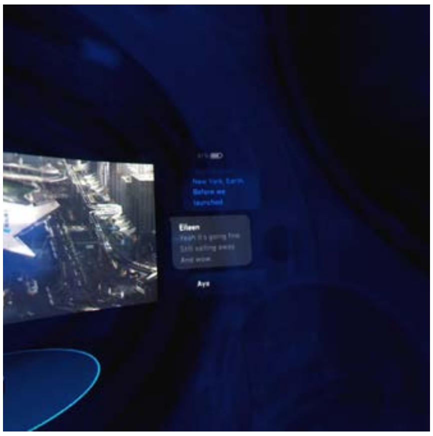
Navigation

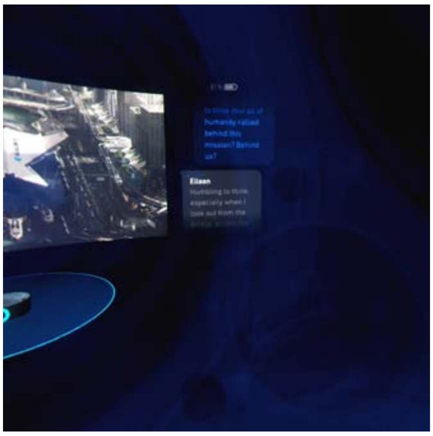
Menus


16. Rec Room-64.png

20. The Lab-14.png

26. Robison_The Journey-10.jpg


26. Robison_The Journey-13.jpg


26. Robison_The Journey-14.jpg

Special Screens
Text

6. Virtual Speech-03.png

7. InMind 2-05.png

Loading screen
Special Screens

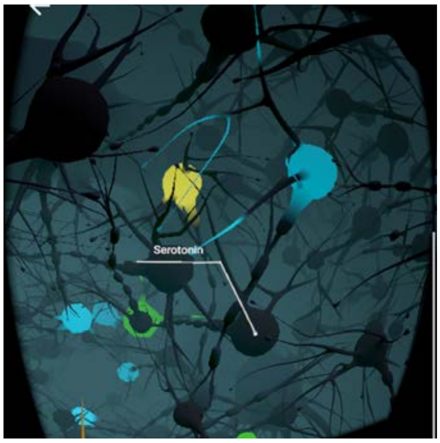
26. Robison_The Journey-02.jpg

Notification

Special Screens

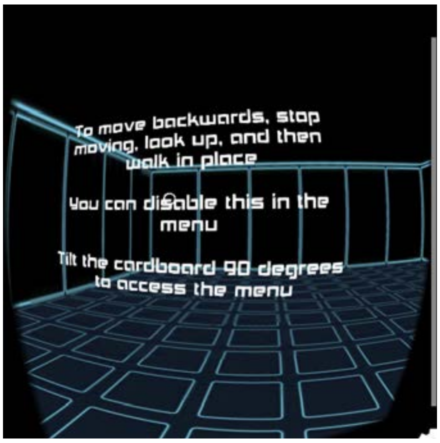
4. Cardboard Crash-05.png

7. InMind 2-06.png



7. InMind 2-09.png

9. InMind-03.png

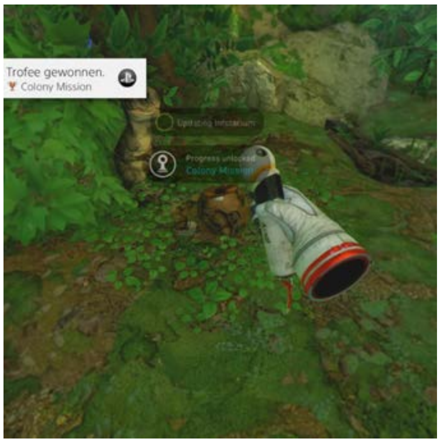


10. Gravity Pull VR-01.png

11. Tilt Brush-03.png

16. Rec Room-24.png

25. Eagle Flight-09.jpg



26. Robison_The Journey-03.jpg

26. Robison_The Journey-04.jpg

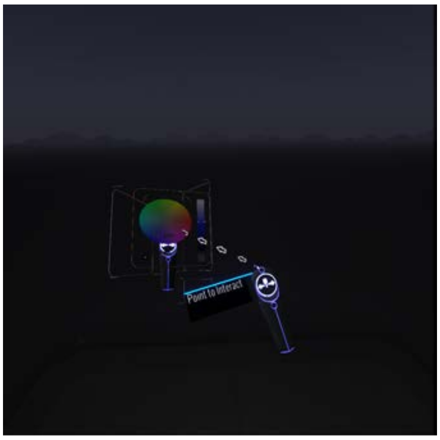
Error

Special Screens

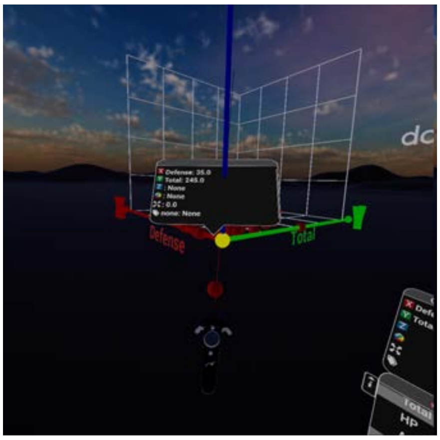
18. Budget Cuts Demo-36.png

Info

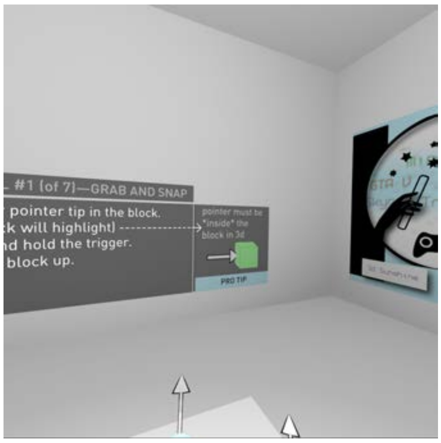
Special Screens



11. Tilt Brush-09.png

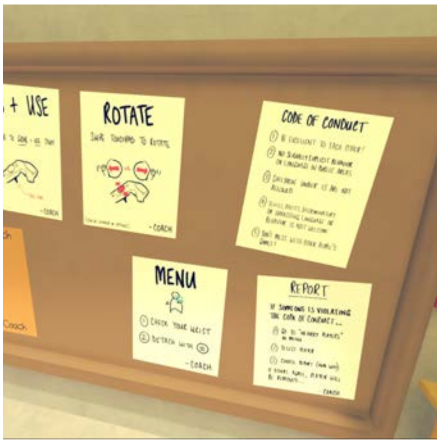


12. Data Visualizer-15.png



13. 3D Sunshine-04.png

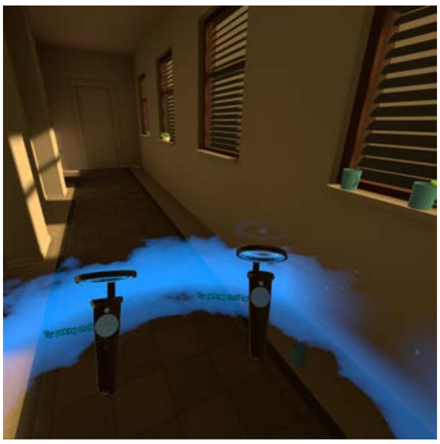
16. Rec Room-10.png



16. Rec Room-32.png

16. Rec Room-58.png

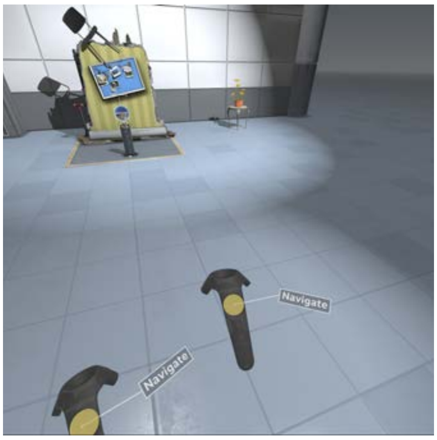
17. PaintLab-06.png



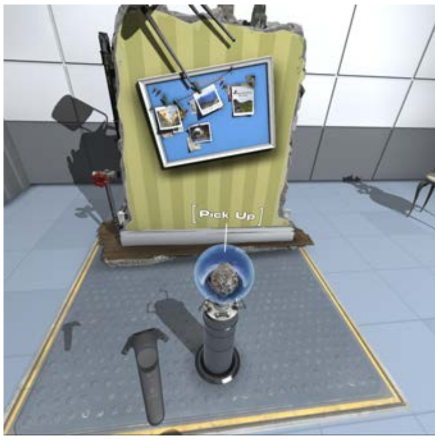
18. Budget Cuts Demo-02.png

18. Budget Cuts Demo-14.png

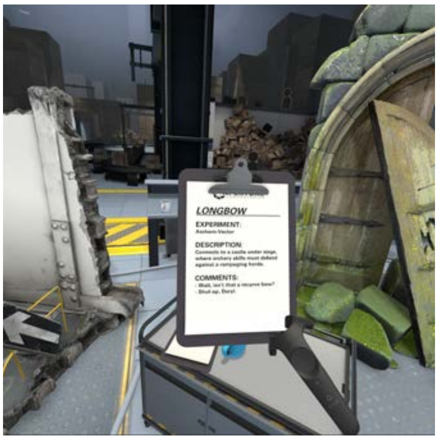
19. Google Earth VR-06.png



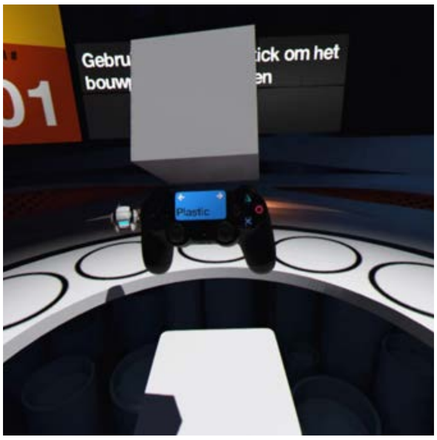
20. The Lab-06.png



20. The Lab-10.png

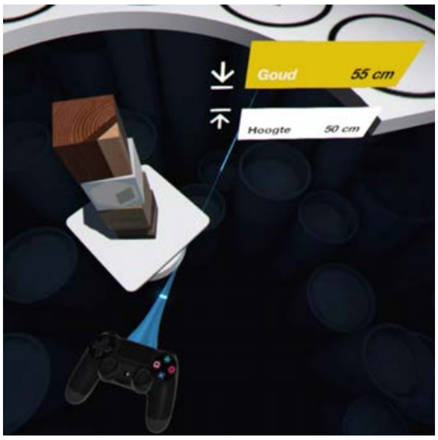


20. The Lab-16.png



22. PlayStation®VR Demo Disc-06.jpg

22. PlayStation®VR Demo Disc-07.jpg



22. PlayStation®VR Demo Disc-08.jpg

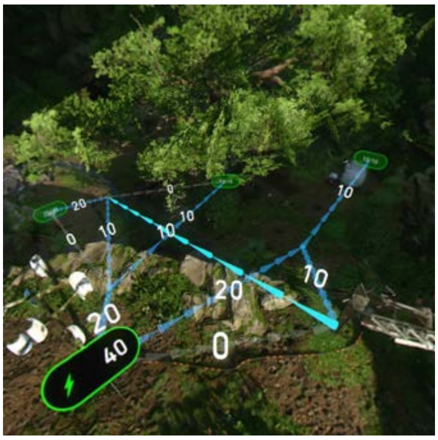
22. PlayStation®VR Demo Disc-14.jpg

Screenshot_Fri_Mar_03_16-16-25_2017.png

c2 3D objects

Spatial Dimensions

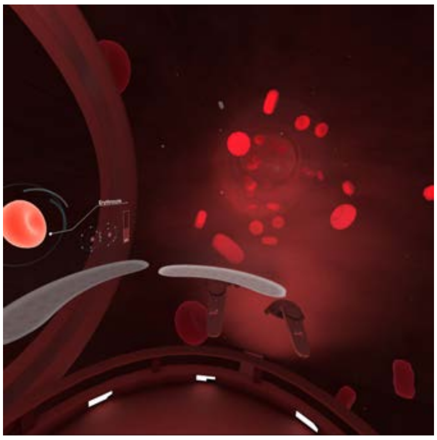
Size



26. Robison_The Journey-12.jpg

Place

Spatial Dimensions



14. The Body VR-08.png

APPENDIX A.6

Scenarios in which guiding attention can be used

It has been stated before that guiding attention can be useful when actions happens outside the field of view of the head mounted display. Some examples will be stated here to reinforce the argument for the need of such tools.

Calling up something with a button
Menu's
Windows
Objects
Actions

When the assumption is made that most of the action in VR will happen in front of the user, the above scenario will happen when the user is for some reason looking somewhere else than to the front or the described objects do not appear in the front. This could happen for reasons like not enough space in the front, VR environments that are built like actual spaces or when the object has different associations that are better kept separated spatially.

Examples of these are:
IKEA VR
Shopping
Content Navigation
Training programs
Physical Exercises (Medical)

Automatic Actions that happen in the environment
Animations
Media

Examples of these are:

360 video
Media players
Telecommunication
Construction

"Highlights" and "Features"
When selling or showcasing information, the user can look around and has the ability to discover. But sometimes you want to make sure certain information is conveyed. After a certain criteria (e.g. time) attention could be guided towards specific features. This could be useful when showcasing buildings and products to prospective clients or for educational experiences in schools, museums and exhibitions.

Lost immersants
The reverse could also be the case when everything is happening in the front, but the immersant is facing another direction. In this case attention needs to be focused back to the front. This could happen when a virtual environment is loaded in

a different direction then where the user is initially facing. Or when an immersant is distracted by its surroundings and his or her focus needs to be at the front. For example when there is a commercial playing, instructions are given or when the program is waiting for the users input.

Waiting for input
Sometimes, the program is waiting for input. With the HTC Vive the controllers can shake, but this doesn't necessarily indicate where the user needs to look. Sometimes it's an object in the environment, sometimes it is the remote itself.

APPENDIX B.1

Selection of domains in VR Applications

According to the Virtual Reality Society (2017) VR applications are most common in the following domains:

- Military
- Education
- HealthCare
- Entertainment
- Fashion
- Heritage
- Business
- Engineering
- Sport
- Media
- Scientific Visualisation
- Telecommunications
- Construction
- Film
- Programming

To design attention it is helpful to have a specific context to design for. Therefore certain domains were ignored. A key criteria was whether the domain is primarily focused on consumers, or focused on a specific niche. When relevant aspects of certain domains for this research were covered by the education domain, the specific domain was also discarded.

Domains that are discared:
Military was deemed to specific and not appropriate for most consumers.
HealthCare consists partly of trainings and providing information (either general for patients, or specific for professionals).
Entertainment seems to be a domain entirely on its own. It has already been decided to not pursue games.
Fashion is part of designing. Designing is part of a too specific design to account for everyone. However, representing designs in order to sell is about conveying convincing information.
Engineering is designing and closely related with the functions of the application. Together with the fact that it is aimed at a closed group, engineers, makes it unsuitable for inclusion.
Sport is either used for training or measuring. The training part is already contained with the education domain.
Media is about how VR is captured in media, not how media is captured in VR.
Telecommunications is more about representing other people and was deemed a to specific domain as it only has one function.
*Constructio*n was disregarded for the same reason as engineers. As a sidenote, it is often used to better inform stakeholders. This could be grouped under the domain “information”.
Film is mostly about captured experiences, disallowing interaction with the elements. Navigating through content is more appropriate with “informing” immersants about the possibilities and has it’s own domain.
Programming languages is about the actual languages to code VR. Therefore

inappropriate in a user study of immersants.

Chosen Domains

Education seems to be a robust VR domain as you can emulate situations that would otherwise be expensive, dangerous or impossible. This makes VR the preferred choice over many other options. VR makes it cheaper and possible for companies and institutions to fully train their students and will therefore likely be a growing and steady domain for the coming years. Many of the domains thats were discarded also contained elements of educating or training the immersant.

The domains *Education*, *Heritage*, *Business*, *Healthcare* and *Scientific Visualisation* are all about informing and training immersants. Therefore they are grouped under the cluster domain "information" or aspects belong to "education". Think of a Virtual World in which extra information is given about objects and sceneries that you see.

Informing

- **Education**
- **Business**
- **Heritage**
- **HealthCare**
- **Scientific Visualisation**

Training

- **Education**

APPENDIX B.2
Interview with VR-Lab

On the 29th of march, 2017, a visit was made to the VR-Lab in Nijmegen. They offer a place for developers in the old “Honig” factory.

Teun van Tijffelen was the contact person and showed the environment. They have several Vive kits, Oculus Rifts and Google Cardboards variants. Teun felt like VR could grow big, especially in the medic sector and that one of the biggest hurdles is convincing companies to invest in VR. One of the big issues is that you need to try VR before you understand it’s potential. So they use the VR-Lab to also showcase demo’s and let potential clients try VR.

Clients like the immersive experiences with the more expensive set-ups, but they wish that they could give something along with their customers. So one challenge is to transport the experience to cheaper set-ups, like google cardboard, that don’t have the possibility of tracking through space or extensive controllers. The future will be in smartphones that are able to track the environment through their cameras and can identify hands and gestures.

One of the biggest advantages of VR is the ability to show products that are otherwise hard to showcase; because of supply, difficulty of moving it, size and danger. Another great application would be training as difficult to reach, dangerous and sometimes impossible situations can be trained in VR.

It was also expressed that the interactions for VR can be improved and that guiding the attention, or showing what is possible in VR would greatly improve the user experience.

Teun thinks that VR video probably won’t be the biggest sector as it lacks interactivity.

APPENDIX C.1
Chosen Tools

Early Selection:
+ Spoken commands – too easy, focus on visual; this is audio
+ Vibrating Controller – can only attract attention, not guide it somewhere
+ Arrows – Combined with reticle
+ Sound cues – might get lost in the video sound, focus on visual
+ Lighting
+ Changing reticle (combination with Arrow)
+ Converging lines Middendorf (2012)
+ Animation
+ Movement at the point (moves inside FOV)

Chosen	Tools	Considerations
	Overview	
No	Widgets (that contain important information)	Not subconscious, needs attention already
No	Bars (that are always on top and show status)	Not subconscious, needs attention already
No	Navigation (through menus or content, order or layout can play a role)	Too specific. Works only with multiple elements
	Human	
No	Personification	To difficult to convincingly achieve with the time-frame
No	Eye-contact	To difficult to convincingly achieve with the time-frame
No	Gaze	To difficult to convincingly achieve with the time-frame
No	Spoken commands	Focus is on visual; this is audio
	Physics	
No	Snap	Too specific, only works when moving an object

No	Vibrating Controller	Too vague, doesn't point in any direction; only asks for attention
	Cues	
Yes	Arrows	Is there ever a time arrows are inappropriate?
Yes	Sound cues	Focus is on visual; this is audio
No	Lighting	Not noticeable when object is outside the FOV or when there is no mist
Yes	Changing reticle (comb. Arrow)	Very effective, always in sight. Only not in the peripheral vision.
No	Affordances (handles, buttons)	Only works with objects and noticing affordances differs between people
No	Visual complexity Middendorf (2012)	Not specifically on guiding attention outside FOV
No	Text that ends at an element Middendorf (2012)	Text isn't always present
Yes	Converging lines Middendorf (2012)	Passive method that is based on Gestalt principles. Worth a try!
	Place	
No	x,y,z position	
No	Close	Not in the peripheral vision
No	In front	Not in the peripheral vision
No	Eye-level	Not in the peripheral vision
No	Z-figure pattern Middendorf (2012)	Converging lines seem a better option
No	On the right Middendorf (2012)	Doesn't work when things are on the left
No	Page wide Middendorf (2012)	Doesn't guide it to a certain spot
No	Close to gaze position Middendorf (2012)	Doesn't guide it to a certain spot
No	At the end of white space Middendorf (2012)	Not always applicable
No	At vanishing points Middendorf (2012)	Not always applicable
	Properties	
	Physics	
No	Size	Outside the FOV
No	Shape	Outside the FOV
Yes	Animation	
No	(in)complete movement towards a point	Outside the FOV

Yes	Movement at the point	Moves inside FOV and can be very specific
No	blinking	Outside the FOV
	Chemistry	
No	Colour	Outside the FOV, not precise guiding
No	Opacity	Outside the FOV, not precise guiding
No	Highlights	Outside the FOV, not precise guiding
No	Contrast	Outside the FOV, not precise guiding
No	Brightness	Outside the FOV, not precise guiding
No	People choose what is brightest Weinschenk (2015)	Outside the FOV

APPENDIX C.2
Consent Form

Consent Form

Experiment: VR interaction patterns
Investigators: students TU Delft Fac IDE, Graduation project Arjen Wiersma

This study involves research subjects. I will investigate how participants react to certain tools in VR. The expected duration of the subject's participation is 15 minutes. The subject will perform certain tasks in a VR environment with the HTC Vive headset and will then have to fill in a questionnaire and answer some questions. Participation is voluntary. We do not foresee any risk (or discomfort) resulting from participation. We will record the subject's age, gender, education level, VR experience and record audio and video during the test and store this data on protected hardware that can only be accessed by authorised researchers involved in this project (hard drive and a private google drive and dropbox folder). Incidental findings will be handled anonymously. Arjen Wiersma may be contacted for answers to pertinent questions about the research and research subjects' rights, and in the event of a research-related injury to the subject. The subject has the opportunity to ask questions and to withdraw at any time from the research without consequences. All personal data will be deleted after the end of the research period or sooner if they are no longer needed (i.e. if results have been used in the graduation project). Personal data will not be retained or sent/sold to a third party for further research. The results of the research might be presented during interim and/or final presentation at TU Delft, or published in international refereed journals / conference proceedings using anonymous presentations or initials.

Please sign if you understand this information and if you consent to participation:

Name	Signature	Date

APPENDIX C.3

Online Survey

Evaluation

*Vereist

Age *

Jouw antwoord

Gender *

- Male
- Female

VR Experience *

- Never tried it before
- Tried it once
- Tried it a few times
- Regular user

Moving ball *

- Not noticed
- Noticed, but looked at wrong direction
- Noticed, looked at right direction
- Moved head all the way in the right direction
- Moved head all the way in the wrong direction

Other remarks - Moving Ball

Jouw antwoord

Swirl *

- Not noticed
- Noticed, but looked at wrong direction
- Noticed, looked at right direction
- Moved head all the way in the right direction
- Moved head all the way in the wrong direction

Other remarks - Swirl

Jouw antwoord

Gaze Arrow *

- Not noticed
- Noticed, but looked at wrong direction
- Noticed, looked at right direction
- Moved head all the way in the right direction
- Moved head all the way in the wrong direction

Other remarks - Gaze Arrow

Jouw antwoord

VOLGENDE

Evaluation

*Vereist

Ranking the tools

In this test, three tools that should help guide your attention were used; a moving ball, a swirling picture in the background and an arrow attached to your gaze, that would appear at the border of your sight.

Order the tools from best (1) to worst (3) *

	Moving Ball	Swirl	Gaze Arrow
1	○	○	○
2	○	○	○
3	○	○	○

Could you please explain why you made this order?

Jouw antwoord

VORIGE VOLGENDE

Verzend nooit wachtwoorden via Google Formulieren.

Evaluation

*Vereist

Questionaire -1

This section is about the moving ball that went from the screen to the side

Moving Ball *

	1	2	3	4	5	6	7
Technical - Human							
Discouraging - Motivating							
Cautious - Bold							
Bad - Good							
Repelling - Appealing							
Distractive - Helpful							
Rejecting - Inviting							
Ugly - Attractive							
Unpleasant - Pleasant							
Tacky - Stylish							
Disagreeable - Likeable							
Comfortable - Uncomfortable							
Conventional - Inventive							
Unprofessional - Professional							
Complicated - Simple							
Unimaginative - Creative							
Unpredictable - Predictable							
Dull - Captivating							
Confusing - Clearly Structured							

What do you think is effective about this tool and why?

Jouw antwoord

How would you improve this tool ? *

Jouw antwoord

VORIGE VOLGENDE

Verzend nooit wachtwoorden via Google Formulieren.

Evaluation

*Vereist

Questionnaire - 2

This section is about the swirling lines that appeared behind and around the video

Swirl *

	1	2	3	4	5	6	7
Repelling - Appealing							
Unpleasant - Pleasant							
Bad - Good							
Confusing - Clearly Structured							
Unimaginative - Creative							
Dull - Captivating							
Cautious - Bold							
Tacky - Stylish							
Distractive - Helpful							
Disagreeable - Likeable							
Ugly - Attractive							
Conventional - Inventive							
Technical - Human							
Unpredictable - Predictable							
Complicated - Simple							
Discouraging - Motivating							
Comfortable - Uncomfortable							
Unprofessional - Professional							
Rejecting - Inviting							

What do you think is effective of this tool and why?

Jouw antwoord

How would you improve this tool?

Jouw antwoord

VORIGE VOLGENDE

Verzend nooit wachtwoorden via Google Formulieren.

Evaluation

*Vereist

Questionnaire -3

This section is about the arrows that appeared on the borders of your vision.

Gaze Arrow *

	1	2	3	4	5	6	7
Rejecting - Inviting	○	○	○	○	○	○	○
Dull - Captivating	○	○	○	○	○	○	○
Comfortable - Uncomfortable	○	○	○	○	○	○	○
Unprofessional - Professional	○	○	○	○	○	○	○
Confusing - Clearly Structured	○	○	○	○	○	○	○
Bad - Good	○	○	○	○	○	○	○
Distractive - Helpful	○	○	○	○	○	○	○
Conventional - Inventive	○	○	○	○	○	○	○
Unpredictable - Predictable	○	○	○	○	○	○	○
Technical - Human	○	○	○	○	○	○	○
Tacky - Stylish	○	○	○	○	○	○	○
Unimaginative - Creative	○	○	○	○	○	○	○
Ugly - Attractive	○	○	○	○	○	○	○
Discouraging - Motivating	○	○	○	○	○	○	○
Repelling - Appealing	○	○	○	○	○	○	○
Disagreeable - Likeable	○	○	○	○	○	○	○
Complicated - Simple	○	○	○	○	○	○	○
Unpleasant - Pleasant	○	○	○	○	○	○	○
Cautious - Bold	○	○	○	○	○	○	○

What do you think is effective of this tool and why?

Jouw antwoord

How would you improve this tool?

Jouw antwoord

VORIGE VOLGENDE

Verzend nooit wachtwoorden via Google Formulieren.

Evaluation

The end

Any remarks or suggestions?

Jouw antwoord

VORIGE VERZENDEN

Verzend nooit wachtwoorden via Google Formulieren.

APPENDIX C.4

AttrakDiff Questions and Selection

The AttrakDiff questionnaire was used as it features semantic differentials that allow you to discover what meaning people give to your design. Since the test needed to be run multiple times, it was necessary to shorten the list. In previous experience with testing a microwave, it was also observed that some word pairs weren't understood by the participants, therefore rendering these answers less useful as it cannot be ascertained that the questionnaire was filled in entirely proper.

Also, since the tools serve a certain goal, some word pairs seemed unnecessary. Below are the all the semantic differentials and the considerations to remove them.

The word pair "Comfortable – uncomfortable" was added to gain insight in how comfortable participants found a certain tool. The word pair "Distractive – helpful" was added to see whether participants appreciated the tool and found it helpful or did not appreciate it and found it distractive.

Chosen	*Word pairs*	*Consideration*
	usability	
Yes	+ Technical – human	
Yes	+ Complicated – simple	
No	Impractical – practical	Effectiveness will already be recorded
No	Cumbersome – straightforward	Predictability and structure already cover this
Yes	+ Unpredictable – predictable	
Yes	+ Confusing – clearly structured	
No	Unruly – manageable	The tool is not designed to be managed by immersant
	Identify with it	
No	Isolating – connective	Tools are not in a social context
Yes	+ Unprofessional – professional	
Yes	+ Tacky – stylish	
No	Cheap – premium	Covered enough by the “tacky-stylish” word pair
No	Alienating – integrating	Tools are not in a social context
No	Separates me – brings me closer	Since it attracts the attention away, it could be both; separating from current activity, closer for object that needs attention
No	Unpresentable – presentable	Visual aesthetics were purposefully not integrated into the design
	Hedonic	
Yes	+ Conventional – inventive	
Yes	+ Unimaginative – creative	
Yes	+ Cautious – bold	
No	Conservative – innovative	Covered by “conventional – inventive”
Yes	+ Dull – captivating	
No	Undemanding – challenging	It is not a cognitive task
No	Ordinary – novel	Covered by “conventional – inventive”
	Quality	
Yes	+ Unpleasant – pleasant	
Yes	+ Ugly – attractive	
Yes	+ Disagreeable – likeable	
Yes	+ Rejecting – inviting	
Yes	+ Bad – good	
Yes	+ Repelling – appealing	
Yes	+ Discouraging – motivating	

APPENDIX C.5
Participants remarks

MOVING BALL

“The movement attracts attention”
“moved over the video screen, made me see it”

Inherently not a cue
“The ball is vague, it could’ve been a random ball passing by”
“Unclear what to do with it”
“doesn’t inherently have a clue or directing message”

Follow movement
“I had the tendency to follow the moving object”
“Makes you wonder where it goes”
“you feel attracted to follow the ball”
“Moving ball forces your attention to follow it”
“It takes you along, sort off”

Subtle and simple
“Moving ball is subtle”
“The moving ball was most intuitive”
“Very simple and yet it does attract attention”
“Too simple, and not content related”

Playfull
“It is a little playful”
“It seems playful”

Video
“I thought it was part of the video”
“It distracted from the video”

Visible
“It is clearly visible”

Improvements
Initial movement
“vertical movement so it asks for your attention”
“A follow-me movement … bouncing”

Coherent style
“Better fit with the style”
“A shape fitting with the video”

Slower, organic movement
“make the movement slower to make it les forceful”
“less structured movements”

SWIRL

Aesthetically pleasing
“The swirl is nice to look at”
“I think it looks nice”

Size
“It’s large / visible fast”
“make it smaller”

Direction unclear
“Less clear that I had to look in a direction”
“Unclear it is pointing towards a certain direction”
“The swirl could draw my attention to both sides”

"Direction can be more clear"

Misunderstanding
"Looked like a mistake"
"Didn't understand it because it was too big"

Lines lead
"the lines could take your attention to multiple points"
"the lines lead to somewhere"
"The lines are organic … naturally"

Unnoticed
"It's subtle, too subtle"
"Standing still, it doesn't attract attention"
"I didn't notice it"
"Had I seen it, this would have been an attention grabber"
"More notable"
"It is always visible"

"The swirl supports the video"

Improvements
"make a directional fade towards the product"
"Combine it with something else"
"Roll towards a certain direction"
"It must be more inviting"

GAZE ARROW

Clear Instruction
"Arrow clearly indicates where to look"
"Arrow has a clear direction, so you automatically look in the right direction"
"Within the blink of an eye it's clear what it wants from you"
"Arrow was most clear as it actually indicated to look somewhere"

Familiair
"Feels cliché and outdated"
"very familiar"
"Function instantly clear"
"An arrow would be clearer in purpose and direction"
"you know what is expected of you"

"large arrows" [work]
"Less noticeable"

Improvements
"Because the arrow moves it clearly communicates which direction the user should look"

More interesting
"Less boring arrows"
"more dynamic, less boring"
"more subtle, more playfull in its animation and smaller in shape"

Dynamic
"Let the arrow wait until I follow it's "advice"

OTHER REMARKS

"Make the video screen move"
"Like in Call of Duty … Light up one side"
"make it react to a users gaze"
"My situational awareness is quite low, and it would take me longer than average to notice something like these objects"
"Make the objects… closer to the central axis of someones sight"

APPENDIX D.1

Evaluation Form Test 2

Evaluation

*Vereist

1. **Age** *

2. **Gender** *
   Markeer slechts één ovaal.
   - Male
   - Female

3. **VR Experience** *
   Markeer slechts één ovaal.
   - Never tried it before
   - Tried it once
   - Tried it a few times
   - Regular user

4. **Moving ball** *
   Voorbeeld: 8:30

5. **Swirl** *
   Voorbeeld: 8:30

6. **Gaze Arrow** *
   Voorbeeld: 8:30

7. **Mirror Ball** *
   Voorbeeld: 8:30

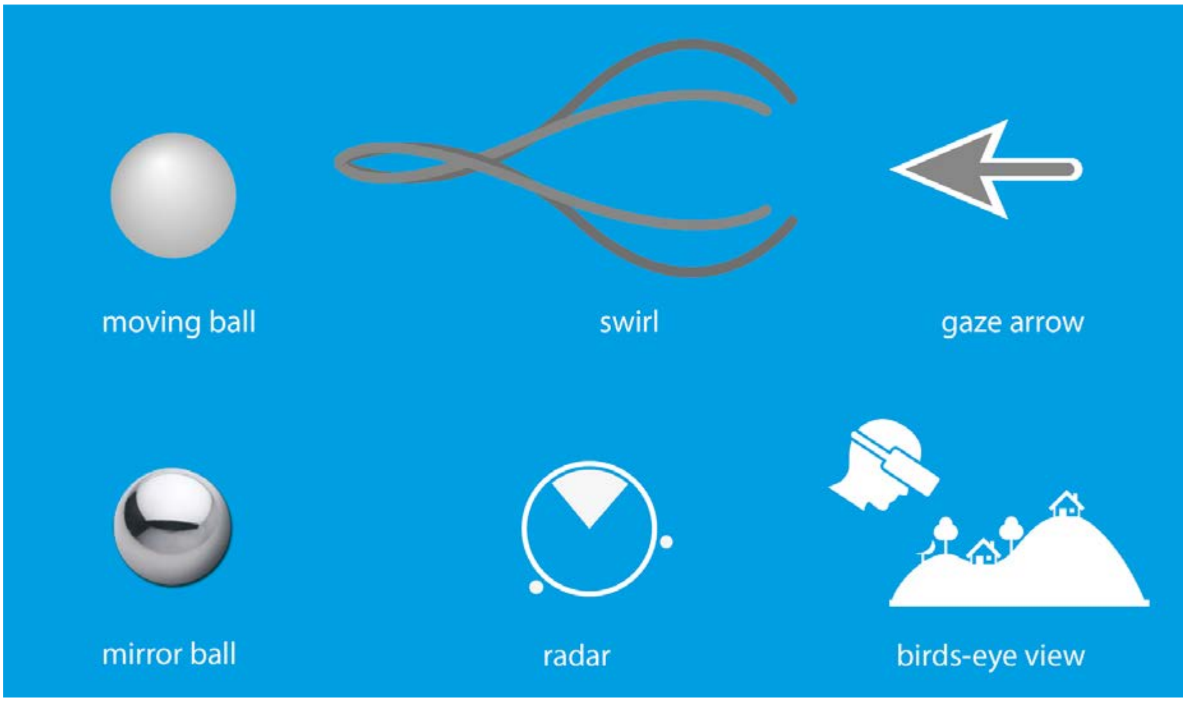
8. **Radar** *
   Voorbeeld: 8:30

9. **Birds Eye-View** *
   Voorbeeld: 8:30

10. **Remarks**

Ranking the tools

In this test, three tools were used; a mirror ball in front of you, a blue radar and the ability to get a birds-eye view. There are also other tools to see more.



11. **Order the tools from best (1) to worst (7)** *

Markeer slechts één ovaal per rij.

	Moving Ball	Swirl	Gaze Arrow	Mirror Ball	Radar	Birds-eye view	Nothing
1	⬭	⬭	⬭	⬭	⬭	⬭	⬭
2	⬭	⬭	⬭	⬭	⬭	⬭	⬭
3	⬭	⬭	⬭	⬭	⬭	⬭	⬭
4	⬭	⬭	⬭	⬭	⬭	⬭	⬭
5	⬭	⬭	⬭	⬭	⬭	⬭	⬭
6	⬭	⬭	⬭	⬭	⬭	⬭	⬭
7	⬭	⬭	⬭	⬭	⬭	⬭	⬭

12. **Could you please explain why you made this order?**

13. **What has your preference?** *
Markeer slechts één ovaal.

- Attention guided towards object so that it becomes visible to me.
- Make everything visible so that the object itself can grab my attention.
- Anders: ____________________

14. **Please explain your reasoning** *

____
____
____
____
____

Questionaire -1

This section is about the mirror ball that went from the screen to the side

15. **Mirror Ball** *
Markeer slechts één ovaal per rij.

	-3	-2	-1	-	1	2	3
Rejecting - Inviting							
Discouraging - Motivating							
Unprofessional - Professional							
Confusing - Clearly Structured							
Cautious - Bold							
Repelling - Appealing							
Unimaginative - Creative							
Bad - Good							
Conventional - Inventive							
Dull - Captivating							
Disagreeable - Likeable							
Complicated - Simple							
Comfortable - Uncomfortable							
Distractive - Helpful							
Ugly - Attractive							
Unpredictable - Predictable							
Tacky - Stylish							
Unpleasant - Pleasant							
Technical - Human							

16. **What do you think is effective about this tool and why?**

____
____
____
____
____

17. **How would you improve this tool ?** *

Questionnaire - 2

This section is about the blue radar.

18. **Radar** *

Markeer slechts één ovaal per rij.

	-3	-2	-1	0	1	2	3
Unprofessional - Professional							
Tacky - Stylish							
Distractive - Helpful							
Bad - Good							
Confusing - Clearly Structured							
Repelling - Appealing							
Discouraging - Motivating							
Cautious - Bold							
Unimaginative - Creative							
Rejecting - Inviting							
Conventional - Inventive							
Unpredictable - Predictable							
Complicated - Simple							
Disagreeable - Likeable							
Unpleasant - Pleasant							
Dull - Captivating							
Technical - Human							
Comfortable - Uncomfortable							
Ugly - Attractive							

19. **What do you think is effective of this tool and why?**

20. **How would you improve this tool?**

Questionnaire -3

This section is about the birds eye view.

21. **Birds Eye-View** *

Markeer slechts één ovaal per rij.

	-3	-2	-1	0	1	2	3
Rejecting - Inviting							
Complicated - Simple							
Dull - Captivating							
Unimaginative - Creative							
Unpredictable - Predictable							
Technical - Human							
Repelling - Appealing							
Unpleasant - Pleasant							
Unprofessional - Professional							
Bad - Good							
Conventional - Inventive							
Tacky - Stylish							
Ugly - Attractive							
Confusing - Clearly Structured							
Discouraging - Motivating							
Disagreeable - Likeable							
Comfortable - Uncomfortable							
Distractive - Helpful							
Cautious - Bold							

22. **What do you think is effective of this tool and why?**

23. **How would you improve this tool?**

The end

24. **Any remarks or suggestions?**

Mogelijk gemaakt door Google Forms

APPENDIX D.2

Structured Reactions Test 2

GENERAL COMMENTS

Not too big
“larger objects were more obtrusive to the view”

Cognitive load
“I had to think before I could use the tool [radar] whereas the other tools went naturally well”
“birds-eye view and mirror add an extra step of interpretation making it more difficult”
“I did not take the time to figure out how the mirror ball and radar were helping me”

Familiarity
“The familiarity with indicators plays a big role in the perception for me”
“Arrow is often used, so I am familiar with it”

Human
“A person in front of you looking at the object”

All quite the same
“they were actually all quite useful, it was difficult to make an order”

GUIDING VS ATTENTION

Fast
[Guiding Attention] “It’s the most efficient”
“Guided towards the object worked the fastest”

No searching
“Seeing everything makes it harder to process, as you still need to search through all the extra information”
“Having a guide makes it easier as you no longer need to search”
“I think I prefer being led to the goal”

Difficulty filtering details
[Visibility] “Difficult to perceive details of the total picture”
“it shouldn’t be made to easy, if it’s a game”
“it might be difficult to find something in a complex area”

Confidence
[Guiding Attention] It lets you explore the world more freely, doesn’t force you as much
“I feel like I would get lost if I don’t have a guide”

MIRROR BALL

Small Details
“The reflection [is] small”
“it is more difficult to see the capsule”

See everything
“You can see the surroundings”
“You get a kind of panorama”
“You can see everything behind you, which is nice”

"You can look behind you"
"You are aware of your surroundings"

Cognitive step
"Once you know how to use it, it's sort of helpful"
"The mirro ball is not instantly clear"
"the fact that it's a mirror requires you to think still"
"Same as with regular mirrors, the positioning always confuse me"

Shape
"Make the mirror image flat instead of round"
"The ball shape is not directions"
"Maybe it should not be a ball-like shape"

Size
"Slightly larger"
"Experiment with different sizes"

Human
"make it more likeable, like a robot guide or give it a voice"

Curiosity
"It makes me curious"

RADAR

Dots inside the radar
"I would include the filled circle within the hollow circle"
"Like those radar for airplanes"
"Make the dot fall withing the area"
"Ball on the inside of the circle"

Filtering
"The isolation of elements of interest and only displaying those within the radar's frame made this the most effective tool"
"isolates key points of interest"
"I think it's best for things that require more searching"

Cognitive step
"The radar was a bit confusing at first"
"radar also takes a bit time to understand"
"Once you know how it works, it's very clear"
"A bit tricky to use"
"It was quite confusing in the beginning to understand how the two dots indicate the object"
"This tool requires some explanation"
"It's a bit more technical, innovative"
Distance
"the radar was best since the object was so close. You only needed the direction to watch in" (radar doesn't say much about distance)

Orientation help
"you know what you are looking at in the 360 space"
"with the radar I could quickly see where the object was"

Color
"use different colors for one of the dots"
"A small pulse around the white dot on the radar"
"Different colors"

Familiair
"The radar was intuitive because of previous gaming experiences"
"It is one often used in games"
"Familiair"
"Easy to understand"
"clear how it would work"

Subtle
"It doesn't require immediate attention"

BIRDS-EYE VIEW

Overview
"Top view provides a clear overview"
"The birdseye view also helped to have an overview"

“A clear overview in one click”
“A good overview … do not have to look around so much”
“Gave a different perspective”

Orientation
“Most important is to locate your position related to the environment, Birds-eye view instantly presents this information”
“It is quite difficult to position yourself when you switch from birdview to the current view”
“Switch back from the birds-eye view, it makes me feel a bit lost”
“Provide an indication about your current position in birds-eye view”

Sudden movement
“birds eye view worked, but it teleported me immediately”
“A smoother transition to the birds-eye view”

Small and too many details
“the birds-eye view was cool and easy too, but might be more difficult for smaller objects or more complex areas to use as a search tool.”
“The object of interest shrinks along with the environment”
“Blur out non-important details”
“The birds-eye view could be simplified to only show important information”

Acrophobia
“It gave me a feeling in my stomach”
“Scary to be so high up all of a sudden”
“Fear of heights can be very uncomfortable”
“Warn people”
“Make the platform … bigger”
“Make people feel safe up there”
“Give the platform a railing”
“It made me scared, I thought it was unpredictable and distracting”

Different steps
“Make it possible to go to different heights”
“Zooming out so the overview becomes slowly visible”

Familiair
“Familiar tool for me as a gamer”

Control
“Keeps the human in control”

“birds-eye view … it’s more fun”