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HOW CAN VR BE USED TO LET PEOPLE MAKE AN INFORMED DECISION ABOUT RENTING OR BUYING A PROPERTY?

How VR, by increasing trust, can increase sales.

Internal Promotor: HENK BOSTYN
External Promotor: DONNA FLANAGAN
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JAN HOLBROUCK

To achieve the Bachelor's degree in

NEW MEDIA AND COMMUNICATION TECHNOLOGY

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PREFACE

This bachelor's thesis "How can VR be used to let people make an informed decision about renting or buying a property?" was written to fulfill the graduation requirements of the New Media and Communication program at Howest, Belgium.

The topic is a personal interest that did not fit my internship. Based on some personal experiences regarding the research question, I considered that the current market solutions offering renting services were not optimal, and thus there is potential value in doing research on this subject. After defining what I wanted to do my bachelor's thesis about, Henk Bostyn and Ann De Raedt helped me refine the research question.

I would like to thank my supervisors for their guidance during this process. I also wish to thank Faizan Shaikh and Piet Holbrouck for their cooperation which allowed me to write this bachelor's thesis. Furthermore, I thank the respondents that helped me perform some research, acting as test-subjects.

Also the people at my internship at Swarco were of great help, and I was able to discuss my ideas with them despite it being out of scope of the internship. A final thanks goes to my friends and family, who kept me motivated at all times.

I hope you enjoy reading my thesis.

Jan Holbrouck

Borås, May 20th, 2017

ABSTRACT

This bachelor's thesis' research question: "How can VR be used to let people make an informed decision about renting or buying a property?" deals with the current problems that can be noticed when looking for renting or buying a property. In the current situation, one might not have a good idea of what a house looks like, and thus have to physically go there before making a decision. However, this is not always possible, as sometimes people hire properties for a short period, hence it is not worth seeing it for yourself. This hints towards a possible solution: using VR to look around in the property, allowing you to have a better idea of what it looks like, making you able to make an informed decision.

In this bachelor's thesis, a prototype product is defined and designed, resulting in a design that allows to address the research question through tests with real test persons according to a number of scenarios. The results of these scenarios are analyzed, leading to some conclusions about the use of VR for renting or buying properties.

The conclusion drawn in this bachelor's thesis, is that the use of VR allows for increased trust in real-estate market transactions. For trust-based platforms such as AirBnB and booking.com, VR has the potential to increase the number of transactions as it allows users to better know what to expect and thus have more trust.

TABLE OF CONTENTS

1. INTRODUCTION

One of the recent trends, is the development of services that exploit available private capital, such as Uber exploiting unused cars to provide taxi services, or AirBnB exploiting unused properties.

AirBnB is a huge online service founded in 2008 which allows people to book short-term lodging. However, the company itself does not own these lodgings. The system allows anyone to create an account and let their property. Thus, AirBnB is trust-based. When this report was written, the company has over three million listings in more than 65.000 cities spread over more than 191 countries[1]. Hence, it is one of the biggest community marketplaces to let or book accommodations all over the world.

Trust is crucial to the success of AirBnb's service:

1. If the person looking for an accommodation does not trust the owner, that person is very unlikely to rent.
2. If the owner has a reputation of having a lot of unsatisfied customers, which translates itself into getting bad reviews, the owner will have a much harder time letting his accommodation.
3. If the person who wants to book an accommodation has the reputation of not leaving the property in a clean state, the owner might not want to let to him his place.
4. If people do not have a clear view of what the place they consider renting looks like, it lowers their chances of renting it.
5. If people do not have a clear view of what the place they rented looks like beforehand, it increases the chances of not being pleased by it, and leaving a bad review, which in turn will make it more difficult for the owner to get it rented by other people.

To improve the match between any accommodation and its customer at the right price, it is important that the connection process between the accommodation and the tenants is done as well as possible.

This thesis addresses cases #4 and #5, because of some personal experience: When traveling with some friends, we were looking for a place to stay, and thought that we found the perfect accommodation per our need. However, at arrival, the place was not at all as expected: The owner of the place had taken photographs that made the kitchen look spacious, while only one person could fit. During that vacation, I pondered about what could be done to prevent this kind of unhappiness? We felt like we had been scammed by the owner, while the owner probably didn't think so. In this case, the connection process between the owner and us was poor.

This gave rise to the following idea for a practical solution:
If one gives the owners the possibility to take a spherical picture, which can be done with any smartphone, and one allows the potential customers to look at those pictures with VR glasses, they will have a much better idea of what they consider renting. This solution would allow the renter to get a proper approximation of the size, look, mapping and so on of the place being rented. In short: They will know almost exactly what they rent, before they rent it. This solution would lead to customers being able to better find the right accommodation, with decreased chance of unhappiness as it would be less likely that their expectation would not be met. It would also lead to the owners getting better reviews, since they are able to find the right customers. Improving this connection process, would thus improve customer happiness and renters' happiness, while lowering the prices of overpriced accommodations.

Hence, the subject of this thesis is the research question "How can VR be used to let people make an informed decision about renting or buying a property?". Its answers should help in proposing a practical solution, a product that allows people to see spherical pictures of an accommodation.

[1] AirBnB. (n.d.). About Us. Retrieved from https://www.airbnb.com/about/about-us

The approach adopted to address this research question is as follows:

First a **brief intro into Virtual, Mixed and Augmented Reality and their uses** is given (chapter 2)

Next a **Product is defined and designed in order to be able to address the research question** (chapter 3).
The inputs for this Prototype Product are

- Market Research
- Technology assessment
- Design of a First Prototype
- Nielsen's 10 usability heuristics applied to First Prototype
- Feedback from test persons on First Prototype

After chapter 3 defines and designs a prototype, this chapter takes the outcome of Nielsen's heuristics and the test persons into account, leading to a more **final design of a useable product.**

Next the **research question** is addressed by testing this design with several test persons according to three scenarios (chapter 4).

The outcome of these scenario's is **analyzed** in chapter 5, leading to the **conclusions** presented in chapter 6.

2. BRIEF INTRO INTO VIRTUAL, MIXED AND AUGMENTED REALITY

What is Virtual Reality?

Virtual Reality is a technology that uses VR headsets to generate a virtual world around the user. The user uses the VR headset to view that virtual world. The reason that VR is what it is today is because of how realistic you can make it look. The VR headsets have a stereoscopic head-mounted display, providing separate images for each eye[2].

Virtual Reality has multiple necessities for it to work decently, one of these is head motion tracking sensors. These may include gyroscopes (used also in phones), accelerometers, etc.

VR also requires input: The user needs a way to interact with the screen while not being able to use a touch screen like you usually would. Since we still want to be able to interact with objects in VR, this means that the 'click' that we usually use our fingers for on a touch screen should be replaced by a new way of input.

This is a problem that is still a bottleneck of VR. There are however already quite a few possible/partly solutions to it, depending on the device you're using:

Gaze-timed input

Probably the simplest, least hardware requiring, but most restricting option of all: When an object is in the middle of your eyesight for a predefined amount of time, you interact with it, replacing for example a regular mouse click. This is not optimal for a system requiring a lot of interaction, because the waiting time would rise quickly, and the software would become tedious to use.

It is however a good choice, if you want the software to be accessible to all. The only requirements for this are a simple VR viewer like the Google Cardboard Viewer, and a smartphone with the right tracking sensors.

To make the product as accessible as possible, and as there is no need for a lot of input actions, the gaze-timed input is part of the preferred solution.

Button input

The second simplest solution requires specific hardware that is a bit more complicated, but still cheap to use: it uses a button as input. This button, when implemented in the VR-headset interacts with the screen. This way, one can remove the gaze-timed input and replace it by the click of a button. Using a button makes it easier to have quick interactions.

The downside is that the VR-headsets are usually not fit for all devices, depending on screen size, and whether the button can click on the screen.

It is perfectly possible to use button input in combination with gaze-timed input.

[2] Wikipedia. (2016, July 27). Virtual reality headset. Retrieved March 18, 2017, from https://en.wikipedia.org/wiki/Virtual_reality_headset

Controllers

This solution is a lot less accessible and quite a lot more expensive. Input is provided through a controller held in the hand with usually multiple buttons. This allows the hands to be tracked, to mimic a real body in the virtual world. This solution is often used in gaming and simulations.

Figure 1: Person using VR controllers

Figure 2: Person using Virtuix Omni walking pad

Complicated hardware[3]

Even more niche, one can get input from different kinds of complicated hardware. These solutions are the least accessible of all, and are still being developed a lot. An example of this is the walking pad. is a construction lifting you, while your feet are on a walking pad. This allows you to walk freely while staying in place. When combined with controllers, one can basically monitor all important movements of one's body. This translates itself in a lot of input, offering new opportunities when adequately processed.

What is Augmented Reality?

Augmented reality is a bit different. It starts from the real world and adds something to it. To speak of augmented reality, we need to fulfill three requirements:

1. It must be real-time interactive
2. It must combine the real and virtual images/worlds
3. It must use three dimensions

One of the more famous augmented reality examples is the Microsoft HoloLens, but there are many more examples such as the snapchat filters, Pokémon go, and many more.

What is Mixed Reality?

Mixed reality, is more based on mixing the virtual and the real world together, to make an experience that's a combination of both. Mixed reality allows you to interact with the real world through your headset. An important aspect of Mixed Reality is that the user does not know whether objects are real, or virtual.

[3] Virtuix. (2017). [Virtuix Omni Product page]. Retrieved April 26, 2017, from http://www.virtuix.com/product/omni-package/

What are the differences between VR, AR and MR? [4][5]

Specification	Virtual Reality	Augmented Reality	Mixed Reality
VR-Glasses	Required	Optional: can include holodisplays and other tech	Optional: can include holodisplays and other tech
Image source	Computer graphics or real images produced by computer	Combination of computer generated images and real life objects	Combination of computer generated images and real life objects
Environment	Fully digital	Both virtual and real life objects are blended	Both virtual and real life objects are blended
Perspective	Virtual objects will change their position and size cording to user's perspective in the virtual world.	Virtual objects behave based on user's perspective in the real world	Virtual objects behave based on user's perspective in the real world
Presence	Feeling of being transported somewhere else with no sense of the real world	Feeling of still being in real world, but with new elements and objects superimposed	Feeling of still being in real world, but with new elements and objects superimposed
Awareness	Perfectly rendered virtual object can't be distinguished from the real deal	Virtual objects can be identified based on their nature and behavior such as floating text that follows a user	Perfectly rendered virtual object can't be distinguished from the real deal

Table 1: Table containing the differences between VR, AR and MR

[4] Jaquith, T., & Futurism. (n.d.). VR, AR, And MR: What's the difference? Retrieved from https://futurism.com/images/vr-ar-and-mr-whats-the-difference-infographic-2/

[5] Foundry. (n.d.). VR? AR? MR? Sorry, I'm confused.. Retrieved from https://www.foundry.com/industries/virtual-reality/vr-mr-ar-confused

What are the possible uses of VR, AR and MR?

Virtual Reality[6]

- Video games
  - VR is making quite an entrance in a rather broad range of video games platforms, such as the Wii-remote, the Kinect and more. There are also some well-known new VR gaming headsets on the market such as the Oculus Rift, the HTC Vive and the PS4 headset. The commercializing of these headsets lead to quite a few games releasing VR versions. These games would be able to make good use of the advanced inputs I discussed in the inputs section.
- Cinema & Entertainment[7]
  - There have been upcoming uses for VR in this area as well, such as certain production companies creating interactive VR films. As it is with VR gaming, we do not know where exactly this will go, and whether this will be groundbreaking and replacing modern cinema. There are quite a few roller coasters and theme parks that use VR to create a more immersive experience, one of them being "Mount Mara" in "Bobbejaanland".

Figure 3: Bobbejaanland, Mount Mara VR

- Healthcare and clinical therapies[8]
  - This is one of the areas in that you might not think of when you hear the words VR. It is however, a very useful and important aspect of it. It is in some cases used to trick the mind, or to flood the mind with positive experiences, so that the distracted mind pays less attention to pain for example. It has a lot of more possible uses in this area, of which most still should be discovered.
- Education and training
  - VR is also a major player in education and training; there are a lot of professions that require training that is hard to acquire without VR. Think about the military, astronauts, surgeons or pilots. These require training that is very expensive or next to impossible to just let them experience what to expect in the real environments. In these cases, VR makes their world a lot easier and less expensive. Surgeons can practice their skills without risking a patient's life; Astronauts

Figure 4: Military using VR for training

[6] Wikipedia. (2004, November 6). Virtual Reality. Retrieved March 24, 2017, from https://en.wikipedia.org/wiki/Virtual_reality

[7] Bell, L. (2016, June 10). How VR will change the face of cinema - we asked the experts. Retrieved from https://futurism.com/images/vr-ar-and-mr-whats-the-difference-infographic-2/

[8] Eonreality. (2017). Augmented and Virtual reality medical. Retrieved from https://www.eonreality.com/solutions/augmented-virtual-reality-medical

and pilots can train on Earth, without risk. Education and training is a very important aspect of VR

- Engineering
  - In this case VR can help to close the bridge between product design, and the actual product. For example, engineers designing a bridge, can see what their bridge would look like, from any angle, and sometimes even see how their structure would react to winds/weight or other elements. The jump to VR is quite small in engineering as 3D modelling is already standardly used because of manufacturing needs and to verify structural properties.
- Heritage and archeology
  - In this case, VR can be very useful to depict what an archeological site used to look like. By making people able to watch it through VR, they don't have to go to the actual place, which is often not even open to the public, due to preservation issues. Therefore, VR comes in handy once more, to make archeology accessible to all. An example of this is "Ancient Rome"[9], an app available for the Gear VR and the Oculus which allows you to see ancient Rome, and what it was like in VR.

Figure 5: Ancient Rome in VR

- Music and concerts
  - Another case, where not everyone may be able to go to the same lengths to see their favorite band. By using VR, you can come a lot closer to the real experience, than a regular video. By doing this, artists allow their fans all over the world to experience it in a much more immersive way, for free.
- Marketing
  - Another area that can make good use of VR, is marketing. Since VR is viewed as something new and entertaining, it is a good way to interest people. On top of being renewing, it also serves good use in having a closer connection with the target audience, and allowing them to have a better idea of what a product will look like, and how it would fit into their home. IKEA[10] is one of the companies that has used this.

Augmented Reality[11]

- Archeology[12]
  - Archeology does not only make use of VR, archeologists have also used AR before, to show archeological features on modern landscape, to show possible site configurations from existing structures.

[9] Unimersiv. (2017, January 13). Explore Ancient Rome in Virtual Reality. Retrieved from https://unimersiv.com/ancient-rome-virtual-reality/

[10] Åkesson, T. (2016). Virtual Reality - Into the magic. Retrieved from http://www.ikea.com/ms/en_US/this-is-ikea/ikea-highlights/Virtual-reality/index.html

[11] Wikipedia. (2005, April 26). Augmented Reality. Retrieved March 24, 2017, from https://en.wikipedia.org/wiki/Augmented_reality

[12] Detev, J. (2014, March 06). Augmented reality in archeology. Retrieved from http://www.academia.edu/6308881/Augmented_reality_in_Archaeology

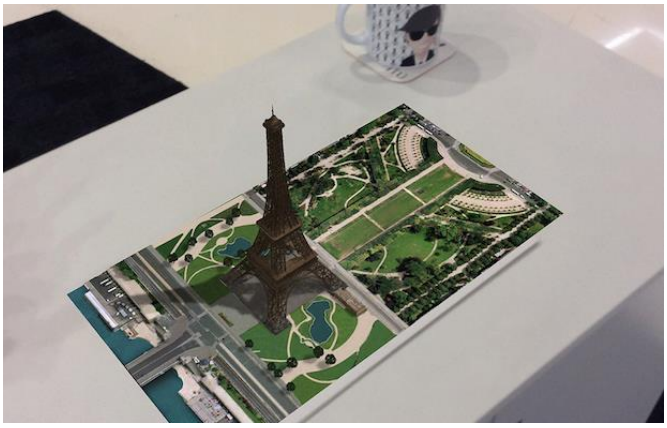

Figure 6: 3D visualisation in drawing

- Architecture
  - Architects can generate a view of a structure in a certain place before the building is there. Also, AR allows them to rendering 3D visualizations in their drawings. AR in architecture can prove quite useful and has a lot of unexplored options that need more research.
- Commerce[13]
  - This is a rather major part of AR; AR can solve quite a few problems that consumers often deal with, such as not knowing what exactly a packaged product looks like. With AR, you would be able to see exactly what it looks like, in an environment of your choosing. It is also possible with AR, to see a catalog at home, and to browse it and see what it would look like in your environment. For example, if you were thinking of buying a couch, you could see what it would look like in your living room. Another example of this is Volvo cooperating with the Microsoft HoloLens allowing everyone to see a hologram of the car, zoom in on it etc. You could even see what the car would look like on your driveway, and thus make a more informed decision. This is something VR wouldn't be able to accomplish, since you would be in a completely virtual world.
- Education
  - By using superimposed graphics, video and audio in textbooks, you can display embedded information when scanned by an AR device. This way students could read their textbooks interactively, keeping them interested, while also losing less time looking for certain extra information. There are a lot of different uses for AR in education, that could improve the current education system.
- Video games[14]
  - One of the video game examples is Pokémon Go, and since their great success many other developers have made similar games using the real world as an environment. Some examples are: Ingress, Real Strike and more.

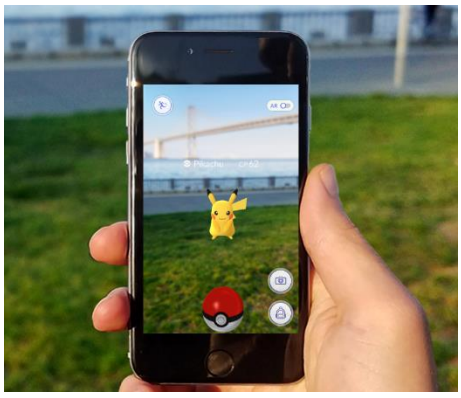

Figure 7: Augmented Reality in Pokémon Go

- Medical[15]
  - There is an existing AR device that processes images to locate the veins onto the skin, and displays them. There also are applications such as patient monitoring, which can get all the patient information the doctors need.
- Navigation
  - AR can augment the effectiveness of navigation devices by displaying extra information. For example, information could be displayed on the windshield of your car, indicating directions, weather, speed and so on.

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[13] Volvo. (2017). Microsoft Hololens. Retrieved from http://www.volvocars.com/nl-be/over-volvo/de-wereld-van-volvo/menselijke-innovaties/pilot-projects/hololens

[14] Ashish, A. (2016, November 28). 10 Best Augmented Reality Games Like Pokemon GO. Retrieved from http://www.mobipicker.com/games-like-pokemon-go/

[15] Eonreality. (2017). Augmented and Virtual reality medical. Retrieved from https://www.eonreality.com/solutions/augmented-virtual-reality-medical

- Workplace
  - During assembly, maintenance or surgery, you can easily simplify the tasks by inserting additional information. This information could be in the form of labels, but there have been examples where assembly lines used AR to allow you to look through the different layers of a machine, allowing them to easily find the problem in a malfunctioning machine.
- Translation[16]
  - There are applications that replace all foreign text with a translated text in the desired language. This is a feature that is very handy, and replaces a lot of translation work, saving you time.

Figure 8: Translation app using augmented reality

Mixed Reality[17][18]

- Art
  - Microsoft Hololens allows to design real world objects, with virtual brushes and colors, and gives a good idea what something would look like. There are lots of designing / artistic possibilities with MR
- Entertainment
  - The Microsoft Hololens is also busy with entertainment, changing the way you can watch and interact with watching sports, or the way you can play games, such as Minecraft.


Figure 9: Person playing Minecraft using the Hololens

- Education
  - By using MR in education, we could maintain the real world, while seamlessly adding objects in it. For example, a medical student, could study the anatomy of a human easily, without needing any physical objects/people for that.
- Communication
  - MR allows a new way of communicating with people on the other side of the globe: Imagine calling your friends, while having a hologram of the person you're interacting with you in the room able to move around and talk freely; it would give a much more realistic way of interaction.
- Medical[19]
  - MR also has its medical uses. The HoloLens is able to fuse images of highly accurate, previously acquired 3D contrast-enhanced MRI with the actual patient's breast. This way the surgeon can see the tumor to the full extent, right before the surgery. This

[16] Wikipedia. (2010, December 18). Word Lens. Retrieved April 22, 2017, from https://en.wikipedia.org/wiki/Word_Lens

[17] https://thenextweb.com/insider/2017/01/07/mixed-reality-will-be-most-important-tech-of-2017/#.tnw_TTMTBORi 18-04-2017

[18] Wikipedia. (2006, November 26). Mixed Reality. Retrieved March 24, 2017, from https://en.wikipedia.org/wiki/Mixed_reality

[19] Stanford. (2016). Technologies for Mixed-Reality breast surgery. Retrieved from https://biox.stanford.edu/research/seed-grants/technologies-mixed-reality-breast-surgery

technique could be improved, and be widely used in a whole number of medical related issues, providing higher accuracy or more knowledge to the user.

- Offices[20]
  - MR can create virtual workspaces, reducing the need for large offices and thus saving on office space. It allows you to work "from your office" wherever you are, keeping information you wrote down in the virtual environment. This has some serious economic advantages, and allows us to cut down on real-estates for offices.
- Distractions[21]
  - Another advantage, is that MR can immerse you in an environment, optimal for learning, or focusing. This could be useful for working, studying, or anything else that requires you to put your mind to it. You can create an environment, without distractions, with only the necessary items.
- Factories[22]
  - In factories, MR could be of great use, to show workers metrics, instructions, data about the machines and so on. *Figure 10* shows a few scenarios where smart goggles could be of good use in a company.

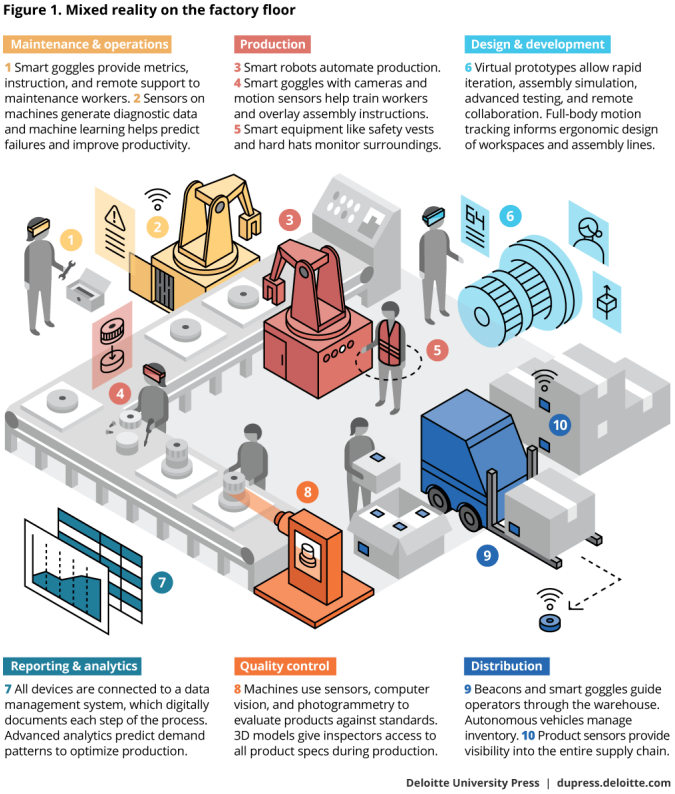

Figure 10: Mixed reality on the factory floor (MR uses)

[20] Sena, P. (2016, January 30). How The Growth Of Mixed Reality Will Change Communication, Collaboration And The Future Of The Workplace. Retrieved from https://techcrunch.com/2016/01/30/how-the-growth-of-mixed-reality-will-change-communication-collaboration-and-the-future-of-the-workplace/

[21] Sena, P. (2016, January 30). How The Growth Of Mixed Reality Will Change Communication, Collaboration And The Future Of The Workplace. Retrieved from https://techcrunch.com/2016/01/30/how-the-growth-of-mixed-reality-will-change-communication-collaboration-and-the-future-of-the-workplace/

[22] Kunkel, N., & Soechtig, S. (2017, February 07). Mixed reality: Experiences get more intuitive, immersive, and empowering. Retrieved from https://dupress.deloitte.com/dup-us-en/focus/tech-trends/2017/mixed-reality-applications-potential.html

3. PRODUCT

Now one has a good idea of what exactly Virtual Reality is, how it differs from AR & MR, and how it can be used, let us use this information to create the VR product.

Market Research[23]

As mentioned earlier, the idea came up while travelling, experiencing that the AirBnB service does not provide all knowledge one needs to make a well-informed decision. To proceed on creating a plan, the first step was to do market research on the idea, and elaborate on how to implement it successfully.

Summary

The goal of the market research is to find out how the product could be used in the market, and whether it could prove useful for certain renting platforms or estate-related sites to implement the product in their architecture. For this product the market research focuses on one such platform, being AirBnB.

Target Audience

The target audience is quite broad: all users and potential users of AirBnB, implying everyone who has ever considered using or has used AirBnB.

Target Audience demographics[24]

Since of the AirBnB target audience is quite broad, it is important to understand what categories these people exactly fall in. The graph below shows the percentage of people of a certain age that are interested in letting their place, or rent someone else's place.

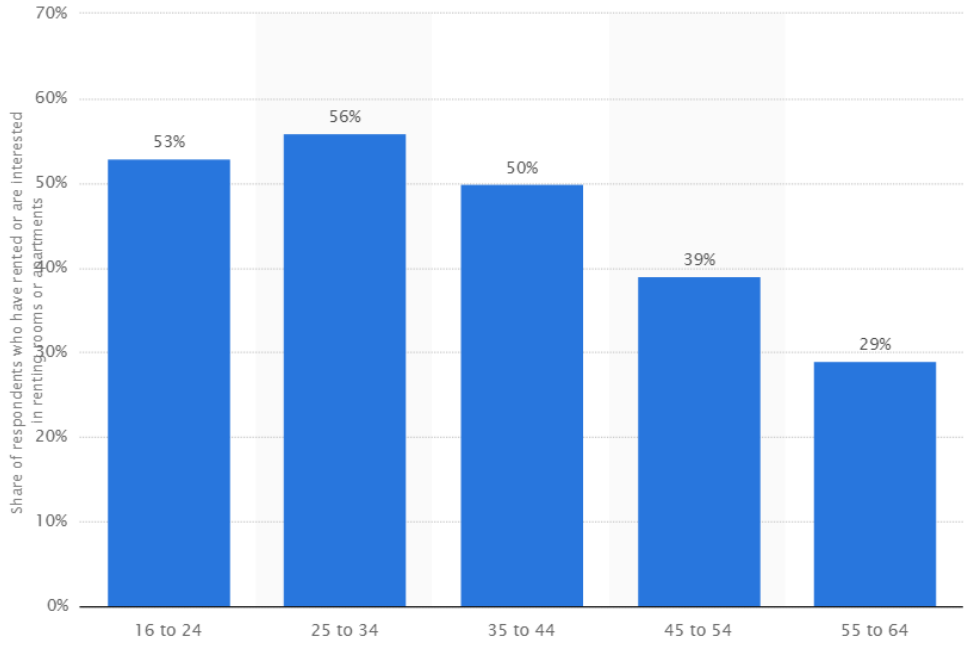

Figure 11: Target audience demographics AirBnB

[25]Here one observes that more than half the people between 16 and 44 are interested in AirBnB. However, only a bit more than a quarter of the people within the 55 to 64 age range are interested in AirBnB. Thus, it is safe to say that the largest group of the current target audience is 16 to 44. 54% of the AirBnB community is female.

[23] https://www.pandadoc.com/market-research-proposal-template 18-04-2017

[24] Shavit, N. (2015, August 20). Airbnb Infographic: Who Uses Airbnb and Why. Retrieved from https://www.jumpshot.com/airbnb-infographic-who-uses-airbnb-and-why/

[25] Statista. (2014, May). [Interest in renting accommodation through services such as Airbnb worldwide as of May 2014, by age group]. Retrieved from https://www.statista.com/statistics/298996/interest-in-services-such-as-airbnb-worldwide-by-age-group/

Another trend however, that cannot be disregarded, is the rise of elderly people using AirBnB: The fastest-growing demographic of AirBnB hosts are people of 60 years and older[26] (currently the smallest group) To be a bit more specific: women of 60 and older[27]. Another noteworthy thing about this trend, is that they tend to have more five star reviews than the other age categories.

Target Audience Description

The target audience is very broad, it includes people that travel, it being for either work or holidays, and all people that consider renting their accommodation. The conclusions we can draw from this is that our target audience ranges from:

- Being young to being old (16 or even younger to 60+)
- Traveling alone or traveling with family, friend or in big groups
- Looking for cheap accommodations to more expensive accommodations, sometimes even castles
- Having a lot of technical experience, being at ease with using a computer to not having any technical experience at all.
- People trying to make money to people trying to save money

One thing the entire audience has in common: They need to be able to use the internet, by accessing it through a computer or smartphone, to use AirBnB.

Analysis of target audience

Since our application is made for mobile phones, it is important that we know, who within our demographics owns a smartphone[28]. Between the age of 18 - 29, 92% owns a smartphone, while between the ages of 30 – 49, 88% owns a smartphone. The older the age, the lower the number becomes, being between the age of 50 - 64, only 74% owns a smartphone. The absolute lowest is if you count the smartphones of the people who are 65 or older. Only 42% of them owns a smartphone.

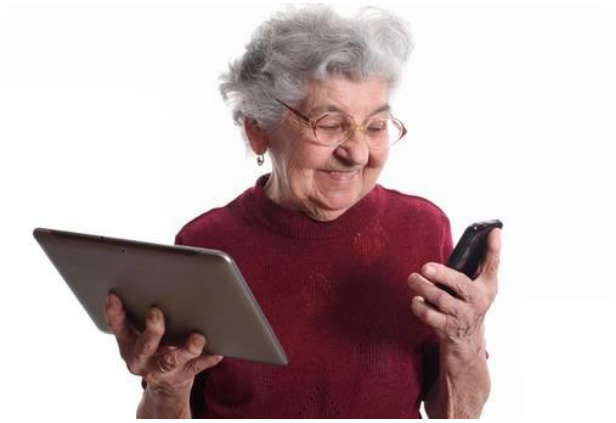

Figure 12: Older woman using smart devices

With the raise of elderly people letting their accommodations, becoming hosts, it is however still important for them to be able to use the system.
One of the dangers thus would be, that elderly people not being able to use the VR function because they cannot take pictures of their accommodation, makes them less likely to find people that want to rent it.

Requirements specific for target audience

With the very broad audience, and their different standards, it is important that we create a design that allows the entire audience to use it.
The requirement list derived is the following:

- Cheap, so that people with little money can use it
- Option for richer people to work with better hardware to make it more user-friendly

[26] Grieco, L. (2015, August 30). CELEBRATING AIRBNB'S 60+ HOST COMMUNITY. Retrieved from http://blog.atairbnb.com/celebrating-airbnbs-60-host-community/

[27] Grieco, L. (2015, August 30). Airbnb's Growing Community of 60+ Women Hosts. Retrieved from https://www.airbnbaction.com/wp-content/uploads/2016/03/Airbnb_60_Plus_Women_Report.pdf

[28] PEW RESEARCH CENTER. (2017, January 12). Mobile Fact Sheet. Retrieved from http://www.pewinternet.org/fact-sheet/mobile/

- Option for people with technical knowledge to tweak usability

Since the demographics pointed out an interesting rise in elderly people using AirBnB as a host, it is very important that one makes the system well-designed, and easy to use, with an explanation of how it works. This creates another notable requirement:

- Well-designed interface so people with little technical knowledge know how to use it

Desired Product

Using the information from the market research one can put together a list of features for the product, with their justification (why they are beneficial to the product), and what those features imply to the product:

Figure 13: Cardboard (Left) & Gear VR (Right)

- Usable with Google Cardboard
  - Reason: Everyone should be able to use it, so it should be available to use with the cheapest VR-headsets
  - Consequence: should to be usable without any physical buttons or inputs
  - Benefits: The app can be used with the cheapest VR headsets
- Usable with fancier VR-headsets
  - Reason: Users already owning more advanced headsets should not feel like they're being held back by the people who don't own them, so their headsets should be able to provide their full functionality
  - Consequence: Make sure that it works on as many VR-headsets as possible, without limiting their functionality, thus having multiple input possibilities, such as gaze-timed input and click input
  - Benefits: The app can be used with all kinds of VR headsets
- Landing page that explains how to use
  - Reason: Not everyone has used VR before, and not everyone is as technical
  - Consequence: Create clear instruction page on what the app is, and how it should be used
  - Benefits: All users will know how to use the app, and they will not be held back by limited knowledge
- As little navigation necessary as possible
  - Reason: With gaze-timed input a lot of navigation would become very slow and tedious
  - Consequence: Create decent wireframes which show the best navigation path, and perform usability check on those
- Easy to implement in different platforms
  - Reason: Since AirBnB was selected as an example but they may not be interested while potential other platforms might be interested in this app, it is important to ensure platform flexibility.
  - Consequence: Make the app flexible and make sure that the vital parts for implementing in a new platform are easily adjustable.
  - Benefits: Application would be useable for all kinds of platforms, such as AirBnB, Booking.com, hotels, etc.
- Settings page to tweak usability

- Reason: People who are familiar with the application might want to tweak inputs to fit their VR viewer, or other settings such as certain colors to their preferred settings.
- Consequence: Make settings such as disable Gaze-timed input, certain color settings to for example the viewpoints, …

Used technologies

For the creation of the app itself, there were two possibilities that were eligible: Unity and WebVR[29][30].
They both have some negatives and positives, briefly reviewed in what follows, so as to make the final choice:

The definition of Unity might make it seem like a bad choice for our product:
'Unity is a cross-platform game engine developed by Unity Technologies and used to develop video games for PC, consoles, mobile devices and websites.'

The alternative, WebVR[31], looks to be more suitable: 'WebVR is an experimental JavasScript API that provides support for virtual reality devices, such as the HTC Vive, Oculus Rift or Google Cardboard, in a web browser.'

There are thus a few things we can derive from these definitions:

1. Unity is marketed as a game engine
   This may seem like a problem, but it is not. Being marketed as a game engine, it means that Unity can handle the complicated logic, that is typically needed for games. This implies that anything the app requires can be handled with the logic of Unity.
2. Unity can be used to make mobile apps, on multiple platforms.
   In Unity I will be able to create apps for windows, IoS, and Android, which means almost all devices will be able to use the app.
3. WebVR is only usable from a browser
   WebVR only runs in a browser. Every device has access to browsers though, which makes WebVR accessible from all devices.

These points lead to WebVR being the most accessible of both, while Unity is more flexible.
One of the things to be considered when making this decision is, that if the product targets AirBnB, they will want it in their existing AirBnB app, making WebVR less preferred: It is not very user friendly, if the user gets redirected from the app to the WebVR application and back.

Another concern to consider, is not being able to implement the required logic within WebVR. At the start, I had no exact idea of what the application would look like and what functionalities it would need. Because WebVR is more limited than Unity, this concern favors Unity.
On top of that, Unity has been doing work on supporting WebVR[32], which would make it easily implementable. Because of these reasons, the preferred choice is to go with Unity.

[29] Pfaff, J. (2015, November 18). WebVR : Virtual Reality available for the open web. Retrieved from https://vrdeveloper.org/2015/11/18/webvr-virtual-reality-available-for-the-open-web/

[30] Fabricius, C. (2015, December 22). Why WebVR matters. Retrieved from https://medium.com/immersion-for-the-win/why-webvr-matters-9f383fee04e5

[31] Wikipedia. (2015, November 03). WebVR. Retrieved April 11, 2017, from https://en.wikipedia.org/wiki/WebVR

[32] Echterhoff, J. (2016, September 23). WebGL and WebVR. Retrieved from https://forum.unity3d.com/threads/webgl-and-webvr.390445/

The next decision required, was deciding what version of Unity to use. At the time of the decision Unity 5.6 was in BETA. The decision was not too hard to make: Unity 5.6 BETA[33]. The reason for this is because Unity 5.6 has better support for VR in general, increasing performance and supporting Google Daydream & Cardboard VR support.
Unity 5.6 also offers the option of easily switching in and out of VR mode, so that your application does not need to be completely in VR. Unity 5.6 has been officially released at the 31th of march and is no longer in BETA version.

By using Unity, it is easy to build the app for windows or IoS without having to change any code. Because of lack of testing devices, I will however develop and test it for Android. To use this app, the phone should support VR, and should have the right tracking sensors, such as a gyroscope.

Thus, Unity 5.6 is used to create the product, which will be usable for people who have an Android device with the right tracking sensors, and a VR-Headset such as a Google Cardboard.

For the initial product, the target audience will thus be limited, but it could easily be expanded, if necessary.

Difficulties

Before starting my thesis, I had no experience with VR or Unity at all, so I encountered quite a few difficulties. When watching some guides and trying some basic things, I ran across a lot of things not working, needing effort to figure out why. Once these initial obstacles were solved, it started to become more fun, and actual programming could be started without having to figure out why one phone couldn't run the app, while another could and similar issues.
The challenging parts in creating this product were mainly composing a decent requirements list, learning Unity, and getting the basic things to work.

First Prototype

Current Design

For the first prototype, focus was on checking the basic key concepts required for the final design. The prototype thus only has two pages: the choose accommodation page and the look around page.

Currently, the entire app is in VR mode. There is a reticle in the middle of the screen that changes into a hollow circle when one stares at an object one can interact with. After gazing at such object for two seconds, one interacts with it. One can also click on the screen if one has a compatible VR-headset with a button. Currently, it is not yet possible to turn off the gaze function, because there is no settings page yet.

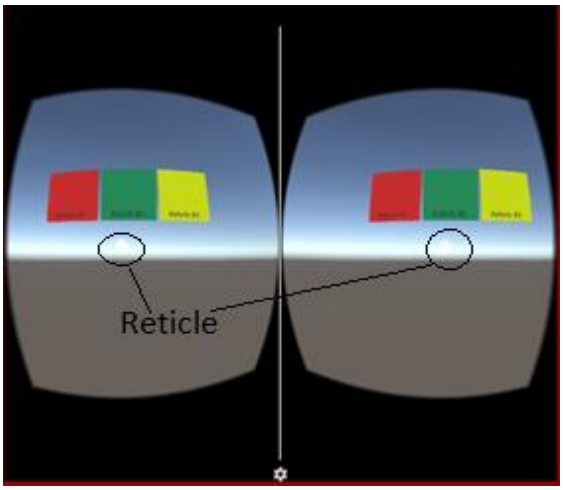

Figure 14: VR view of main menu with the reticle in the middle

[33] Lian, A. (2016, December 13). Unity 5.6 beta is now available. Retrieved from https://blogs.uni.ty3d.com/2016/12/13/unity-5-6-beta-is-now-available/

When one opens the application, one starts on the "choose accommodation" page. The accommodation page consists of a canvas with one menu item for every accommodation, and those menu items contain different spherical pictures. Currently this page is also 360° degrees, but it is planned to make this 180° or at least more user friendly and easier to find the menu. By interacting with one of the menu items (i.e. gazing for two seconds to the accommodation one desires), one goes to the next page, which is the "Look around page".

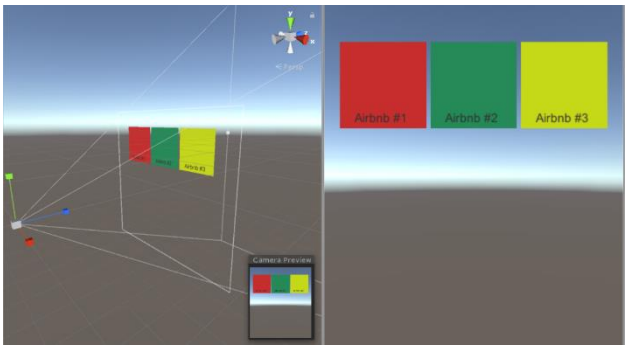

Figure 15: Editor view of main menu (left) and choose accommodation page (right)

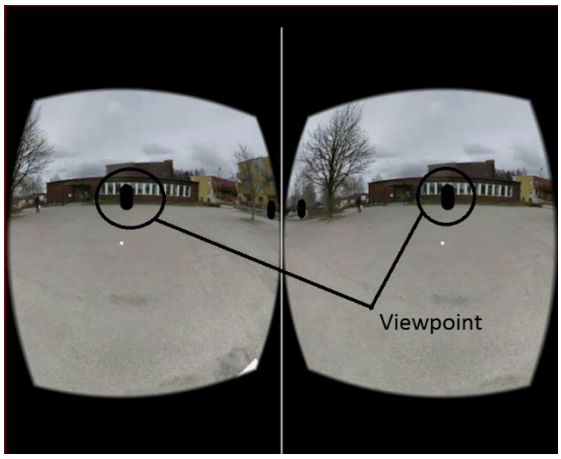

Figure 16: Viewpoints in "Look-around page"

The look around page is a bit more complicated, yet should have an easily useable design. It consists of a spherical picture around the user. This simply means that if the user looks around, the user will see the picture undistorted in 360°. When one opens the look around page, one starts in the middle of the picture. However, it felt like just looking around was not enough, so 5 viewpoints were created in total in the middle of the height of the sphere, (one in the middle, then close to the side of the sphere every 90°) and if one interacts with them the camera will move to that viewpoint. This way, one can see the room from multiple angles, and get a better idea of what the room looks like.

Another part of the look around page is the menu. The menu consists of three buttons: "Next picture", "previous picture" and "back to menu", as seen in *figure 17*.

The next picture button, takes one to the next 360° picture. Some accommodations might only have one 360° picture, so in these cases the button will be disabled or removed. Currently this has not yet been implemented.
The previous picture button, takes one to the previous 360° picture. Again, as some accommodations might only have one 360° picture, the button may be disabled or removed in these cases. Currently this has not yet been implemented.

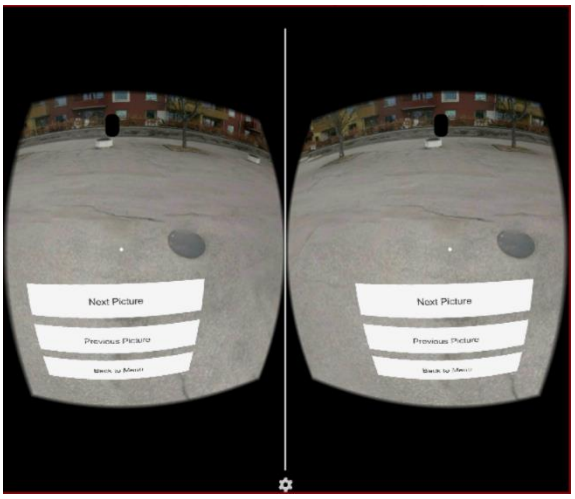

Figure 17: Menu in "Look-around page" showing the "Next Picture", "Previous Picture" and "Back to Menu"

The back to menu button takes one back to the menu, where one can choose another accommodation one might want to see.

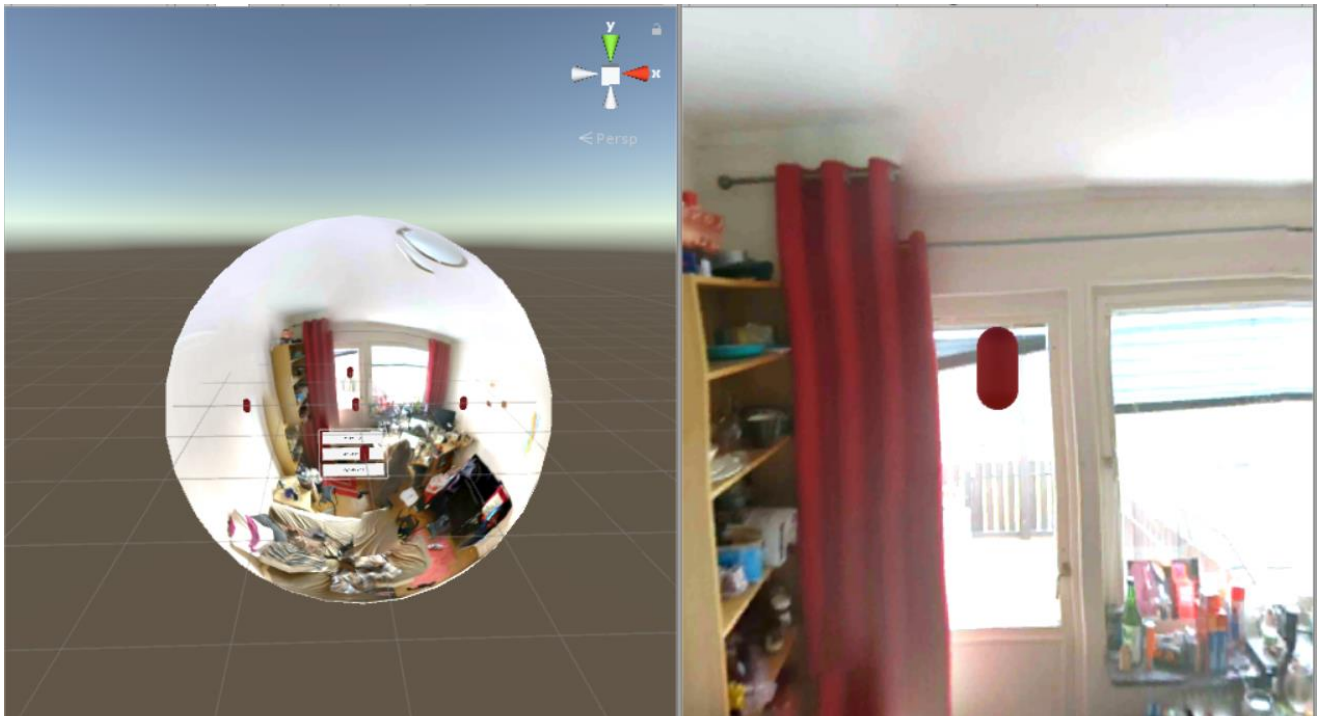

Figure 18: Editor view of "Look-around page"

Feedback

Nielsen's ten usability heuristics

To know if some functionalities or usability principles were miscalculated, Nielsen's ten usability heuristics[34] for user interface design were assessed: these give a good depiction on what is not good and should be improved, and what is good. The result, whether they have been decently applied in the prototype, is shown in following table:

Usability Heuristic	**Task Description**	**Results (Satisfied/Party satisfied/not satisfied)**
Visibility of system status	User stares at interactive object	Party satisfied
		Remarks: reticle in the middle of the screen becomes bigger, so the user knows he is staring at an interactive object. However, there is no loading bar so the user does not know how long to stare at the object.
Match between system and the real world	User navigates through app, by staring at an accommodation, on the next page he browses through all the pictures, and finally he goes back to the main menu	Satisfied
		Remarks: There are only three buttons to press, which have clear text. The user knows exactly what each button will do. There is also the home menu, which consists of pictures so the user also knows what these are.

[34] Designprinciplesftw. (2013, July 11). 10 Usability Heuristics for User Interface Design. Retrieved from http://www.designprinciplesftw.com/collections/10-usability-heuristics-for-user-interface-design

User control and freedom	User accidently clicks the wrong accommodation and wants to go back, so he interacts with "back to menu" and clicks the right accommodation	Satisfied **Remarks:** There are no undo/redo buttons, but they are not necessary because the app only has two screens, it is easy to go back and forth between them. The user can look at 'back to menu' without having to go through all the pictures.
Consistency and standards	User navigates through app, and he meets the terms "Previous picture", "Next picture" and "Back to menu". He knows exactly what these do	Satisfied **Remarks:** Because there's not a lot of words involved, and the used ones are clear, the user is never left in doubt about what does what
Error prevention	The user presses an accommodation and wants to go to the next picture, he clicks next picture but nothing happens.	Not satisfied **Remarks:** The next and previous buttons should be greyed out if there is only one picture.
Recognition rather than recall	The user interacts with an accommodation and wants to go back to the menu. The user reads the entire menu to go back.	Not satisfied **Remarks:** The buttons on the menu should have some more obvious colors and icons so that the user can see in a glance what they are.
Flexibility and efficiency of use	A user has a headset with a button, so does not want to gaze at objects. The user cannot turn the gazing off so is annoyed.	Not satisfied **Remarks:** As said before, a settings menu should be implemented so experienced users can tweak the app to their liking.
Aesthetic and minimalist design	User navigates through the entire app without meeting any dialogues or unnecessary information.	Satisfied **Remarks:** Only the required information is shown in the app.
Help users recognize, diagnose, and recover from errors	User tries to open app, but it won't load correctly, and crashes immediately	Not satisfied **Remarks:** There is currently no way of error handling at all.
Help and documentation	User does not know how the app works and wants to read up on it, but doesn't find any documentation	Not satisfied **Remarks:** User does not have a landing page of any kind; a landing page could. show basic instructions and tell the user what to do.

Table 2: Table containing Nielsen's ten usability heuristics

These heuristics thus identify following points to improve for the final product;

- Adding a loading bar to the gaze option
- Grey out the next and previous picture buttons if there is only one picture
- Give the buttons icons and colors so that the user can easily recognize them
- Implement a settings menu so the user can tweak the app more to their liking
- Create a landing page explaining what the app is and how it works.

Tests by test persons

The product was also shown to four persons that did not get any information at all to check if they would be able to find out how it works.
The product was however not tested with elderly people with no technological knowledge at all. The four persons could operate the app, so it was rather self-explanatory.

After they tested it by themselves and found out how it worked, a decent explanation was given on what exactly it is and how it's supposed to be used. Then I asked them for some feedback. In general, they all were satisfied with how it works, but that might be due to them never having used VR before, and being impressed by the concept of VR itself, and not the product.

There was a complaint that two of them had though: they found it difficult and tedious to reach the menu in the "look around page" because you must look down completely to reach it. The reason I put it there is, because if it were in the middle of the screen it would be in the way of the scenery to be viewed. This complaint required a solution. One of the ideas is a small hide/show menu button which would be less blocking the scenery.

Other realizations

When testing, I considered whether the prototype is missing some other functionalities:

The main menu with the accommodations doesn't show any information at all except for a name. This page should display information such as pricing, the amount of rooms, type of the house and perhaps a rating.

The next and previous buttons are not very clear, because one doesn't know what picture one is at. It would be a lot clearer if it said for example (picture 2/4).

The prototype version was limited to three accommodations; however, one needs to reflect about what it would look like if there are many accommodations: this will require an elegant way to navigate through them, such as an arrow going to a next page. This may make the main menu a lot larger, and led me to consider also a curved interface.

Conclusion prototype

The list of items to work on for the final design is the following:

- Add loading bar to gaze
- Grey out the next and previous picture buttons if there is only one picture
- Give buttons icons and colors
- Implement settings menu
- Create landing page
- Move menu on "look around page"
- Create hide/show menu button
- Show more information on main accommodation page
- Add numbers to next and previous buttons
- Make it possible to view more accommodations on main menu
- Create curved interface on main menu

Design

The above conclusions from the prototype result in a good idea of what the final design should look like. However, it is very difficult to draw this in wireframes, so what follows is a text-explanation of what exactly there will be on those pages, with some support of pictures.

Landing page

This page would be a simple page, that would not be in VR, so it would be impossible to miss. It is not yet clear what exactly to be written on that page, but it be something more specific/clear along the lines of:
'Nameofapp' is made to show you the accommodations you want to see in Virtual Reality. For this, you need a VR viewer. For more information, go to 'link'. The functionality of the app is simple: the default setting works with a gaze function, by staring at an object for 2 seconds, you interact with it. Just pick

the accommodation you want to see, and browse through the pictures. In every picture, there are red viewpoints, you can interact with these to move to those points, to get a different angle of that picture. To tweak the app to your liking, you can go to the settings page.

Settings page

This page would also be a VR page, because it would be annoying to get your phone out of your VR-headset every time you want to change your settings. Since this page would be accessible through the main menu, it will all be in VR.
It would contain only a few settings, such as the type of input, the color/size of the viewpoints and maybe the angle/size of the menu.

Choose accommodation page

This page will look quite different when finished: I'm considering adding a curved menu, and limiting the field of view to the menu, so that one can't accidently look away from it. Additional information will be displayed on the accommodation tiles, such as pricing, the number of rooms and the type of house.
Also, a link to the settings page will be created somewhere in this menu, and a page referring to the landing page, for people who missed some information on that.

Look around page

This page will stay mostly the same, although probably the menu will be at a different angle, and maybe an object is added to stare at to be able to make the menu appear, so that it is easily accessible, yet not in one's way. The *previous* and *next* button will be modified with icons and colors, to be more easily recognizable, and will show what picture out of how many is currently being shown. If there is only one picture the buttons will be greyed out.

4. RESEARCH QUESTION

Gathering all the information from the research and prototype assessment allows to answer the research question "How can VR be used to let people make an informed decision about renting or buying a property?".

To test the impact of the product, some tests were conducted. These were based using a few scenarios, with pictures of a property and its rooms, while also having the VR pictures of that property.

Test information

Scenarios

Three different scenarios were used, explained in what follows, to check the response of the people, and to understand which pictures complied with their expectations. Since I did not have access to a small property which is often typical to AirBnB I split up a single property, consisting of ten sleeping rooms, two kitchens, three bathrooms and two living rooms. I used certain rooms of this property, and took pictures of it, in which the user cannot see that the house is bigger. The preferred solution here, would have been to have two smaller properties.

For the first property, I used one kitchen, a bathroom, a bedroom and a living room.
For the second property, I used one kitchen, a sleeping room, and a bedroom.

Test subjects

In total, eight people were selected as test subjects to represent the different types of target audience.

- Test subject #1: Male, Indian, 19 years old, student
  - Participated in test #1 & #3
- Test subject #2: Female, Turkish, 27 years old, student
  - Participated in test #1 & #3
- Test subject #3: Male, American, 63 years old, retired
  - Participated in test #1 & #3
- Test subject #4: Male, Belgian, 55 years old, working
  - Participated in test #1 & #3
- Test subject #5: Female, Belgian, 54 years old, working
  - Participated in test #2 & #3
- Test subject #6: Male, Belgian, 21 years old, student
  - Participated in test #2 & #3
- Test subject #7: Female, Chinese, 22 years old, student
  - Participated in test #2 & #3
- Test subject #8: Male, Swedish, 36 years old, working
  - Participated in test #2 & #3

Scenario #1

In the first scenario, the goal was, by using 2D pictures, to try to deceive the end user as much as possible by trying to create false depth, making the house look very spacious.

After showing the test subjects the deceiving 2D pictures of the property, the test subjects were asked how much they would be willing to pay per night in the property. After they made their estimate, they were given the VR-view of the property, and they were asked again how much they would now be willing to pay.
Next, they were asked to draw a top-view of the property (two test subjects drew one based on the VR view, and the other 2 based on the 2D view), with special attention to what room is where, and how big the rooms are.

After asking these questions, I showed them the physical property, and asked them a final question, they had to rate the property out of five: Giving a five, if they would still pay their first mentioned price after seeing the 2D view. I did the same thing for the VR view: a rating out of five, five meaning it was as expected, 0 meaning a lot worse than expected, and thus unhappy with the paid price.

The pictures used for this test are the following:

Figure 20: Bedroom of first property

Figure 24: Bedroom of first property

Figure 21: Kitchen of first property

Figure 19: Living room of first property

Figure 22: Badroom of first property

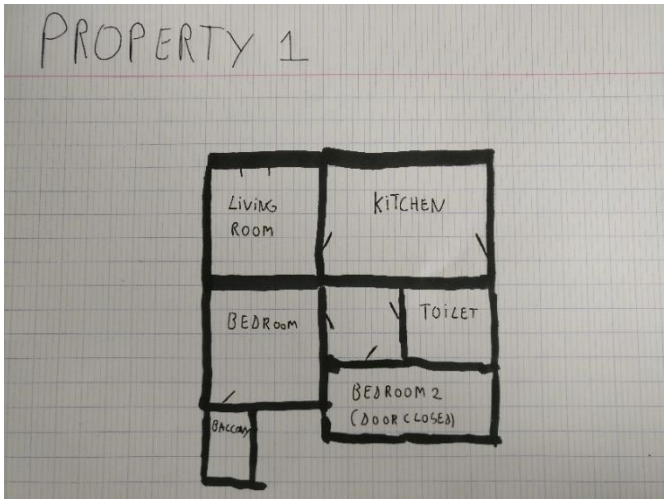

Figure 23: Top view of first property

The VR pictures have been left out, because they are meaningless if seen in a document.

Here are the results from this scenario:

Test subject #1:

1. Estimate /night of property after deceiving 2D picture
   €60 / night
2. Estimate /night of property after VR-view
   €40 / night
3. Top view of property after 2D view
   Picture
4. Rating out of five for 2D view
   3 / 5
5. Rating out of five for VR view
   5 / 5

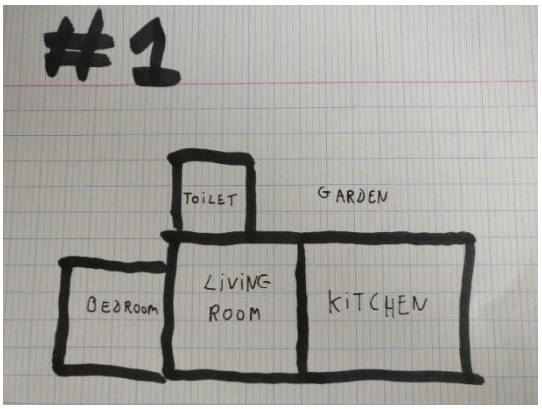

Figure 25: Top view according to test subject #1

Test subject #2:

1. Estimate /night of property after deceiving 2D picture
   €90 / night
2. Estimate /night of property after VR-view
   €70 / night
3. Top view of property after 2D view
   Picture
4. Rating out of five for 2D view
   3 / 5
5. Rating out of five for VR view
   4 / 5

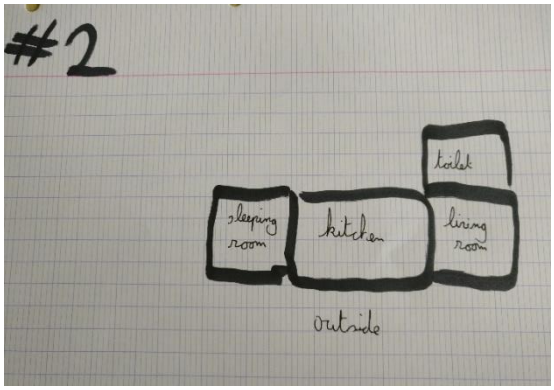

Figure 26: Top view according to test subject #2

Test subject #3:

1. Estimate /night of property after deceiving 2D picture
   €70 / night
2. Estimate /night of property after VR-view
   €65 / night
3. Top view of property after VR view
   Picture
4. Rating out of five for 2D view
   3.5 / 5
5. Rating out of five for VR view
   4 / 5

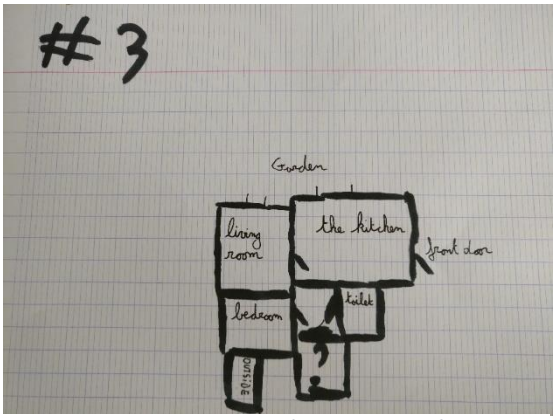

Figure 27: Top view according to test subject #3

Test subject #4:

1. Estimate /night of property after deceiving 2D picture
   €40 / night
2. Estimate /night of property after VR-view
   €40 / night
3. Top view of property after VR view
   Picture
4. Rating out of five for 2D view
   4 / 5
5. Rating out of five for VR view
   4.5 / 5

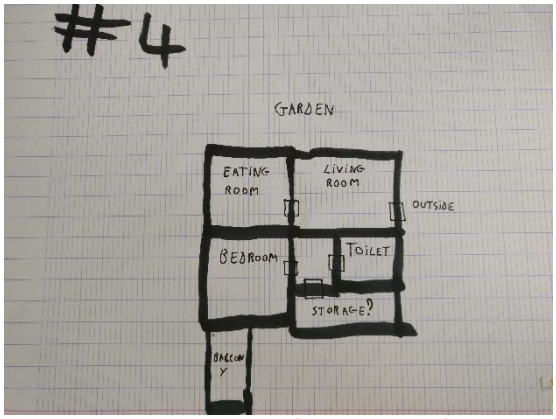

Figure 28: Top view according to test subject #4

There are a few noticeable trends in these results:

1. The prices people would pay after having seen the VR-views are mostly lower than the prices they would offer after seeing the 2D view
2. Thus, as trend 1 leads to lower ratings, this would also lead to bad reviews
3. The people who drew a top view after seeing the 2D view, have a less detailed idea of what the house looks like, and have bad guesses about the room size, and sometimes no idea at all.
4. The people who drew a top view after seeing the VR view, put in details such as where the entrance is, how to rooms are connected, and have better ideas about the size of the room

Scenario #2

In this scenario, the goal was the opposite as in scenario #1: Goal was to make the pictures as correct as possible, trying to give the test subjects a good idea of what the room looks like.The questions asked to the test subject in this scenario were identical to the ones asked in scenario #1.

The pictures used for this test are the following:

Figure 29: Hallway of second property

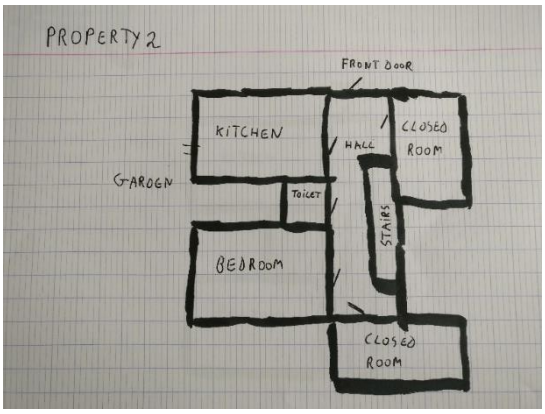

Figure 32: Top view of second property

Figure 30: Bedroom of second property

Figure 31: Kitchen of second property

Figure 33: Bathroom of second property

The VR pictures have been left out, because they are meaningless if seen in a document.

Test subject #5:

1. Estimate /night of property after honest 2D picture
   €40 / night
2. Estimate /night of property after VR-view
   €45 / night
3. Top view of property after 2D view
   Picture
4. Rating out of five for 2D view
   4 / 5
5. Rating out of five for VR view
   4.5 / 5

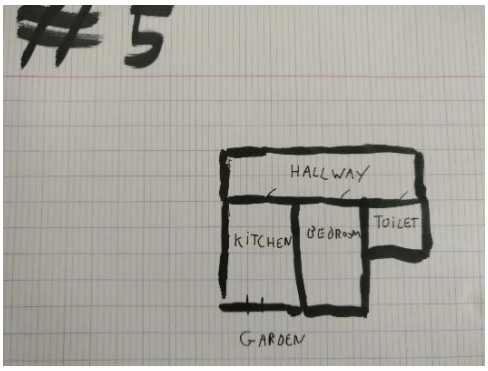

Figure 34: Top view according to test subject #5

Test subject #6:

1. Estimate /night of property after honest 2D picture
   €50 / night
2. Estimate /night of property after VR-view
   €50 / night
3. Top view of property after 2D view
   Picture
4. Rating out of five for 2D view
   4.5 / 5
5. Rating out of five for VR view
   5 / 5

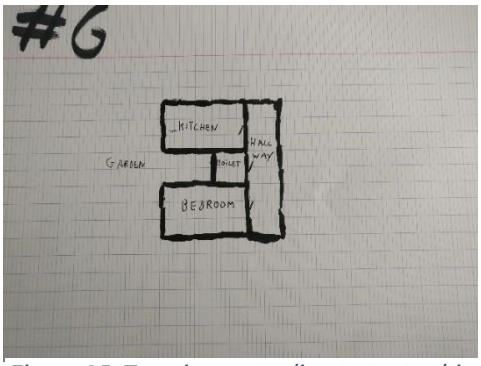

Figure 35: Top view according to test subject #6

Test subject #7:

1. Estimate /night of property after honest 2D picture
   €50 / night
2. Estimate /night of property after VR-view
   €60 / night
3. Top view of property after VR view
   Picture
4. Rating out of five for 2D view
   4 / 5
5. Rating out of five for VR view
   4.5 / 5

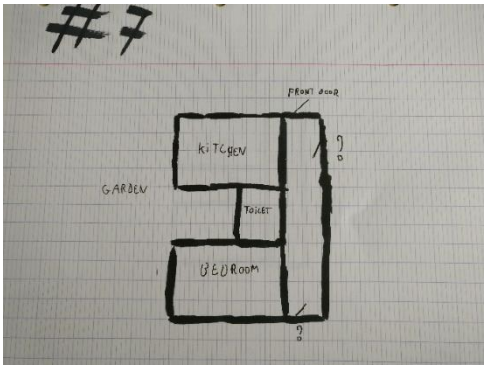

Figure 36: Top view according to test subject #7

Test subject #8:

1. Estimate /night of property after honest 2D picture
   €70 / night
2. Estimate /night of property after VR-view
   €60 / night
3. Top view of property after VR view
   Picture
4. Rating out of five for 2D view
   4 / 5
5. Rating out of five for VR view
   5 / 5

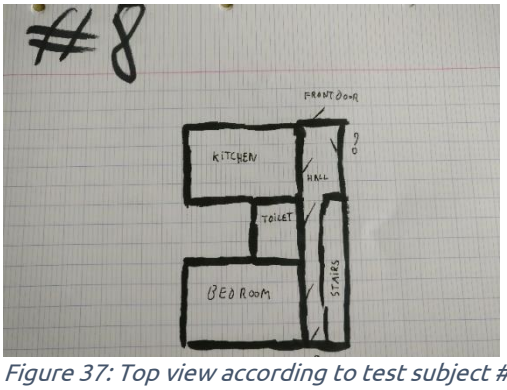

Figure 37: Top view according to test subject #8

The trends noticed in these results are the following:

1. The ratings for the VR – view are slightly higher than the ratings for 2D views: the test subjects have a better idea of what to expect, but not as good as a VR-view.
2. The price estimations are very close to each other, some willing to pay more after seeing VR, some wanting to pay less.
3. The top views by the people that saw a VR-view, are a bit more detailed compared to the other two top views. Also, the top views by the test subjects that saw the 2D pictures, have some mistakes in the room connections.

Scenario #3

In this scenario, again honest pictures were used, but the test subject was only shown either the VR set or the 2D version.
Again, the test subjects were asked what they deemed a fair price to pay for the property. After having made their estimate, they were shown the physical property and asked the following questions:

- Do you feel like you paid too much, too little, or the right amount?
- Would you feel more inclined to leave a bad review, or a good review?
- Would you consider staying in another property of this owner?
- Would you recommend this property to a friend?

The pictures used for this test are the same pictures from scenario #2.

Test subject #1 (Honest 2D picture):

1. Do you feel like you paid too much, too little or the right amount?
   Too much
2. Would you feel more inclined to leave a bad review, or a good review?
   Bad review
3. Would you consider staying in another property of this owner?
   No
4. Would you recommend this property to a friend?
   No

Test subject #2 (Honest 2D picture):

1. Do you feel like you paid too much, too little or the right amount?
   The right amount
2. Would you feel more inclined to leave a bad review, or a good review?
   Neutral review
3. Would you consider staying in another property of this owner?
   Yes
4. Would you recommend this property to a friend?
   No

Test subject #3 (Honest 2D picture):

1. Do you feel like you paid too much, too little or the right amount?
   The right amount
2. Would you feel more inclined to leave a bad review, or a good review?
   Good review
3. Would you consider staying in another property of this owner?
   Yes
4. Would you recommend this property to a friend?
   Yes

Test subject #4 (Honest 2D picture):

1. Do you feel like you paid too much, too little or the right amount?
   The right amount
2. Would you feel more inclined to leave a bad review, or a good review?
   Good review
3. Would you consider staying in another property of this owner?

Yes

4. Would you recommend this property to a friend?
   Yes

Test subject #5 (VR picture):

1. Do you feel like you paid too much, too little or the right amount?
   The right amount
2. Would you feel more inclined to leave a bad review, or a good review?
   Good review
3. Would you consider staying in another property of this owner?
   Yes
4. Would you recommend this property to a friend?
   Yes

Test subject #6 (VR picture):

1. Do you feel like you paid too much, too little or the right amount?
   The right amount
2. Would you feel more inclined to leave a bad review, or a good review?
   Good review
3. Would you consider staying in another property of this owner?
   Yes
4. Would you recommend this property to a friend?
   No

Test subject #7 (VR picture):

1. Do you feel like you paid too much, too little or the right amount?
   The right amount
2. Would you feel more inclined to leave a bad review, or a good review?
   Good review
3. Would you consider staying in another property of this owner?
   Yes
4. Would you recommend this property to a friend?
   Yes

Test subject #8 (VR picture):

1. Do you feel like you paid too much, too little or the right amount?
   The right amount
2. Would you feel more inclined to leave a bad review, or a good review?
   Good review
3. Would you consider staying in another property of this owner?
   Yes
4. Would you recommend this property to a friend?
   Yes

5. ANALYSIS OF SCENARIO RESULTS

To draw conclusions out of these results from the three scenarios, first a comparison was made between scenario 1 and scenario 2, since these are the most similar. To allow to adequately compare the two, it is desirable to use relative factors rather than absolute price or rating data: ratios have been introduced: The 2D to VR price ratio (estimated 2D price divided by the estimated VR price) and the 2D/VR rating ratio (2D rating divided by VR rating).

Comparison between scenario 1 and 2

Test subject #	2D/VR price ratio[35]	2D price	VR price	2D/VR rating ratio[36][37]	2D rating	VR rating
1 (Deceiving)	1.5	€60	€40	0.6	3	5
2 (Deceiving)	1.29	€90	€70	0.75	4	5
3 (Deceiving)	1.08	€70	€65	0.88	3.5	4
4 (Deceiving)	1	€40	€40	0.89	4	4.5
5 (Honest)	0.89	€40	€45	0.89	4	4.5
6 (Honest)	1	€50	€50	0.9	4.5	5
7 (Honest)	0.83	€50	€60	0.89	4	4.5
8 (Honest)	1.16	€70	€60	0.8	4	5

Table 3: Test results and calculated price and rating ratios of scenario 1 and scenario 2

Test subject #	2D/VR price ratio	2D/VR rating ratio
1 (Deceiving)	1.5	0.6
2 (Deceiving)	1.29	0.75
3 (Deceiving)	1.08	0.88
4 (Deceiving)	1	0.89
Average	**1.22**	**0.78**
Standard deviation	**0.22**	**0.14**

Table 4: Average and standard deviation of first four test subjects that were deceived

Test subject #	2D/VR price ratio	2D/VR rating ratio
5 (Honest)	0.89	0.89
6 (Honest)	1	0.90
7 (Honest)	0.83	0.89
8 (Honest)	1.16	0.80
Average	**0.97**	**0.87**
Standard deviation	**0.14**	**0.05**

Table 5: Average and standarddeviation of last four test subjects that saw honest pictures

If one takes a closer look at these results, one can draw some meaningful conclusions. When using deceiving pictures (Test subject 1 – 4) the 2D/VR price ratio has an average of 1.22. However, when using honest pictures (Test subject 5-8), the 2D/VR price ratio has an average of 0.97.

These averages indicate that deceiving pictures manage to deceive the customer more in their 2D variant than in their VR variant. This leads us to the conclusion that it is easier to create a "wow" feeling with 2D pictures, even though the physical place might not give one that feeling.

[35] A value exceeding 1 implies that the price after viewing VR is lower than the price viewing 2D. A value of 1 implies that the price remained unchanged.
[36] Keep in mind: These ratings do not match what the user thinks about the property, they match how the user feels about paying their estimated price of the 2D view and VR view after seeing the physical property.
[37] A value less than 1 implies that the 2D view of the property was rated less than the VR view of the property.

However, if one looks at the honest pictures' price ratio, the ratio is 0.97. If one looks at the standard deviation of 0.14, it means that one cannot be certain that VR pictures are better than honest 2D pictures to show what a property looks like. However, VR does exclude the possibility to deceive the user. Using 2D pictures, will leave the person unable to tell, whether they are being deceived or not. Therefore, VR pictures are better suited for this.

If you look at the 2D/VR rating ratio in deceiving pictures, you have an average of 0.78. If you look at the 2D/VR rating ratio of the honest pictures, there is an average of 0.9. Again, the honest pictures ratio is close to 1, leaving uncertainty. The numbers of the deceiving pictures confirm the last conclusion drawn: that in the case of deceiving pictures, the VR pictures give the user a better idea of what the property looks like.

For more certainty on the numbers, especially of the test results of test subjects #5 - #8, who had used honest pictures, this test should be redone, with a larger group of test subjects.

The VR ratings themselves, are almost identical through the deceiving and honest pictures, which leads to the conclusion that one cannot cheat with VR pictures. It is not possible to make a room look better than it is. If, on the other hand, one looks at the 2D ratings, one observes that the deceiving pictures only have an average rating of 3.6, versus the 4.1 rating of the honest pictures. This means that in 2D pictures, one can easily cheat, making the room look better than it is.

The last part of the comparison between scenario #1 and scenario #2 is the top views. In both the honest and deceiving scenarios, the top views of the VR views were significantly better, and pretty much equally correct, with the drawings containing some details such as where the door is, or where a window is. In the 2D pictures, there was however a difference between the deceiving and honest pictures. People who had to draw a top view from the deceiving pictures, had no clue as to how the rooms were connected, how big the rooms were, where the entrance was, and things like that. Their top views were the worst, and the rooms were often completely misplaced. Their counterparts, who saw honest pictures had similar problems, although they had better guesses at the sizes and connections of the rooms. What they lacked, was details.

Comparing these top views shows that VR-views allow the user to have a good idea about the different aspects:

1. The size of the room
2. The details, such as windows and entrances
3. How the rooms are connected to each other

The honest 2D pictures only gave the users an idea of the size of the room, while the deceiving 2D pictures didn't give the user any of this information.

Conclusions from scenario #3

From the results of scenario #3, where test subjects were either shown honest 2D pictures or the VR and next introduced to the real property, following conclusions can be drawn:

- By using honest pictures, even the 2D pictures have good reviews in general.
- Only test subject #1 would not consider staying in another property of the same owner again
- 75% of the test subjects would recommend the property to a friend after seeing a VR picture, while only 50% would recommend it after seeing the 2D picture. This is however on a very small number of people, also one of the four test subjects who saw the 2D pictures, thought they paid too much. While this data is based on a small number of people, it might

mean that the test subjects have a better idea of what the property looks like from the VR-pictures.

6. CONCLUSION

Research Question

In summary, the information of chapter five leads to following conclusions:

1. With 2D pictures it is more difficult to show what a property looks like. VR pictures are better for this.

2. VR pictures are always honest, it is not possible to deceive the user with certain angles

3. 2D pictures can easily be deceiving, and make you think the room looks better than the physical room

4. It is easier to create a "wow" feeling with 2D pictures, even though the physical place might not give you that feeling.

5. VR-pictures give the viewer a good idea on: The size of the room, the details of the room, and how the rooms are interconnected.

6. Honest 2D pictures give the user an idea of the size of the room, but not the details or interconnectedness of the room, while deceiving 2D pictures don't even give an idea of the size of the room

7. Only one of the test subjects wouldn't consider staying in a property of the same owner again, and this was after a deceiving 2D picture.

8. 75% of the test subjects would recommend the property to a friend after seeing a VR picture, while only 50% would recommend it after seeing the 2D picture. This is however on a very small number of people, also one of the four test subjects who saw the 2D pictures, thought they paid too much. While this data is based on a small number of people, it might mean that the test subjects have a better idea of what the property looks like from the VR-pictures.

9. By using honest pictures, even the 2D pictures have good reviews in general.

In a nutshell, these conclusions indicate, in a more tangible way, that, using VR makes it much more difficult to cheat on what a room looks like, because you have a better depth-feeling of the room, and you know what the room looks like, so this is beneficial to the end-user

One might consider that it might not be a good feature for the owner as the owner cannot make the user pay more than what the rooms are worth, but instead has no option as to be honest and lower the price. Yet, is is not good for businesses trying to "scam" their customers by giving them deceiving pictures, while asking higher prices, as those customers will not return, and will also give negative reviews that reduce probability of being selected. But on top of that, as Scenario 3 showed, when being honest, use of VR leads to more recommendations than use of 2D, so ultimately honest owners will experience an increase in business opportunity because of an increase in positive recommendations.

If VR were to be widely implemented in the field of renting/buying properties, this would lead to a more trusted market, where one would know what to expect. This would in turn lead to a better classification of the lower tier properties being cheaper, while the higher tier properties would be more expensive. This classification is one that everyone would deem logical, but which isn't always the case in the current system, due to some owners deceiving customers.

Therefore, VR should have a positive impact on trust-based user to user markets such as AirBnB, while also having a good effect if implemented in businesses such as hotels.

Product conclusion

Another conclusion to be drawn, is that is possible to create this kind of product. The final designs are useable, and should lead to a product that is straightforward and easy to use. Furthermore, the prototype was working, and could easily be improved upon leading to the final product.

The workload to achieve this, would be manageable in a few weeks, working normal hours. Therefore, this is definitely an area worth businesses should consider investing in, the implementation being cheap and easy.

Personal conclusion

In conclusion, VR appears suitable for trust-based user to user platforms like AirBnB, as the user knows much better what to expect, and he thus will be happier with the service.

Probably, the proposed VR app can also offer added value to businesses such as hotels because they also aim at high "customer happiness" and rely on customer feedback. If the hotel meets their customers' expectations, they are more likely to get a good name, and thus more customers.

I am inclined to conclude that implementing VR in the field of trust-based markets, will help both the end-users, and the owner of the property: it increases trust by allowing the end-user to make a better-informed decision, that ultimately leads to more satisfaction, better reviews and recommendations, and thus more business for the owners.

I think the trust based market is what we are heading to, and VR is a good way to get there more quickly

FIGURES AND TABLES

LIST OF ABBREVIATIONS

Abbreviated word	Full word
VR	Virtual Reality
MR	Mixed Reality
AR	Augmented Reality
2D	Two dimensional
3D	Three dimensional
MRI	Magnetic resonance imaging
PC	Personal Computer

GLOSSARY

Term	Definition
Virtual Reality	Explained in depth at 'What is Virtual Reality?'.
Augmented Reality	Explained in depth at 'What is Augmented Reality?'.
Mixed Reality	Explained in depth at 'What is Mixed Reality?'.
Unity	Unity is a cross-platform game engine developed by Unity Technologies and is used to develop video games for PC, consoles, mobile devices and websites.[38]
IoS	The mobile operating system of Apple Inc.
Android	The mobile operating system of Google.
AirBnB	Explained in depth at "Introduction".

[38] Wikipedia. (2006, June 7). Unity (game engine). Retrieved March 13, 2017, from https://en.wikipedia.org/wiki/Unity_(game_engine)

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ATTACHMENTS

Some code samples from the product:

```
ChoosePictureScene*
Directional Light
EventSystem
VRMain
GvrViewerMain
Canvas
Menu
Panel
BigPanel
SixColumns
Column1
ItemsItemContainer
Item1
Screenshot 1
Image
Text
Item7
Item13
Column2
Column3
Column4
Column5
Column6
GameManager
Sphere
```

```
Directional Light
GvrViewerMain
VRMain
Main Camera
MenuBar
Cube
EventSystem
Sphere
Corner1
Corner2
Corner3
Corner4
Center
```

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

0 references
public class LoadFirstPicture : MonoBehaviour {
    private List<Material> pictures = new List<Material>();

    // Use this for initialization
    0 references
    void Start () {
        pictures = ClickOnPicture.RelevantPictures;
        Mesh mesh = this.GetComponent<MeshFilter>().mesh;
        MeshFilter meshFilter = this.GetComponent<MeshFilter>();
        meshFilter.sharedMesh = mesh;
        MeshRenderer meshRenderer = this.GetComponent<MeshRenderer>();
        meshRenderer.material = pictures[0];
    }

    // Update is called once per frame
    0 references
    void Update () {

    }
}
```

```
GameManager.cs
BPconcept
GameManager
SelectedID
34
35      }
36
37      private void Awake()
38      {
39          MenuPictures = new List<Object>();
40          PanoMaterials = new List<List<Material>>();
41          int i = 1;
42          while(i < 19)
43          {
44              Object o = Resources.Load("MainMenuPictures/Picture" + i);
45              MenuPictures.Add(o);
46              i++;
47          }
48          i = 1;
49          while (i < 19)
50          {
51              object[] PanoPictures = Resources.LoadAll("PanoPictures/" + i);
52              List<Material> mats = new List<Material>();
53              foreach (object o in PanoPictures)
54              {
55                  Material m = new Material(shader);
56                  m.mainTexture = (Texture2D)o;
57                  mats.Add(m);
58              }
59              PanoMaterials.Add(mats);
60              i++;
61          }
62
63
64          Texture2D t1 = (Texture2D)MenuPictures[0];
65          Rect rec1 = new Rect(0, 0, t1.width, t1.height);
66          Item1.sprite = Sprite.Create(t1, rec1, new Vector2(0.5f, 0.5f), 100);
67
68          Texture2D t2 = (Texture2D)MenuPictures[1];
69          Rect rec2 = new Rect(0, 0, t2.width, t2.height);
70          Item2.sprite = Sprite.Create(t2, rec2, new Vector2(0.5f, 0.5f), 100);
71
100 %
```

```
7
                2 references
8   public class ClickOnPicture : MonoBehaviour {
9
10      public float gazeTime = 2f;
11      public string levelToLoad;
12      public List<Material> pictures;
                3 references
13      public static List<Material> RelevantPictures { get; set; }
14      private bool gazedAt;
15      private float timer;
16      public int id;
17      // Use this for initialization
                0 references
18      void Update()
19      {
20          if (gazedAt)
21          {
22              timer += Time.deltaTime;
23              if (timer >= gazeTime)
24              {
25
26                  GameManager.SelectedID = id;
27                  ExecuteEvents.Execute(gameObject, new PointerEventData(EventSystem.current), ExecuteEvents.pointerDownHandler);
28                  timer = 0f;
29              }
30          }
31      }
                0 references
32      public void PointerEnter()
33      {
34          gazedAt = true;
35          Debug.Log("Pointer Enter");
36      }
37
                0 references
38      public void PointerExit()
39      {
40          gazedAt = false;
41          Debug.Log("Pointer Exit");
42      }
43
44
                0 references
45      public void PointerDown()
46      {
47          LoadSceneWithCorrectPictures();
48          Debug.Log("Pointer Down");
49      }
50
                1 reference
51      private void LoadSceneWithCorrectPictures()
52      {
53          RelevantPictures = GameManager.PanoMaterials[id-1];
54          SceneManager.LoadScene(levelToLoad);
55      }
56      //void Awake()
```

```
public class ChangePicture : MonoBehaviour {

    public float gazeTime = 2f;
    public bool nextOrPrevious; // next = true previous = false;
    public GameObject sphere;
    public List<Material> pictures = new List<Material>();
    private int currentmaterial = 0;
    private bool gazedAt;
    private float timer;
    // Use this for initialization
    0 references
    void Start () {
        pictures = ClickOnPicture.RelevantPictures;
    }

    // Update is called once per frame
    0 references
    void Update () ...
    0 references
    public void PointerEnter()...
    0 references
    public void PointerExit()...
    0 references
    public void PointerDown()...
    1 reference
    private void ChangeMesh()
    {
        if (nextOrPrevious)
        {
            if (currentmaterial + 1 < pictures.Count)
            {
                currentmaterial++;
            }
            else
            {
                currentmaterial = 0;
            }
        }
        else
        {
            if (currentmaterial - 1 > pictures.Count)
            {
                currentmaterial--;
            }
            else
            {
                currentmaterial = pictures.Count;
            }
        }
        Mesh mesh = sphere.GetComponent<MeshFilter>().mesh;
        MeshFilter meshFilter = sphere.GetComponent<MeshFilter>();
        meshFilter.sharedMesh = mesh;
        MeshRenderer meshRenderer = sphere.GetComponent<MeshRenderer>();
        meshRenderer.material = pictures[currentmaterial];
    }
```

```
public class ViewpointInteraction : MonoBehaviour {

    public GameObject maincamera;
    public float gazeTime = 2f;
    public GameObject picture;

    private bool gazedAt;
    private float timer;
    // Use this for initialization
    0 references
    void Start () {
    }

    // Update is called once per frame
    0 references
    void Update () {
        if (gazedAt){
            timer += Time.deltaTime;
            if(timer >= gazeTime)
            {
                ExecuteEvents.Execute(gameObject, new PointerEventData(EventSystem.current), ExecuteEvents.pointerDownHandler);
                timer = 0f;
            }
        }
    }

    0 references
    public void PointerEnter()
    {
        gazedAt = true;
        Debug.Log("Pointer Enter");
    }

    0 references
    public void PointerExit()
    {
        gazedAt = false;
        Debug.Log("Pointer Exit");
    }

    0 references
    public void PointerDown()
    {
        MoveCameraToCurrentObject();
        Debug.Log("Pointer Down");
    }

    1 reference
    private void MoveCameraToCurrentObject()
    {
        //Destroy(picture);
        Debug.Log("MoveCameraToCurrentObject");
        Vector3 position = this.transform.position;
        Quaternion rotation = this.transform.rotation;
        maincamera.transform.SetPositionAndRotation(position, rotation);
    }
```