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INSTITUTO COPPEAD DE ADMINISTRAÇÃO

Kyle Martin Mills-Bunje

Visual Technology in Real Estate Marketing: Video or Virtual Reality

Rio de Janeiro
2018

Kyle M. Mills-Bunje

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Master of Science in Business Administration dissertation presented to Coppead - Federal University of Rio de Janeiro, part of the necessary requisites for the title of Master of Science in Business Administration.

Supervisor: Prof. Roberto Nogueira

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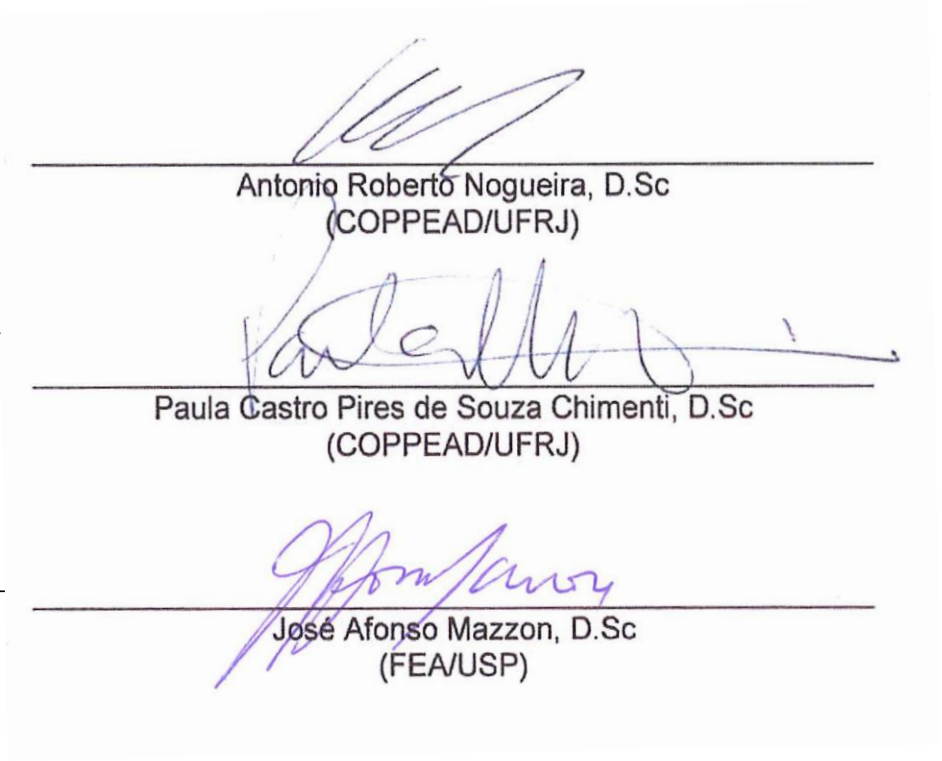

For all of those that has touched my life,
you have helped sculpt who I am

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Abstract

Mills-Bunje, Kyle M. Visual marketing technology in the real estate market: Virtual reality or Video. Rio de Janeiro, 2017. Dissertation (Master in Business Administration) – Instituto de Pós Graduação e Pesquisa em Administração, COPPEAD, Universidade Federal do Rio de Janeiro, 2018.

Exponential advances and economies of scale in mobile technology has created an excess of cheap and easily accessible computing hardware. As a result the exponential growth in immersive virtual reality (VR) headsets technology, which has garnered billions of dollars of investment from some of the worlds largest technology brands. Yet investment does not always result in a successful product or business. Media sources point to gaming, entertainment, healthcare and real estate as the markets most likely to be immediately affected by VR as a disruptive technology. We aim to focus on real estate and and the characteristics that could define the value proposition of VR in that market. Research tells us that current visual marketing strategies in the industry use images as a standard, with video tours as a premium that leads to higher sales price and lower time on market. An experiment to test to difference in the public's opinion of these two visual tools was created, each subject saw either a video tour of an apartment or a virtual reality tour of the same apartment. the results of which showed that while immersion and interaction aspects were voted significantly higher in virtual reality the realism had no significant differences.

Keywords: Virtual Reality, Real Estate, Video Tour, Immersion, Interaction

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Introduction

We have come to an age of technology, where in the things we build in one form or another is becoming more than the tools for success in business but defines a standard of living. As new technologies come to rise in popularity, it can be hard at times to differentiate the value the new technology brings and the hype that the manufacturers of these technologies promote. Virtual Reality is one of these technologies. while having its start in the mid twentieth century with machines like the Sensorama and followed by other displays to view digital recreations of real or fictional environments. Yet these machines were large expensive and out of reach of the general public (Tom's Hardware).

As an externality of the dropping cost of screens and sensors like gyroscopes for cellphone production, it has only recently become possible to create a head mounted virtual reality display that is small enough to be carried on the head of the viewer with no additional support. As these parts became more readily available Lucky Palmer in Irvine California realized he could use these parts to make a headset and after making a very basic prototype he launched a Kickstarter crowdfunding campaign to gain the funds he needed to build the VR headset at scale and build a business around it. After over two million dollars in pre orders form his crowdfunding efforts Lucky started Oculus, the first public facing virtual reality head mounted display (Tom's Hardware) .

Only about two years after Oculus's successful crowdfunding campaign Facebook acquired the business for $2 billion, and in a later statement after a year of on boarding the virtual reality firm, Zuckerberg admitted the acquisition had cost an additional billion dollars in employee retention fees and goal setting, and not to mention a $500 million lawsuit settlement surrounding some pirated software built into the Oculus headset (Business Insider 2017).

Figure 1 Oculus Rift

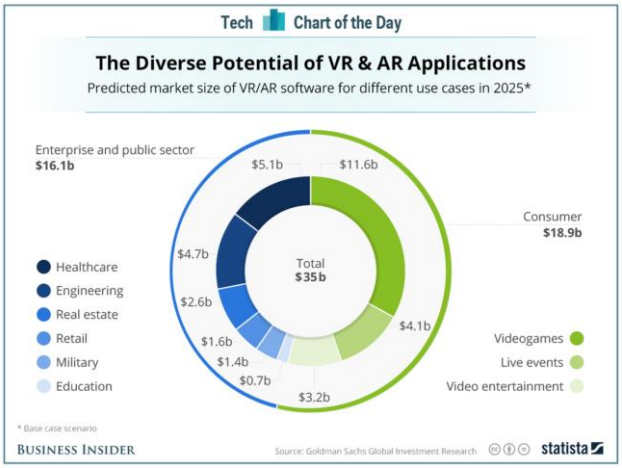
Soon after businesses like Google followed suit and created a piece of cardboard that placed two lenses between the viewers eyes and their own smartphone, to create the same capabilities for any smartphone user instead of a stand alone head mounted display. Many supporters of Google hailed them for this ingenious way of using the cell phones already in people's pockets and lowering the cost barrier to entry in virtual reality. Citing characteristics like the ability to leverage their application developers that build apps for their android operating system Google is believed to be a large opportunity to grow in their virtual reality offering (Branstetter of the Kernel).

Figure 2 Google Cardboard

Another large player is Samsung who created a headset to work with their new line of Galaxy and Note phones starting at the end of 2015, in a partnership with Oculus. These new VR headsets were not only used in store demos but pop up roller coaster experiences all across the United States and Brazil. Samsung has also created a $150 million dollar fund to invest in small and growing startups focused on new technologies like virtual reality and artificial intelligence (Vanian, 2017)

Figure 3 Samsung Gear VR

Beyond the Facebook's and Google's, many other large technology companies have started to bet big on virtual reality. HTC the cell phone manufacturer has come out with the Vive, a top tier virtual reality headset, tethered to a computer, is a direct competitor to the Oculus Rift. The higher processing power needed to run these devices have lead chip manufacturers like Intel realize they need to increase efforts on their GPUs (graphics processing units, specialized computer circuit optimized for large graphics computation, as apposed to a general CPU or central processing unit) and have sponsored the virtual reality content creation for the coming winter Olympic Games. From here it is easy to see that there has been a lot of investment in the hardware and software for virtual reality, in 2016 the number being estimated at over $5 billion, with estimations that by 2020 that number will rise to $162 billion (Rosoff, Business Insider)



Impressed by the wave of virtual reality innovations coming out of some of the world's tech giants, large and small investors alike began to take notice and were looking to invest. Noticing the trend Goldman Sachs hired Equity Research to dive into to whom and where the big innovations are going and where this might lead to. This investigation was published in early 2016 and resulted in some very promising conclusions. In particular In an infographic the specifically denoted that the Real Estate market was on the verge of disruption by this technology stating that "$52 billion is the size of the Real Estate commissions market VR is

stands to disrupt". they point to the abilities of VR to give the appearance of teleportation to the home or apartment for sale, and taking a full tour of the property without having to leave home. Goldman Sachs also estimates that by 2025 the VR and AR combined markets will be valued at over $80 billion and of that 2.6 billion will be in the real estate market alone.

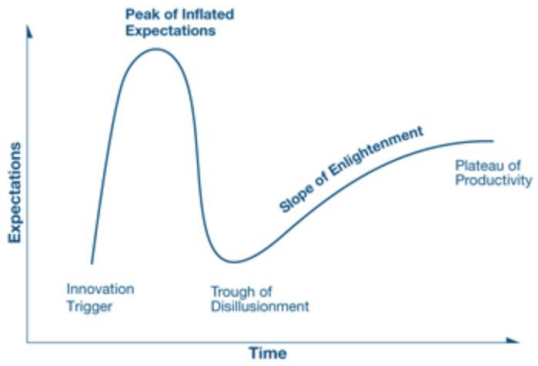
Furthermore stats from Digi-Capital, a virtual and augmented reality consulting company with partnerships to many large technology investors in the United States and China, has closely tracked the sector for some time, and since the Goldman Sacks estimations were made the trend has been positive. By the end of 2016 there had been $2.3 billion invested into VR and AR industry enterprises, (Digi-Capital, Feb 2017) and then in 2017 that number rose to over $3 billion (Digi-Captial, Jan 2018). Furthermore Digi-Captial has released their own estimations of the industry and expect investment to rise to $30 by 2020 in the same 2017 blog post.

While several different industries, especially gaming, entertainment and marketing, took to Virtual Reality to use the publicized excitement about the new technology to help promote their product, brand or service. With some jumping on as early adopters, they are still many who do not believe in the excitement and think that there is not a value offering that accounts for the investment in VR. One market however has seen a lot of investment form companies with very little debate as to the benefits VR brings it, I am talking about Real Estate.

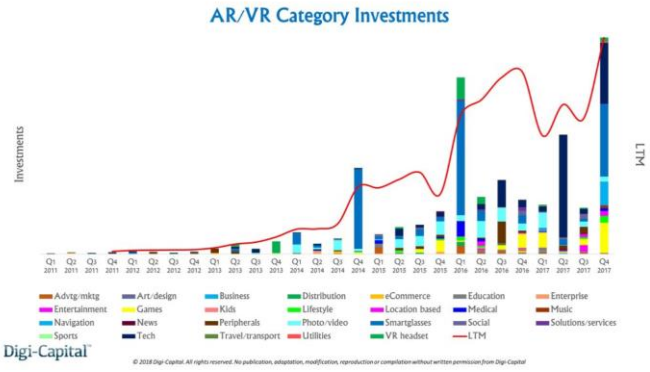
On the development side of the real estate market BIM (building information modeling), has been around for a long time helping architects, engineers and designers better communicate the details of modern construction. The benefits of being able to three dimensionally model as many of the details of a finished project as possible before the time, effort and funds of construction has shown to not only save cost on time, but help mitigate future problems otherwise unnoticed. However the BIM process has historically been only used by developers in early stages, and rarely seen by the person that eventually inhabits the new building. It has not been until these recent years that we see businesses use this type of technology with the explicit intention of conveying the building information to customers who intend on living these buildings.

Interestingly the Real Estate market had started to adopt not only photographs but videos, though limited, to their marketing efforts some time before the recent resurgence of virtual reality. On most major MLS (multiple listing service) agencies allows agents, brokers or homeowners

themselves to post these videos to accompany the photos and give possible customers a sense of what it could feel like to take a walking tour through the property for sale. In a sense these videos are an attempt to recreate the feeling of taking a tour, but does not allow the viewer to choose where to look, how long to look at certain areas or objects, or in what way the viewer would choose to explore the property. While it could be perceived as a step above pictures but one below the affordances of virtual reality to give more freedom of choice to the viewer in VR, this visual means of conveying information has not been scientifically proven.



While many early adopters and early adopters praise new inventions for their qualities and ingenues construction most new inventions do not grow past these early adopters and die out in what many call the chasm of the adoption curve or trough of disillusionment (Gartner). The trough of disillusionment happens after an ignition bubble of excitement pops in the adoption of a product, popularized by Gartenr, the Garter Hype Cycle Expresses this as a moment where there is saturation among early adopters but the buzz they create around the new product or service does not live up to the expectations. It is a very critical moment where most new technologies, products or services collapse but if overcome the curve points up towards mass adoption. And to give a comparison Digi-Captial has tracked investment in VR per quarter for several years, and it shows a similar looking shape.



An example of a product that many virtual reality skeptics are reminded of is the Google Glass. This product was an augmented reality screen display that would be worn in a fashion similar to glasses or sitting atop a users glasses. This small screen over the view space of the right eye allows people to have detailed information and images projected to a space that can be seen just by looking up and to the right. After beta testing in 2013 they started selling Google Glass to the general public, and very few were sold to early adopters. Furthermore

users of the Glass were seen as not only as “nerdy” but having a camera also mounted on the device many people felt uncomfortable around the Glass user not sure if they were being filmed or not. While early adopters reviewed this product as extremely useful and a great asset to their work and personal lives, the overwhelming mass public opinion lead to the eventual demise of the glass being discontinued in 2015.

Figure 4 Google Glass

Virtual Reality has come a long way since the twentieth century, and so too has the research on the benefits and value VR brings to different situations. For the purposes of this dissertation, a focus on the value given to customers in the real estate market and how they perceive its benefits in relation to other means of property representation like images and videos.

Objective of Study

While there has been a lot of large investments in virtual reality, its abilities as a technology has only recently hit a curve of exponential growth in innovation but yet is still unclear whether or not the greater public will see enough value in virtual reality to become owners or at even average users of virtual reality technology. Explicitly stated as a industry to be disrupted by in their 2016 report, Goldman Sachs named real estate to be one of the best current use cases for virtual reality technology, yet outside of a select number of brokerage firms using virtual reality for marketing there has been no hard evidence that this technology will become a new standard in the industry. We plan to develop a body of work that will point to the direction of the technological growth and

consumer acceptance of virtual reality. From this body of work we will develop and test hypotheses about user's perception about virtual reality experience on real estate. Can virtual reality create a better customer experience for real estate customers than current presentation techniques?

Research Methodology

Having the explicit purpose of understanding the possible benefits of immersive virtual reality, this paper needs to create a foundation of the cumulative understanding of the greater academic community and their research, results and conclusions found in the cross section of virtual reality and real estate markets. To build this body of research upon which an unbiased understanding of the current state of virtual reality use in real estate marketing or sale efforts it was decided to adopt a systematic approach to finding and curating the scholarly works used to build this foundation of knowledge. Inspired by the bibliometrics data collection process of Nobre & Tavares (2016) this systematic approach will feature a multilayer search filtering and refinement process to search and select papers with the most relevance to the topic of virtual reality in real estate. To efficiently search through a large collection of scholarly articles the use of the database Scopus was chosen for its robustness and reliability as well as being more rigorous on the quality of articles and journals they choose to leverage (Nobre & Tavares 2016).

I began my search looking for what has been done in the real estate research in terms of the use of virtual reality with the two key terms of "real estate" and "virtual reality". Though virtual reality as it is known and used today by many is considered a very new technology it was decided that for this early stage no date was specified. This query resulted in only 44 scholarly articles, of which only twelve had relevance to virtual reality in the sector of real estate. In attempt to broaden the spectrum, from these twelve articles I than dove into their key words to build a more robust data set. I found that terms like virtual environment, virtual tour, immersive virtual environment and virtual experience had been used interchangeably in referencing this new form of technology. Also the term real estate was also a term that I found was very limiting, other terms like property, house, apartment, condominium, or floor plan was used to reference the physical space I intend to use this technology with.

These new broadened searched terms were used as interchangeable synonyms with the OR statement and combining the virtual reality terms and real estate terms with the AND statement allowed for a much larger set of articles. While growing the data set to 12,632 articles unfortunately this new set of articles was mostly unrelated to my topic as well and I had to further define the search query. Hoping to find papers that focused on the marketing or advertising efforts of real estate agents, brokers or owners I added the terms “marketing” “advertising” “consumer behavior” “consumer research” “interactive marketing” “interactive design” or “user experience”. Moreover I was especially interested in any experiments that have been done in the past so the terms “experiment” “test” and “survey” was added as well as a term “immersion” which from other papers has been a key to evaluate the virtual reality experience. This addition of defining terms only slightly shrank the volume of papers to 8,702.

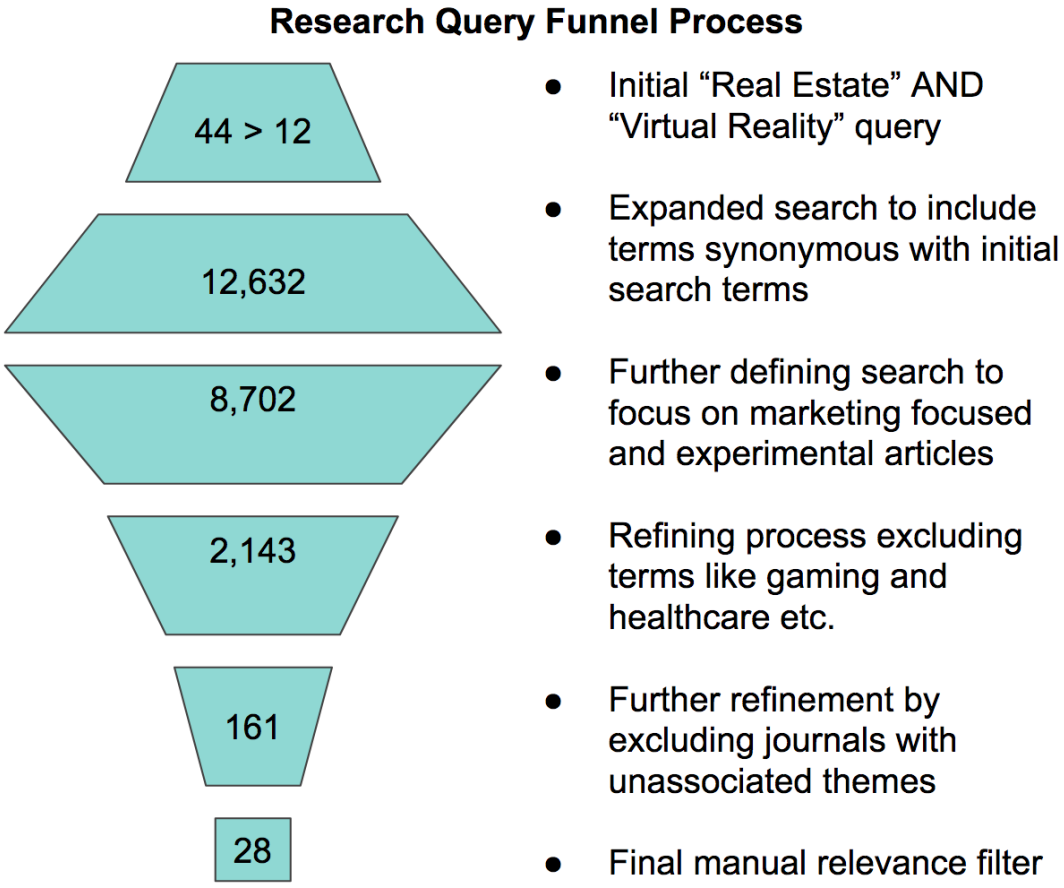
While adding search terms to find the paper that fit my field of study best has helped define what I want in the articles I review, I noticed the need to negate certain terms to get rid of the articles and themes that are unrelated to my topic. Two of the biggest areas or research that are unrelated to mine were gaming and medicine. As gaming has been the primary use and largest market for virtual reality it makes sense to have a lot in this area but not of value to me. Medicine also has used virtual reality for cognitive tests focusing either physically only the eye and brain connection or psychologically dealing with different forms of psychic distress like trauma. To exclude these areas of research I included a NOT statement to discard papers on “medicine” “therapy” “healthcare” “rehabilitation” “trauma” “biology” “gaming” “games” and “robot”, as well as “coaching” and “museum” to take out the education research that I noticed latter became another area of research with little overlap to mine. This filtering prices was very helpful in sifting out papers that did not belong in this study and brought the total down to 2,143 articles.

In attempts to refine the types of article I was receiving I restricted the types of journals that would be shown in the data by subject area. Similarly to my search restrictions I decided to exclude the subjects of medicine, biochemistry, material science, neuroscience, chemistry, mathematics, astronomy, pharmacology, agriculture, chemical engineering, health professions, energy, earth science, immunology, dentistry and nursing. From this new brand and focused search query I was able to find well over scholarly articles. As I started to read through these articles I found that there was some that pointed to an article written about an experiment done in Second Life, a

virtual reality world for anyone online, testing the benefits of virtual reality over basic websites in 2009. To include this article I kept all of the search terms the same as above with the exception of opening the time up to 2009 so I could include this paper, which also has 33 citations giving this paper credibility to be involved in my study.

This final term resulted in 161 articles of which 28 were related to my research with a focus on either real estate or virtual reality with a sub focus in the other. These 28 articles are going to be used as the foundation of my research into the use of virtual reality in the real estate market. The multi layer screening process I used can be seen graphically below in Figure () with inspiration from the bibliometric process conducted by Nobre & Tavares in 2016. The search query was steadily broadened including only specific terms focused on the interest of this study and then refined to become a focused collection of scholarly works.

Figure



Theoretical Framework

Literature Review

In the beginning of the twenty first century a public virtual reality experience was created on the internet called Second Life, that allowed anyone to create anything they wanted in this new 3D world. Many businesses and universities soon found this was a great place to conduct experiments for marketing all kinds of goods and services. Goel L., Prokopec S. (2009) postulated that with the accelerating rate at which technology of three dimensional virtual environments was growing, it could cause disruptive effects on the way brands inform their customers of their product offerings. Goel and Prokopec choose to use Second Life as the platform by which to create the grounds of an experiment to find out if customers felt like the new virtual environments was more informative or give customers a deeper feeling of trust than regular websites. While 2nd life is a massive multiplayer online game that at its essence is a digital 3d world players can explore build and interact with each other, it is primarily populated by engineers and other tech savvy early adopters. Goel and Prokopec began with a qualitative study interviewing 2nd life players as they happened to pass the virtual store he was intending on testing latter in a more qualitative structure. The companies Reebok and Scion, a shoe and car company respectively, had created 2nd life experiences to attract customers in this new virtual world. the difference being the strategy by which each company used the unique properties of the 3d virtual space to either recreate a real experience called mirroring, Scion visitors could “test drive” virtual cars. While Reebok created a game involving their shoes that was developed synergistically as a way to utilize the capabilities of the 3D technology while marketing and informing their customers of their products. the qualitative study was done to help define the questionnaire that would latter be used for the quantitative experiment. Under lab conditions Goel and Prokopec invited students to take part in either the Scion or Reebok experience, after which a Likert scale survey was taken judging the feeling of trust, level of perceived informativeness and their intention to transact with the brands they experienced. The result of which showed that while there was a higher level of trust associated with the 3D virtual environment over the website, but informativeness was significantly less. Furthermore the intention to

transact was higher for the synergistic stray of Reebok or Scions mirror strategy. are many opportunities for brands to make virtual environments to promote their products, it was rated as less trustworthy and less informative than the website counterparts.

Some limitations of the study conducted by Goel and Prokopec are that Second Life, while being a 3D virtual environment is not an immersive experience, viewers are still looking a computer screen and not wearing a headset that provide a more visceral experience of the virtual environment. Furthermore Second Life in 2009 was a very limited technology in the type and amount of information that could be presented to the viewer. Both limitations have been surpassed of their last eight years with the exponential growth of this technology. Also the products that were used in this experiment were from different industries and customers of these products have different buying patterns, i.e. people buy multiple pairs of shoes within a year while people usually buy cars once every few years, let alone the cost difference.

Zetzsche C., Wolter J., Galbraith C., Schill K. (2009) were interested in how we relate to virtual environments in the way we construct mental models of virtual environment being experienced. Based on an Euclidean, or sense perceiving cognitive map which is created as a two dimensional map in the mind of the viewer, this 2D, map style representation of the real work comes from our ability to use maps to understand our environments and how e interact with them. But in a virtual environment developer are no longer bound by the limitations of the real word and “impossible” worlds can be created by violating metrical and topographical. The question being, would an impossible world be harder for viewers to navigate because of their unrealistic geometry cause a confusion when creating a mental map of the world? Surprisingly subjects could navigate both the virtual environment with normal geometry and that of an “impossible” virtual world with the same level of ease. Unfortunately the experiment was conducted only on 16 subjects and the results had “substantial inconsistencies” , which could be caused by the subjects prior experiences with virtual worlds like how often they play video games. Furthermore this experiment was also done while the subject was seated in front of a computer screen and not immersed in an environment with a head mounted display and the ability to move around adding realistic motor actions to more realistically test a person's navigation of a large location.

Stamps III A.E. (2010) was focused on defining what environmental properties of 3d virtual spaces and how they are used could entice subjects, or potential customers to want to explore the virtual space. Stamps defined four environmental properties, slines, entropy, floor area and shape, and tested how these factors related to subject exploration time tested over 38 different rooms to be explored and 60 subjects. A sline is a continuing geometric line the continues form the corner of a wall, while not being a visible line, a pointed corner has two lines extending from each plane that creates the corner in the room, while a corner causes two slines, a large rectangular pillar in the center of a room would cause four slines extending out directly from each of the four planes that make the pillar. Entropy is measured as the amount of diversity in the room, in this case the more walls, the more art installations and visual concepts were accounted for not only in number but the different types of content represented in the space. The floor area is a strictly metric number of square meters, which could have the same room being much larger or smaller, while the shape could also very form squares and rectangles to more complicated combinations of rooms and hall-ways. Stamps found that the more slines in a given room, which does related to the specifics of the room shape, the more time spent exploring the space. Also the amount of entropy within a room was a close second for the additional exploring time spent within the virtual environment. Floor area and shape were both extremely low predictors time spent exploring virtual environments.

Nebiker S., Bleisch S., Christen M. (2010) were interested in using laser mapping technology for a “rich point cloud paradigm” to create virtual representation of real urban environments. While most methods in the past has been a laborious process of recreating physical objects, this new type of technology has the ability to add additional information in the 3D rendering as well as having the possibility of being an automated process. This scanning approach has the ability to quickly and accurately get detailed three dimension data, combined with reference points and measure-ments. This high fidelity and simplicity shows to be operationally superior to other means of three dimensional asset creation which historically would be to have a graphics designer recreate the location by hand from images and or onsite visits. Also it is a much faster process with automated processing of the point clouds, which leads to cheaper 3D modelling of real world locations.

Goel L., Johnson N.A., Junglas I., Ives B. (2011) were interest in what types of social, location, and task awareness activities lead to a likelihood to return to a specific virtual environment, and

also their cognitive absorption of concepts learned in the virtual world. This was a study that put forward a questionnaire to directly find the level of intention to return to the virtual world, the subjects cognitive absorption of the information received, the subjects social awareness of others in the virtual world, their location awareness as well as task awareness. This novel Likert scale based survey showed to correctly test these separate characteristics of within the subjects they studied.

Mavridou M. (2012) wanted to see how space and form are related to one another in the viewers perceptions of 3D environments. Using the term scale as a size measurement comparison to that of a human, or in our case the viewer, Mavridou proposed that a person's perception of surrounding objects and their scale to the viewer would change how the environment would be perceived as a whole. To test this hypothesis Mavridou created a test with an immersive virtual environment that was a rendering of an urban city scape. In each version of the city the subject would either passively or actively navigate and each city was made to be that exact same from a topological standpoint, having all roads and building always being in the same location but the size of the building compared to the viewer and compared to each other would change. The result being that perceptions of road distance and width are affected by the forms that line the street sides, shorter buildings making a wider linger open feeling while taller building made roads feel small. Also environments with the same topographical properties (building a road locations) but different geometries (size of buildings) were perceived as different environments. Furthermore environments with the buildings being the same height regardless of scale appeared to be more orderly and easier to navigate. With a group sample size of 22 participants and 12 different virtual environments to test, even though participants would navigate each scene in a randomized order there is an issue of small sample size. This shows an uncurious effect of the size and variety of size of surrounding buildings, and locations with a stand size are more inviting.

Benefield J.D., Cain C.L., Gleason A. (2012) had seen the rise of real estate brokers and homeowners using photographs, virtual tours and other means of visual representation of a specific location, but with the power of today's satellites and access through Google earth, satellite imagery could be added as a selling point. They studied a sample of 4983 properties sold in a “medium sized southeastern coastal city” for the year of 2007, all of which were associated with some sort

of satellite image of the location, yet varying greatly in quality and detail. As a result photography was shown to be a standard, only causing more time on the market if not enough or the quality was not high enough to perceived standards. Yet virtual tours were associated with less time on market after prices were leveled, i.e. more expensive houses tend to have virtual tours but statistically they did not increase price, only lower time on market which could be said to lower cost to broker or agent if using one. Most surprisingly was that the main hypothesis that satellite imagery would be beneficial to the sale of a property was statistically shown to increase with the time on market. On additional metric showed that having an open house tour (a time period anyone from the public could come tour while a agent or broker was present to answer question) was shown to have almost no effect at all on the sales metrics of properties.

Delikostidis I., Fechner T., Fritze H., Abdelmouty A.M., Kray C. (2013) points out that mobile use or mobile application use experiments are tested in a lab environment with specific actions as an attempt to negate any undesired influence of external stimuluses but it is well known that mobile phones are used in a plethora of different environments including while being in a social environment with other people, while watching tv or even in outdoors in public or private environments. Delikostidis et al. developed a novel use of virtual environments to create lab specific environmental stimuli to accompany the use of the mobile application. While pricing to have varying effects, it is an attempt to use the benefits of virtual reality and to include more variables to experimentation than what could be done before. One limitation may be that the test subject was in lab environment looking at a computer screen that had a phone at the bottom center and an environment around it, if immersive virtual reality was used to help cognitively place the subject in the environment could be an improvement to the methodology.

Van der Land S., Schouten A.P., Feldberg F., van den Hooff B., Huysman M. (2013) found evidence that customers of products preferred a 3D rendering of a product over 2D images as well as another line of research that showed the benefits of cooperative tasks in 3D virtual environments which theorized that a group purchase of a common product like an apartment would benefit both individually and collaboratively in the understanding and decision making involved. The test of 192 MBA students split into groups of 3 had 3 options of apartments as well as 3 possible ways each apartment was viewed: 2D floor plan, 3D overhead view, 3D immersion self guided tour.

While it was thought that the most informative means would have been the 3D immersive tour, the 3D overview was the best at informing individuals on specific characteristics of each apartment. Interestingly though while both 3D environments were more informative than the 2D floor plan images, the increase information received from the 3D environments added to the cognitive load of the group understanding causing the group decision making process less efficient. (cognitive load and cognitive fit theory)

Kelly J.W. et al. (2013) were interested in making virtual immersive environments for multiple viewers at the same time, the problem being that humans receive depth information both monocularly and binocularly (through one or both eyes) and the binocular, or stereoscopic, projection there are specific images skewed to each eye, which has historically causing any viewer off the center of projection to perceive the images to be warped and bent from their intended appearance. Kelly et al proposed that when created a communally viewed experience based on projections of a 3D environment to focus on monoscopic means of distance over stereoscopic which will get distorted based on how far the viewer is from the center of projection. Furthermore some of this distortion can be corrected by having a curved screen to project the virtual environment on, but still does not fully correct the problem. With these uncertainties and the high cost it is also still far from direct public, or customer, and the most accessible form of virtual reality involves a cellphone and google cardboard.

Tiainen T., Ellman A., Kaapu T. (2014) were interested in the difference in how customers perceive virtual compared to physical prototypes of products. In the hopes of getting more realistic results this experiment was done in a furniture trade show with physical furniture prototypes in one booth and a 3D projection large screen to show digital life size prototypes of furniture the customers could view. Tiainen et al were also looking to test not only the customers knowledge of product properties but also how well the prototype helped the customer create new ideas on changes to the existing prototype. Interestingly while both physical and virtual prototype forms lead to about equal levels of informativeness of the products properties, the digital prototype lead to more idea creation from the viewers.

Mahdjoubi L., Hao Koh J., Moobela C. (2014) saw the advances in virtual reality and speculated about the benefits of having a humanoid avatar there to guide, inform and help the viewer learn about the virtual environment, which in this case is a model of a home. With options of a guided tour (from an avatar), view walk through (video tour) and a visit (person navigation and exploration) and additionally options to go to a directory of the rooms, customize certain aspects or furniture in the home, and a link to a contact page for the sale of this home, the virtual home showroom had several options that could benefit the viewer. As a result it was found that the virtual home showroom was beneficial to a detailed understanding of specific characteristics of the homes, but surprisingly having an avatar present had no significant effects to the user outcomes. While using over a hundred subjects split into the avatar or non avatar groups, other factors like age and gender also had no effects.

Heidari M., Allameh E., De Vries B., Timmermans H., Jessurun J., Mozaffar F. (2014) were interested in using the advancing field of building information modelling, or BIM, which is used in the design process for architect and engineers, and seeing if it can be used for customer centric prototyping. They found evidence of the collaborative benefits in the design process associated with using BIM in 3D virtual environment expressing the details of the intended final product. Furthermore some environmental issues: They designed a BIM representation of a kitchen and after inviting subjects to perform a basic task of boiling a pot of water (in the digital environment) the subjects could then chose a different location for the burner to be on the counter that would best insure safety and ease of use based on their experience of the task they just performed. This allows for customers to more personally design a home or product to their personal needs and desires in a quickly communicative way with with developers before anything physical is built. In this case the virtual environment was viewed on a large television monitor with up to two participants at a time testing and changing their designated virtual kitchen environment. With a test group of only 32 there was substantial evidence that this type of customer interaction was perceived as being useful for better design specifications.

Allen M.T., Cadena A., Rutherford J., Rutherford R.C. (2015) wanted to define what actions brokers take that help the most with the sale of a property in the sense that it could sell at a high price and or spend less time on the market by studying 67,297 single family homes in the Dallas area

sold over a popular MLS from 2004 to 2008, focusing on key characteristics like public and/or broker open houses, MLS photographs, MLS virtual tours as the primary marketing differences between broker services. In this case a virtual tour is a 2D video walkthrough of the property. As a result it was found that six or more photographs were associated with higher prices, and increased probability of a sale but no effect on time on market, alluding to the idea that photographs were an expectation of customers in this time. The virtual tour however not only was associated with increased sales price but less time on market and increased probability of a sale. Broker open houses led to higher prices and probability to by but was likely to spend more time on the market, and lastly public open house were associated with higher sales prices but longer time on market and less probability of a sale.

Meagher B.R., Marsh K.L. (2015) were interested in how spacious environments are perceived with not only different amount and arrangements of objects in a room but also how that perception can change when associated with a active task. In this experiment a virtual room was created with one specific size, then different arrangements of types like boxes boards, chairs and table are set out in varying number and location. From this base an additional experiment was conducted, this time with a specific action that needs to be performed, like finding, carrying or riding a skateboard in the virtual room. These additional elements of an intended activity coupled with the functional arrangement of the objects in the room had significant effects on the viewers perceived spaciousness of the room. In this case rooms with clear pathway between objects allow for better skateboarding functionality was seen as more spacious than the room with less or smaller objects in a less functional arrangement. This leads to the idea that spaciousness is not a passive perception of a static room, but also be activity depended on how well the environment lends itself to the functionality of the intended action.

Postma B.N.J., Katz B.F.G. (2015) understood that virtual reality can be a great tool to understanding the past, especially in the sense of recreating historic locations and environments. Yet the majority of VR developments has been focused on the visual aspects of the virtual environment and less focused sound which usually accompanies most virtual experiences. Postman and Katz proposed an acoustic calibration model to be used based on the physical dimension and properties, like sounds absorption, of the spaces interior objects. Through testing on different University

buildings a calibration model was devised to allow any virtual environment to be able to closely model the acoustic variations related to that specific environment. This shows that while sound is superfluous to the visual effects of virtual reality, sound can be a driver of a flow state to help "teleport" the viewer to feel like they are really in the digital location.

Kukshinov E.Y. (2015) was interested in the use of an avatar and how that associates with the viewers sense of self. Based on a self-matrix of characteristics and actions that collaboratively create ones concept of self, how can virtual reality possibly affect this balance of self perception? This was tested through creating virtual environments with a social aspect and based on a base level of how the subject presents themselves in these situations and how they latter present themselves when signed to an avatar that differs from their real life form, like being fatter, shorter, or of a different race. This appears to indicate that the idea of oneself is not only dynamic, but can be affected when experiences in virtual environments through the use of different avatars. In this case and many others the idea of a avatar as a digital proxy of a 'self' has many psychological effects on the actors involved, especially including the viewer.

Li L., Duan X., Zhu H., Guo R., Ying S. (2015) wanted to create a application that could work with complex 3D models and their associated textures to be better able to understand and gain vital information from these virtual models. Today the digital information of 3D assets in an virtual environment has a geometric shape and a texture assigned to the surface of that shape, but at times, for example a model of a house, has walls and ceilings that will block a direct view of the interior of the building. Li et al proposed the use of cutting away specific portions of the textured geometry to allow an interior view of the object or environment similar to that which home designers have used for years like when creating a floor pan blueprint of a building showing all interior walls and doors but leaving out the roof and ceiling. Li et al created a fluid and easy application that can temporarily hide portions of the texture and geometry allowing the viewer to see interior designs without having to create a separate model for the interior and exterior designs of a home or building. This result shows that the cut out effect is most useful for representing 3D interiors because it shows the location to scale but allow to not have a viewers vision be distorted by alluding walls or furniture.

Yoon W.J., Hwang W.-Y., Perry J.C. (2016) As the technology of virtual reality continues to develop, more sense are being added to the experience to help with different uses and activities, one of which being touch. Yoon et al wanted to see how the physical haptic feedback that could be given from the tactile use of contorting and handling a robotic arm and the physical feedback it gives the user. This test was conducted to define the limits and precision of a person's perceptions of rigidity and smoothness of a digital object when physically investigating it through the use of said robotic arm. In this test it appeared that the simulated friction was not significant to a viewer's understanding of the objects characteristics, also that the stiffness of the arm was most beneficial for users to have more precise actions. Furthermore the most influential factor was the radius of the object and its relation the the interactive robotic arm, in the sense that large objects and a longer robotic arm radius allows viewers to better understand the objects specific characteristics.

Sauzéon H., N'Kaoua B., Arvind Pala P., Taillade M., Guitton P. (2016) wanted to see the difference between object recognition and memory based on either passive or active navigation of virtual environments as well as the age related effects of the same differences. A virtual environment of an apartment was used as the space to be explored and the means by which was either an active way finding activity where the viewer would walk around a room than later be asked about the objects in the room. Participants were explicitly told before the experience started that there would be a memory test afterworlds about the apartment they visited which consisted of both object recall by listing the items the viewer remembered seeing. They would have to choose from a list of 60 objects that had 40 correct and 20 false items listed. The results showed that active navigation helped subjects overall recognize more objects but it lowered the likelihood of false image recognition in younger adults while increasing the likelihood for older adults. Having a test sample of 30 young and 30 older adults also gave a limited test sample that primarily alluded to the differences of memory due to aging over the benefits of active navigation over passive when in virtual environments. for this reason there does seem to be some differences in age and age should be a characteristic accounted for when creating virtual content.

Smith S. (2016) brings to the table an overall review of the ways most businesses have been using virtual reality to help expand ones business. Unfortunately most uses of the technology comes from a marketing angle that focuses on the company and leaves out the benefits of this technology

in its use case. Novel games and experiences are created just to have something made in virtual reality which does not focus on design the most immersive or engaging experience based on the technology medium it is presented in. Smith encourages designers of virtual environments for business to first take into consideration the benefits and limitations of virtual reality as a technology and than relating that to the type of product or service that is intended on being sold or present in this medium to then design the virtual experience.

Hong S.W., Jeong Y., Kalay Y.E., Jung S., Lee J. (2016) saw the benefits of multi-user virtual environments like SecondLife and wanted to test the ability for these virtual environments to aid with the creation of designs in a collaborative setting. They took 22 pairs or architectural students and had them create designs for public spaces altering the level of immersion (first person view or third person above the assigned avatar view) as well as having either a video screen and audio conversation or another avatar in the virtual environment representing the partner. This is to evaluate the benefit of having collaborators being represented as other avatars in the virtual environment or just as a disembodied voice to relate design ideas to in the co-creation process. The results showed an increase in collaborative exploration which helped create better solutions based on the specifics of the environment where the project was to be designed as well as having subjects found new ways of problem solving and co-evaluation of possibilities in the design process. While having benefits in the the collaboration process, if the environment is to large in comparison to the avatar, having an immersive avatar was a hindrance to exploration and understanding that was not seen in the co-presence less immersive condition.

Miltiadis C. (2016) saw these benefits of using immersive virtual environments and its effects on the design process and proposed a mobile solution for a customer centric design experience called “Project Anywhere”. This solution was based on a cellphone with the google cardboard to make the headset with a virtual reality display, also connected with hand mounted sensors to allow more malleable interactions in the virtual environment. The project anywhere system also allowed for more than one person to explore the virtual environment, by having a base computer standardizing the experience seen by those who have the virtual equipment on. Miltiadis promotes the use of virtual environments for personal or collaborative design, with a focus on architecture to help in the process of design and evaluation as to shorten the iterative process time to create multiple

possibilities of a final project with the intention of finding the best solution for all stakeholders. With a lot of interest and success it makes sense to explore further and see which parts of the hardware and software used is most valuable to customers.

De Tommaso M., Ricci K., Delussi M., Montemurno A., Vecchio E., Brunetti A., Bevilacqua V. (2016) decided to definitively test how markers or other effects in virtual environments would improve the exploration or way finding activity when immersed in virtual reality. Tommasi et al. decided to test the use of illumination, or glowing effect, or specific objects (for example doors glow white, unless targeted, than redo green), and use a EEG (Electroencephalography, medical machine to track heart rate) machine to track the subjects brain waves in real time as they explore the virtual environment modelled after an apartment. This test was performed on 10 elderly adults age 60-80 and 12 young adults age ranging from 20-30. This study shows that the elderly more than the young are affected by the addition of coloured highlights to help in the assistance of way-finding.

Culbertson H., Kuchenbecker K.J. (2017) were also interested on the ability for a viewer to perceive tactile information haptically from virtual objects. This is also helpful in the process of material selection and design. Once again a robotic arm was used to interact with a haptic feedback device. They used 15 real materials as well as their virtual rendering counterparts to test their approximation of feeling, and did so using friction, tapping and the texture to convey the materials specific characteristics that would be otherwise experienced by touch in real life. The robotic arm had capabilities, with internal motors, to give force and vibrate in different directions, through their algorithm to mimic the same feeling one would have if inspecting the object in real life. While show promising results in realism, the haptic feedback given by a robotic arm presents great limitations on its application abilities because of its limited surface area and range of motion makes interaction limited.

Fisher-Gewirtzman D. (2017) was interested in how people perceived spaces, and what type of furniture and other object arrangement in the room effects that perception of spaciousness. They described the growing trend for people to move to or live in large cities and the size of many apartments in these large cities to be shrinking and created an experiment having the same exact

size apartment with four different arrangements of a dresser, desk, bed and their proximity to the door or window. Furthermore a second set of apartments with a loft style design and similar changes in location of large furniture was also used to see how and in what ways the room itself affects the idea of spaciousness. The results of over 100 participants showed that there is a correlation between perceived density and privacy density, in which case an openness to the window allowing for more view made the space feel less dense and more open even though having the same square meter footprint. Furthermore the proximity of the bed to the door, lead to a decrease in visual privacy and the sense of privacy is lower. These findings show that the current act of "home staging" or when a home seller rents home furnishing and furniture to make the location appear as good as possible. Furthermore when a house it put to be sold the orientation of the furniture within a room affects how it is perceived by viewers and possible customers.

Emerging Model

From this body of research we can see a lot of advances in virtual reality and other technologies that assist in the value this technology can create. While there have been several tests on the benefits of VR of regular 2D images, there has been little work testing the differences between video and immersive virtual reality. Furthermore the only two studies that collected large data sets on property sales found that videos as a medium for a virtual tour was significantly better for the time on market and sale price of a location. Unfortunately we have been unsuccessful in finding a large data set using VR as a means of marketing, which could be due to its recent accessibility to the public market. There appears to be a gap in the literature that directly relates the value of a video and a virtual reality tour of a property and its perceived value to a potential consumer. Photos are of the past, is video or VR the future?

From the information gathered, there were some leading characteristics of how and in what way to create good virtual reality experiences, but some of the technology tested in the research are beyond the scope and budget of this experiment, which is why I have separated some of the key emergent characteristics into categories of development best practices, future technology and the surveys used comparing photos and "virtual tour" (video).

Emergent Characteristics

- Virtual Tour (video) lead to higher selling prices and lower time on market (Benefeild et al 2012, Allen et al 2015)

Virtual Reality Best Practices

- Create experience similar to your value proposition (Goel et al 2009)
- Map does not need to be realistic (Zetzsche et al 2009), scale has a lot of impact (Mavridou 2012)
- Understanding vr is better but not for group decision making (Van der Land 2013)
- Successful for prototyping (tiainen et al 2014), including consumers (non-technical), being tested for BIM (Heidari 2014), crowd architectural design (Hong et al 2016), Project Anywhere (Miltiadis 2016)
- Best Capture technology is laser scanned point cloud (Nebiker et al 2010), use occlusion (Li et al 2015)

Future advances

- Avatar salesmen (Mahdjoubi et al 2014), acoustic properties, haptics (Culbertson et al 2017)
- Hardware difficulties for multi viewer 3D virtual creation (Kelly 2013)
- Ideas of spaciousness and the design of a room (Meagher et al, 2015)
- Wayfinding techniques (De Tommasso 2016)

From other parts of my research we have seen how viewers were able to remember more and have a better understanding of virtual environmental details while actively navigating the virtual environment as opposed to passively watching a video or images. To define which form of visual media would be most compelling to a prospective customer, an experiment will be made as to specifically test and evaluate the merits of each. This experiment would be made with a virtual reality version where subjects would were a virtual reality headset as well as a video version used by another group of users, followed by a survey that asks questions about their experience. Furthermore to not influence the opinions of the subjects it was decided to conduct a blind study in which each testing subject will only experience either the immersive virtual reality version or the video version of the apartment tour.

Looking over the research we can see in the work of Van der Land, et al (2013) also conduction a similar experiment where subjects were tested in a virtual reality tour of an apartment and also had a base group that only saw images. While this portion of the study aligns very closely with the focus of visual comparisons, this work also expands into communal decision making where in groups of three test subjects would use images of virtual reality to tour three different homes than make a group decision on where to move in to. Luckily the survey questions were organized in a way that also focused on four key characteristics that would directly impact the case to define a optimal visual media technology for consumer reach. Excluding the other communal decision characteristics tested for in the survey of Van der Land, Et al (2013), the four characteristics we will test for are Immersion, Realism, Interactivity, and understanding. These characteristics and their associated questions, along with their Portuguese translation, can be seen in Figure A in the Appendix

Outlying Question

What technology gives a real estate customer a better viewing experience, video or virtual reality?

Predictions

Hypothesis 1 - Immersion

The use of a virtual reality headset will be considered more “immersive” .

Based on the literature review is expected that most users feel that when wearing headset and having the ability to turn one's head to gain a new view or perspective, imitating real life, they feel very immersed in the experience. Depending on the fidelity of the experience some had said that they feel it to be real, or very realistic. This ability of the viewer to take action and make decisions of not only direction of sight but when and where to move relate closer to real life than watching a video following a fixed storyline of events and perspectives.

Hypothesis 2 - Realism

Even though both forms of content are made from the same images, the difference in the way the viewer experiences the content will make VR feel more “real”.

We have seen in the works of Van der Land, Et al (2013) and more that having the ability to look around at one's own will and not passively watch a video feels more realistic. Another defining quality of the realism of viewing a virtual experience is also affected by the quality of the experience being viewed, but for congruence we used the same images with the same resolution so as to have a even platform to test, this could however normalize the results of realism and this could be a less defining factor than others.

Hypothesis 3 - Interactivity

It is expected that the use of a virtual reality headset will feel more “interactive” than a video.

While being prompted in the initial instructions that they can pause, rewind or fast-forward the video at their own convince it is common for people to watch a video from start to finish as created. conversely in virtual reality a viewer is required to look around to not only see the room they are in, but to choose a target for a direction they would like to move to. We expect that this difference in interaction will be shown that viewers of the video will rarely use the functions of pausing, fast-forwarding or rewinding, and will therefore be passive viewers and rate the experience as un-interactive. Conversely the inherent need to search for the hotspot markers of locations on can move to in the virtual space with elicit a feeling of more interaction from the viewers with the virtual reality headsets.

Hypothesis 4 - Understanding

The understanding of the apartment should be higher when using a virtual reality headset.

While being made from the exact same content to assure that nothing could be viewed in one scenario and not the other, based on the study from Van der Land et al. (2013) The viewer with in the virtual reality headset would believe they have a better understanding of an apartment than those watching a passive video. This could be due to the way we learn about environments by actively searching through them rather that passively watching them.

Experiment Methodology

To create the images and video of the apartment tour a specialized 360 camera was used to capture images from each room. A Ricoh Theta S was used, which has two wide angle lenses that can see 190 degrees and uses its own internal software to stick the overlapping images together to create a full 360 by 180 image, otherwise known as a photo sphere. A total of five photo spheres were taken, two in the living room, one by the dinning table and the other by the couch and TV area; a photo in the kitchen, bedroom and bathroom. Using Eyespy360, an online cloud based software company that uses 360 images to create VR virtual tours, all five photos were uploaded and "hotspots", or linking buttons, were placed on the 360 images to use to switch from one image to another, we created a virtual reality tour.

With virtual reality it has been estimated that having a lag in frame rate the and or the responsiveness to the changes of direction in a customer viewing the apartment, or any other content, would either consciously or unconsciously recognize the incongruencies and may even feel sick. Yet to keep consistency with the video, and being limited by the EyeSpy360 software, the frame rate was left low for virtual reality standards at around 30 frames per second. Furthermore this tour is web based and while it can be viewed in two dimensions on a regular computer or smartphone, the software also creates an immersive virtual reality experience in which can be viewed with a google cardboard like virtual reality headset that uses a smartphone inside the head mounted display. the head mounted display used was made by HooToo and used a Samsung Galaxy 8s smartphone as the display. This HooToo viewer is a POP3 version of the Google cardboard that has larger lenses than the cardboard 1 and 2 viewers, as well has being made of of primary plastic housing with a soft cushion for the face instead of hard cardboard.

The video tour was also created using the 360 images from the Ricoh Theta S camera as well. To create the video each image was viewed in panoramic mode on a computer in which only a portion of the entire image can be viewed at a time. This is to mimic the constraints of a regular camera that has a field of view around 70 degrees from the focal point. Quicktime screen capture was used to record the video in 5 separate parts, one part per room, and than edited together using iMovie, free editing software on Macintosh products. While viewing a portion of the image the

field of view would slowly pan around the 360 image to recreate the sense of a camera turning to show different angles of room in attempts of incorporating all aspects of the room so that nothing would be missed and all the same content could be viewed in the video as could be seen in the virtual reality headset.

A survey based on the work of Van der Land et al. (2013) was used to test the viewers perception of the immersiveness, realism, interactivity and understanding characteristics of each experience. All questions were based on a 1 to 7 Likert scale and the questions chosen were translated into Portuguese to be easy read by the general public of Brazil. Each question used from the 2013 paper was chosen for its application to real estate marketing relevance. The table below shows each question and other authors who have either researched or tested the effects of these types of characteristics.

Table 1: Survey questions, characteristics and autor references.

Realism	
I felt the apartment was presented realistically	Nebiker S., Bleisch S., Christen M. (2010)
I got a good impression of the apartment	Sauzéon H., (2013), Miltiadis C. (2016)
I think my mental image of the apartment resembles how it really is	Nebiker S., Bleisch S., Christen M. (2010), Sauzéon H., (2013), Miltiadis C. (2016)
I obtained a complete impression of the apartment	Nebiker S., Bleisch S., Christen M. (2010), Sauzéon H., (2013), Miltiadis C. (2016)
Viewing the apartment this way resembles a real life visit	Goel L., Prokopec S. (2009), Miltiadis C. (2016)
Immersion	
During the presentation of the apartment, I felt like being present in the apartment	Van der Land S. (2013), Smith S. (2016)
During the presentation of the apartment, I felt I had a sense of "being there"	Van der Land S. (2013), Smith S. (2016), Miltiadis C. (2016)
When I finished viewing the apartment, I felt like I had returned from a real life inspection	Goel L., Prokopec S. (2009), Smith S. (2016), Miltiadis C. (2016)
To me, the virtual environment became reality	Van der Land S. (2013), Smith S. (2016)

Interactivity	
I could control the presentation of the apartment	Stamps III A.E. (2010), Sauzéon H., (2013), Miltiadis C. (2016), de Tommaso M. (2016)
I could view the apartment fro many different perspectives	Stamps III A.E. (2010), Sauzéon H., (2013), de Tommaso M. (2016)
How interactive would you rate the presentation of these apartments interns of ability to navigate through it	Van der Land S. (2013), Sauzéon H., (2013), Miltiadis C. (2016), de Tommaso M. (2016)
Individual Understanding	
I was very well able to imagine the pros and cons of the apartment	Goel L., Prokopec S. (2009), Tiainen T. et al (2014)
The way the apartment was presented enabled me to thoroughly examine the apartment	Goel L., Prokopec S. (2009), Tiainen T. et al (2014)
The way the apartment was presented offered insight in which information was relevant and valuable	Nebiker S., Bleisch S., Christen M. (2010), Tiainen T., Ellman A., Kaapu T. (2014)

Table A-2 and Table A-3 in the appendix shows how the survey was put together on Google Forms and was presented to the subjects of the experiment on an iPad in the same manner. Each experience had the same survey with questions presented in the same randomized order but with different introductory description. After the instructions were read the subject would either watch the video on the iPad or place the headset to begin the experiment. Then once finished viewing the apartment they would read and answer the questions cited above. After all experiment specific questions were answered a second page of demographic related questions would come up asking for age, gender, income level, nationality, and education level as well as asking for more specific questions about weather they own or rent their current apartment, if they were in the market to purchase a property or are familiar with and have used a virtual reality headset before.

To collect subjects for the experiment, it was hosted at a Starbucks cafe located at Av. Nossa Sra. De Copacabana, 1058 Copacabana Rio de Janeiro, RJ, Brazil 22060-002. We politely asked customers who had already ordered their coffee and were either working or relaxing inside

the store if they would be willing to conduct a short survey to help with a school project. If asked it was stated that it would be for my dissertation research as a masters student at COPPEAD and that all responses would be anonymous, but no more instruction was given as not to affect the results. The experiment went over two sequential days, on day focusing on the video and the other virtual reality headset. Because the experiment was not performed in private, the ability to see another subject perform the experiment before the other was common. It was for this reason that we decided not to conduct both at the same day so that those watching the video could see others wearing a headset and filling out a survey.

RESULTS

After the experiment had finished it was time to look over and make sure all the the results had been properly accounted for. While checking the results given from Google forms there was already a trend that had virtual reality as a better option than video, but because questions for each characteristic was randomized they would have to be regrouped before being studied. We were able to gather 61 subjects for the experiment, 30 for virtual reality and 31 for video. To reach this number of voluntary participants we had to ask 73 Starbucks customers, of which 12 declined our offer, which only accounted for 16.4% of the total number of people asked. With a high percentage of the participants accepting invitation there is more validity than is a large number refused leading a a no response bars, or a bias towards the minority which were those who took the survey and do not represent a larger population.

Also as we took a preliminary look at the data, combined with a subjects question about how to tell if she got the right information for the task at hand. It was decided to drop the Understanding portion of the experiment was based on an experiment that had both individual understanding as well as communal understanding, of which we only borrowed the individual questions. Moreover participants in the previous study were placed in groups of 3 with the specific intent to come to a group agreement of which apartment to rent together. Not having this same intent in the experiment and not having a second set of group understand question to relate the individual understand answers to lead to confusion and widely varying answers.

All of the results were exported from google forms onto an Excel spreadsheet to be analyzed. This process created two separate spreadsheets, one for all of the virtual reality subjects and the other for all the video subjects. These two separate spreadsheets where then combined to be in on with an additional binary value called “technology” as to easily define them as separate factors when preparing the results.

This combined single spreadsheet for all the participants surveys was then loaded into AMOS in efforts to create a Confirmatory Factor Analysis. Using the standard loading threshold above 0.7 and a variance of more than 0.50 we found that two questions from the realism characteristic were significantly below the threshold and were dropped. The resulting 3 questions for realism, along with the other seven questions for immersion and interactivity were either above or in a couple instances marginally close to the threshold set, and it was decided keep these marginally significant questions as to keep a minimum of three questions per characteristic to comply with the original instrument. Seen below is the results of the Confirmatory Factor Analysis.

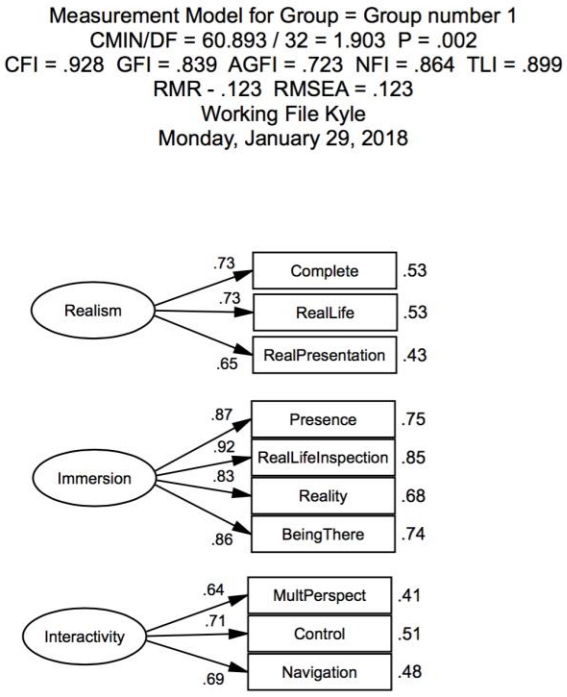


Figure: 6 CFA

Though we had to discard the understanding characteristic and a couple other questions the resulting three characteristics and ten questions were proven in the confirmatory factor analysis shown above to have statistical relevance. Further refining the data to only include these validate characteristics and questions we then proceeded to find out whether or not our subjects preferred virtual reality or video. To do so we exported the resulting data to SPSS to run descriptives and create a few table to easily express our findings.

Table 2: Descriptives

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
REALISM	Video	31	5.3656	1.04476	.18764	4.9824	5.7488	3.33	7.00
	VR	30	5.7778	1.19492	.21816	5.3316	6.2240	2.00	7.00
	Total	61	5.5683	1.13095	.14480	5.2787	5.8580	2.00	7.00
IMMERSION	Video	31	4.7339	1.67945	.30164	4.1178	5.3499	1.00	7.00
	VR	30	5.5750	1.40374	.25629	5.0508	6.0992	1.50	7.00
	Total	61	5.1475	1.59451	.20416	4.7392	5.5559	1.00	7.00
INTERACTIVITY	Video	31	5.1290	1.07730	.19349	4.7339	5.5242	2.67	7.00
	VR	30	5.9333	1.08420	.19795	5.5285	6.3382	2.00	7.00
	Total	61	5.5246	1.14578	.14670	5.2311	5.8180	2.00	7.00

Table 3: Compairable mean by question

	Tech	
	Video	VR
	Mean	Mean
Complete	5.5	5.7
RealLife	4.8	5.3
RealPresentation	5.7	6.3
Presence	4.7	5.8
RealLifeInspection	4.6	5.5
Reality	5.0	5.2
BeingThere	4.6	5.8
MultPerspect	5.8	6.0
Control	4.5	6.0
Navigation	5.1	5.9

As stated in this table, every single question had a higher mean score for virtual reality than video. While this is great evidence to show the superiority of virtual reality as a visual medium for real estate it does not account for the possibility of a false positive. For this we also used SPSS to run an ANOVA for hypothesis validity, which can be seen below.

Table 4: ANOVA Results

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
REALISM	Between Groups	2.590	1	2.590	2.061	.156
	Within Groups	74.153	59	1.257		
	Total	76.743	60			
IMMERSION	Between Groups	10.786	1	10.786	4.489	.038
	Within Groups	141.761	59	2.403		
	Total	152.547	60			
INTERACTIVITY	Between Groups	9.863	1	9.863	8.445	.005
	Within Groups	68.906	59	1.168		
	Total	78.769	60			

Unfortunately the factor of realism, while having a higher mean in favor of virtual reality, the small difference in mean combined with a large total variance of the data lead to a p over 0.15 telling us that while the results seem to favor virtual reality, in terms of the realism, there is no significant difference. Yet the two characteristics of Immersion and Interactivity showed a significant difference in favor of virtual reality.

Additional Notes

During the experiment some notes were taken on the questions, comments and actions of the participants of this study. these were taken down as to add clarity and consistency to the results. One of the subjects tested mentioned that when looking for apartments he always checks the sink and showers for water pressure because in Rio many apartments have very bad plumbing which can result in bad water pressure, something that a remodel cannot fix. Another subject also mentioned that she would like to be able to see inside the closets so that she could see how much storage could be used. On this note something to mention is that as opposed to the United States it is common in Brazil to not have closets built into the floor plan but have them built in, similar to large cupboards, after the rooms are already finished. This point leads to the fact that is a prospective customer would like to renovate the closet area would be something that could be taken down and moved or changed to maximise floor space or suit the preferences of the new owner.

One subject asked mid way through her filling out the survey about #3 (Fidelity) where in the questions asks about the apartment resembling how it “really is” and asked how she could tell if she had not visited the real apartment. Furthermore another subject asked about the question pertaining to the presentation representing information that was relevant and valuable, but relevant and valuable to whom and for what. It was this question that spurred the idea that the questions based on understanding were created for an experiment with different focus than ours and this characteristic might not have the same validity in this setting.

Conclusions

Even though through the process of studying the data we collected we had to exclude one of the four characteristics and five of the fifteen questions the resulting validated information we were able to collect is, in the case of immersion and interaction, significantly better with virtual reality than video, with the “realism” being statistically indifferent.

From the data

Hypothesis 1 - Immersion

Initial Prediction: The use of a virtual reality headset will be considered more “immersive”.

We can see that subjects’ perspective of the immersiveness of the experience was significantly higher in virtual reality than with video. With a mean squared of over 10.8 between the two groups and 2.4 within the group there is a significant difference between the two groups of response to the same question resulting in a significance level of 0.038.

Hypothesis 2 - Realism

Prediction: Even though both forms of content are made from the same images, the difference in the way the viewer experiences the content will make it feel more “real”.

As mentioned before while virtual reality had a higher mean average, this was not a significant difference to the average of video and could therefore not be considered a valid separating

factor of the two technologies. This is could also be attributed to the fact that the same camera images were used for each experience and therefore had the same resolution and image saturation.

Hypothesis 3 - Interactivity

Prediction: The use of a virtual reality headset will feel more “interactive” than a video.

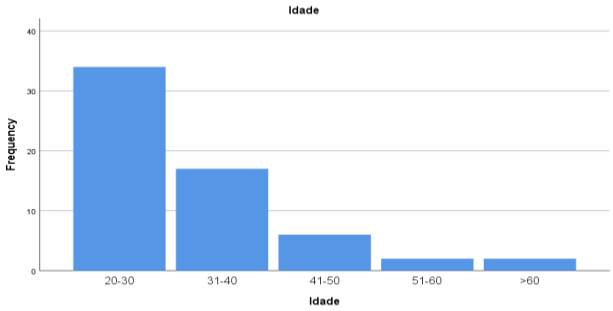
Through the data analysis we were also able to significantly confirm the addition value created by virtual reality and its ability to give more control causing the user to interact more. With a mean squared of over 9.9 between the two groups and 1.2 within the group there is a significant difference between the two groups of response to the same question resulting in a significance level of 0.005.

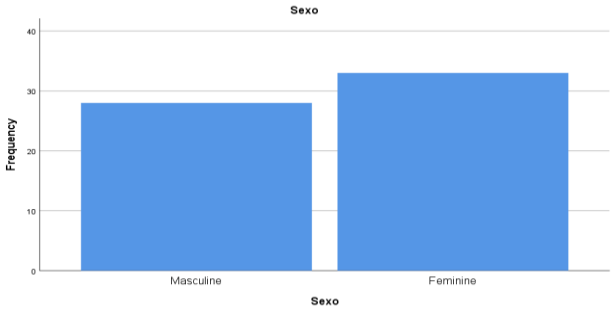
Hypothesis 4 - Understanding

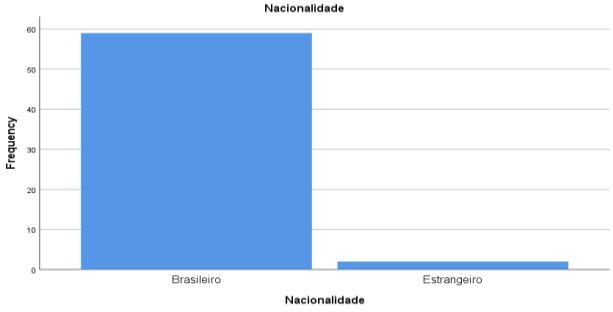
Prediction: The understanding of the apartment will be higher when using a virtual reality headset.

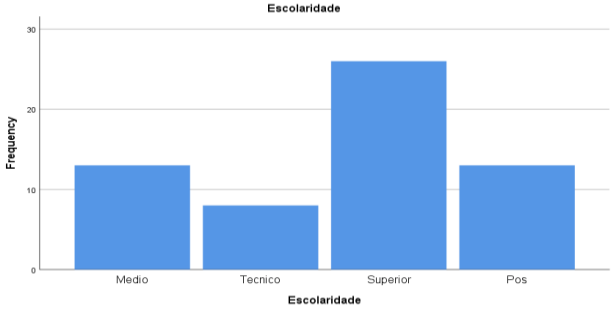
Unfortunately Understanding was discarded from the results as these questions were created to test against another characteristic in a different experimental setting that did not translate to the specific study we conducted.

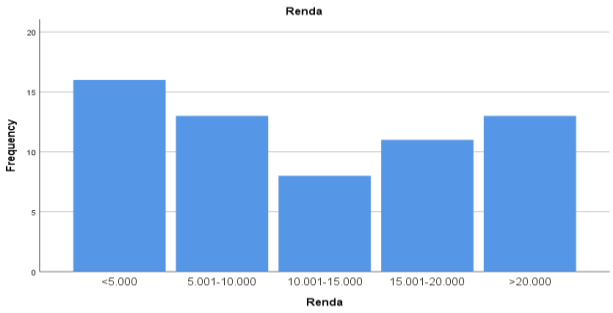
Additionally basic demographic information was collected in an effort to standardize the two study groups. this information included questions on age, gender, education, income and nationality. Being that the experiment was being done in rio de Janeiro, a city in Brazil, the assumption was most of the subjects would be brazilian, but added this question just to make sure, and there only turned out to be two foreigners who participated. Unfortunalty because the experiment involved asking strangers to take part in a school project we were not able to have strict filters on the subjects chosen, and as a result the only demographic intentionally used to guide the act of subject selection was gender, which is more easily determined on sight.











		Tech	
		Video	VR
Idade	20-30	16	18
	31-40	7	10
	41-50	5	1
	51-60	1	1
	>60	2	0
Renda	<5.000	10	6
	5.001-10.000	7	6
	10.001-15.000	4	4
	15.001-20.000	6	5
	>20.000	4	9

Limitations

It was our best attempts to be a rigorous as possible but unfortunately due to time and funding restraints there were many limitations of this study, one of which being not having access to a testing facility and having to conducted the experiment in a Starbucks on regular weekday, which is a semi public setting and subjects were able to see others use before being tested.

Also with little time being afforded to the masters study it was beyond the bounds of this experiment to create a questionnaire from scratch and validate it before conducting the experiment. This could have possibly created a better questionnaire with characteristics more focused on the searching and purchasing process of real estate consumers.

Most critically is that immersion and interaction do not directly correlate to property sales, but based on the literature it does create other externalities like better memory recognition of the location and its contents.

Lastly the experiment could unfortunately only use a 3DOF (degrees of freedom) virtual reality headset and not a 6DOF headset (room scale with walking capabilities) causing our subjects to view the apartment in a stationary position only being able to move there head to change perspective. furthermore there was no other controller used or haptic feedback of any kind.

Implications in Technology use for Real Estate Marketing

These results do show that consumers in different characteristics find virtual reality a better technology for viewing a property. This makes sense as the average agent to day in Brazil takes 2D rectangular images of angles of each room in an apartment and usually uploads these pictures to a gallery many times in a random order, which makes wayfinding and floor plan understanding a struggle. The ability to "teleport" customers to multiple properties in seconds is expected to be a great benefit to agents in that fact that they will have to do less home visits with their clients giving agents more free time for other business building activities and close more sales.

As a result of this research we can say that our subjects prefer the virtual reality experience over the video when looking at apartments. That statement alone gives value to this form of technology and for any real estate broker or agent it would like to benefit and expand their marketing efforts to include virtual reality content to supplement their current sales techniques.

Theoretical Implications for Future Research

This study contributes to a quickly growing body of work that focuses on the value of virtual reality and its use cases in the real world. While the majority of works in this study have found benefits there is still a lot of new improvements being added. As auxiliary technologies like haptics and other sensory or biometric feedback is created and improved upon there are seemingly hundreds of possible technology to accompany virtual reality.

Unfortunately at this time in Brazil there is no multiple Listing Site that has virtual reality as a option and so we cannot find definitive sales details to define how these results affect the real

market. More laboratory tests can also be done, varying the fidelity and intractability to see if the results become more prominent or start to converge to insignificance. Also if access to a quality vetting system to have only subjects in the market for a new home combined with more poignant questions to address their perceived home value and overall property quality could be affected by.

REFERENCES

Allen M.T., Cadena A., Rutherford J., Rutherford R.C. (2015) Effects of Real Estate Brokers' marketing strategies: Public open houses, broker open houses, MLS virtual tours, and MLS photographs. *Journal of Real Estate Research*, Volume 37, Issue 3, 2015, Pages 343-370

Benefield J.D., Cain C.L., Gleason A. (2012) Visual display of residential property information: Some additional evidence. *Journal of Real Estate Practice and Education*, Volume 15, Issue 2, 2012, Pages 89-100

Business Insider Intelligence. (2016) The virtual and augmented reality market will reach $162 billion by 2020. Business Insider august 22, 2016.

Branstetter, Gillian. (2015) *Cardboard is everything Google Glass never was*. The Kernel. June 28, 2015

Brewster, Signe. Behind the Numbers of Virtual Reality's Sluggish Debut. *MIT Tech Review*, December 30, 2016.

Culbertson H., Kuchenbecker K.J. (2017) Importance of matching physical friction, hardness, and texture in creating realistic haptic virtual surfaces. *IEEE Transactions on Haptics*, Volume 10, Issue 1, January-March 2017, Article number 7539397, Pages 63-74

de Tommaso M., Ricci K., Delussi M., Montemurno A., Vecchio E., Brunetti A., Bevilacqua V. (2017) Testing a novel method for improving wayfinding by means of a P3b Virtual Reality Visual Paradigm in normal aging. *SpringerPlu*, Volume 5, Issue 1, 1 December 2016, Article number 1297

Delikostidis I., Fechner T., Fritze H., Abdelmouty A.M., Kray C. (2013) Evaluating Mobile Applications in Virtual Environments: A Survey. *International Journal of Mobile Human Computer Interaction*, Volume 5, Issue 4, October/December 2013, Pages 1-19

Digi-Capital. Mainstream VCs' bigger checks drive record AR/VR investment. October 2016.

Digi-Capital. Record $2.3 billion VR/AR investment in 2016. February 2017

Digi-Capital. Record over $3B AR/VR investment in 2017 ($1.5B+ in Q4). January 2018

Digi-Capital. Augmented/Virtual Reality revenue forecast revised to hit $120 billion by 2020. January 2016.

Fisher-Gewirtzman D. (2017) The association between perceived density in minimum apartments and spatial openness index three-dimensional visual analysis. *Environment and Planning B: Urban Analytics and City Science*, Volume 44, Issue 4, 1 July 2017, Pages 764-795

Gartner. Gartner Hype Cycle https://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

Goel L., Johnson N.A., Junglas I., Ives B. (2011) From space to place: Predicting users' intentions to return to virtual worlds. *MIS Quarterly: Management Information Systems*, Volume 35, Issue 3, September 2011, Pages 749-771

Goel L., Prokopec S. (2009) If you build it will they come? - An empirical investigation of consumer perceptions and strategy in virtual worlds. *Electronic Commerce Research*, Volume 9, Issue 1-2, 2009, Pages 115-134

Equity Research. Profiles in Innovation: Virtual and Augmented Reality, Understanding the race for the nest computing platform. The Goldman Sachs Group, Inc. January 13, 2016.

Heath, Alex (2017) *Mark Zuckerberg reveals that Facebook paid more than we thought for Oculus*. Business Insider January 17, 2017

Heidari M., Allameh E., De Vries B., Timmermans H., Jessurun J., Mozaffar F. (2014) Smart-BIM virtual prototype implementation. *Automation in Construction*, Volume 39, 1 April 2014, Pages 134-144

Hong S.W., Jeong Y., Kalay Y.E., Jung S., Lee J. (2016) Enablers and barriers of the multi-user virtual environment for exploratory creativity in architectural design collaboration. *CoDesign*, Volume 12, Issue 3, 2 July 2016, Pages 151-170

Kelly J.W., Burton M., Pollock B., Rubio E., Curtis M., De La Cruz J., Gilbert S., Winer E. (2013) Space perception in virtual environments: Displacement from the center of projection causes less distortion than predicted by cue-based models. *ACM Transactions on Applied Perception*, Volume 10, Issue 4, October 2013, Article number 18

Kukshinov E.Y. (2015) The virtual self and possible immersive consequences of uncharacteristic self-presentation in the virtual environment. *International Journal of Cyber Behavior, Psychology and Learning*, Volume 5, Issue 4, 1 October 2015, Pages 73-82

Lamkin, Paul. (2017) *Virtual Reaity Headset Sales Hit 1 Million*. Forbes. November 30 2017.

Li L., Duan X., Zhu H., Guo R., Ying S. (2015) Semantic volume texture for virtual city building model visualisation. *Computers, Environment and Urban Systems*, Volume 54, November 01, 2015, Pages 95-107

Mahdjoubi L., Hao Koh J., Moobela C. (2014) Effects of interactive real-time simulations and humanoid avatars on consumers' responses in online house products marketing. *Computer-Aided Civil and Infrastructure Engineering*, Volume 29, Issue 1, January 2014, Pages 31-46

Mavridou M. (2012) Perception of three-dimensional urban scale in an immersive virtual environment. *Environment and Planning B: Planning and Design,* Volume 39, Issue 1, 2012, Pages 33-47

Meagher B.R., Marsh K.L. (2015) Testing an Ecological Account of Spaciousness in Real and Virtual Environments. *Environment and Behavior,* Volume 47, Issue 7, 11 August 2015, Pages 782-815

Miltiadis C. (2016) Project anywhere: An interface for virtual architecture. *International Journal of Architectural Computing,* Volume 14, Issue 4, 1 December 2016, Pages 386-397

Nebiker S., Bleisch S., Christen M. (2010) Rich point clouds in virtual globes - A new paradigm in city modeling? *Computers, Environment and Urban Systems,* Volume 34, Issue 6, November 2010, Pages 508-517

Nelson, Fritz (2014) *The Past, Present, and Future of VR and AR: the Pioneers Speak*. Tom's Hardware. April 30, 2014.

Nobre, Gustavo Cattelan. Tavares, Elaine (2017) Scientific literature analysis on big data and internet of things applications on circular economy: a bibliometrics study. *Scientometrics,* Volume 111, issue 1, April 2017, Page 463-492

Postma B.N.J., Katz B.F.G. (2015) Creation and calibration method of acoustical models for historic virtual reality auralizations. *Virtual Reality,* Volume 19, Issue 3-4, 9 September 2015, Pages 161-180

Sauzéon H., N'Kaoua B., Arvind Pala P., Taillade M., Guitton P. (2016) Age and active navigation effects on episodic memory: A virtual reality study. *British Journal of Psychology,* Volume 107, Issue 1, 1 February 2016, Pages 72-94

Smith S. (2016) Getting queasy about virtual reality. *EContent,* Volume 39, Issue 2, March 2016

Stamps III, A.E. (2010) Slines, entropy, and environmental exploration. *Environment and Planning B: Planning and Design,* Volume 37, Issue 4, 2010, Pages 704-722

Tiainen T., Ellman A., Kaapu T. (2014) Virtual prototypes reveal more development ideas: comparison between customers' evaluation of virtual and physical prototypes. *Virtual and Physical Prototyping,* Volume 9, Issue 3, July 2014, Pages 169-180

Van der Land S., Schouten A.P., Feldberg F., van den Hooff B., Huysman M. (2013) Lost in space? Cognitive fit and cognitive load in 3D virtual environments. *Computers in Human Behavior,* Volume 29, Issue 3, 1 May 2013, Pages 1054-1064

Vanian, Jonathan. (2017) *Samsung Pumping Millions into Artificial Intelligence and virtual Reality.* Fortune. January 4, 2017

Yoon W.J., Hwang W.-Y., Perry J.C. (2016) Study on effects of surface properties in haptic perception of virtual curvature. *International Journal of Computer Applications in Technology,* Volume 53, Issue 3, 2016, Pages 236-243

Zetzsche C., Wolter J., Galbraith C., Schill K. (2009) Representation of space: Image-like or sensorimotor? *Spatial Vision,* Volume 22, Issue 5, 1 September 2009, Pages 409-424

APPENDIX A

Figure A7: Survey questions and translations

Realism

1. I felt the apartment was presented realistically
    1. Eu senti o apartamento ser apresentado realisticamente
2. I got a good impression of the apartment
    1. Tenho uma boa impressão do apartamento
3. I think my mental image of the apartment resembles how it really is
    1. Eu acho que minha imagem mental do apartamento se assemelha a como realmente é
4. I obtained a complete impression of the apartment
    1. Eu obtive uma impressão completa do apartamento
5. Viewing the apartment this way resembles a real life visit
    1. Ver o apartamento desta forma se assemelha a uma visita de vida real

Immersion

6. During the presentation of the apartment, I felt like being present in the apartment
    1. Durante a apresentação do apartamento, senti como estar presente no apartamento
7. During the presentation of the apartment, I felt I had a sense of "being there”
    1. Durante a apresentação do apartamento, senti que tinha a sensação de "estar lá"
8. When I finished viewing the apartment, I felt like I had returned from a real life inspection
    1. Quando terminei de ver o apartamento, senti que tinha retornado de uma inspeção da vida real
9. To me, the virtual environment became reality
    1. Para mim, o ambiente virtual tornou-se realidade

Interactivity

10. I could control the presentation of the apartment
    1. Eu poderia controlar a apresentação do apartamento
11. I could view the apartment fro many different perspectives

    1. Eu podia ver o apartamento em várias perspectivas diferentes

12. How interactive would you rate the presentation of these apartments interns of ability to navigate through it
    1. Quão interativo você classificaria a apresentação desses estagiários estagiários de habilidade para navegar por ele

Individual Understanding

13. I was very well able to imagine the pros and cons of the apartment
    1. Eu estava muito bem capaz de imaginar os prós e os contras do apartamento
14. The way the apartment was presented enabled me to thoroughly examine the apartment
    1. A forma como o apartamento foi apresentado me permitiu examinar minuciosamente o apartamento
15. The way the apartment was presented offered insight in which information was relevant and valuable
    1. A forma como o apartamento foi apresentado ofereceu uma visão em que a informação era relevante e valiosa

Figure A8: Instructions and Survey for the Video Tour

Instruções para assistir o vídeo tour

Por favor, veja o vídeo para fazer o tour. Você pode pausar e voltar a qualquer momento. Veja todos os detalhes do apartamento antes de responder a pesquisa.

* Required

Tour do Apartamento

http://youtube.com/watch?v=q00T-xYHXjU

Pesquisa sobre tour no apartamento

Abaixo estão algumas frases relativas à sua experiência em visualizar o apartamento. Indique quão fortemente você concorda ou discorda de cada frase.

1. **Eu acho que minha imagem mental do apartamento se assemelha a como o apartamento realmente é** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

2. **Foi possível ver o apartamento em várias perspectivas diferentes** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

3. **Durante a apresentação do apartamento, senti como se estivesse presente no apartamento** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

4. **Eu obtive uma impressão completa do apartamento** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

5. **Quando terminei de ver o apartamento, senti que tinha retornado de uma inspeção (visita) na vida real** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

6. **Eu pude controlar a visita do apartamento** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

7. **Tenho uma boa impressão do apartamento** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

8. **A forma como o apartamento foi apresentado ofereceu uma visão em que a informação era relevante e valiosa** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

9. **Para mim, o ambiente virtual tornou-se realidade** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

10. **Durante a apresentação do apartamento, tive a sensação de "estar lá"** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

11. **Ver o apartamento desta forma se assemelha a uma visita na vida real** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

12. **Quão interativo você classificaria a apresentação do apartamento em relação a habilidade para navegar por ele** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

13. **Eu senti que o apartamento foi apresentado de forma realista** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

14. **A forma como o apartamento foi apresentado me permitiu examinar minuciosamente o apartamento** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

15. **Eu sou capaz de imaginar os prós e os contras do apartamento** *

Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

Informação Demográfica

Por favor, responda as seguintes perguntas ao melhor de sua capacidade.

16. **Idade** *

Mark only one oval.

- ◯ 20-30 anos
- ◯ 31-40 anos
- ◯ 41-50 anos
- ◯ 51-60 anos
- ◯ Mais de 60 anos

17. **Sexo** *

Mark only one oval.

- ◯ Masculino
- ◯ Feminino

18. **Nacionalidade** *

Mark only one oval.

- ◯ Brasileiro
- ◯ Other: _____

19. **Qual seu grau de escolaridade?** *

Mark only one oval.

- ◯ 1º Grau Completo (Fundamental)
- ◯ 2º Grau Completo (Ensino Médio)
- ◯ Especialização (Cursos Técnicos, etc)
- ◯ Ensino Superior Completo (Bacharel, Licenciatura, Tecnólogo...)
- ◯ Mestrado ou Doutorado

20. **Renda familiar (por mês)** *

Mark only one oval.

- ◯ Menos que R$5.000
- ◯ R$5.001 - R$ 10.000
- ◯ R$ 10.001 - R$ 15.000
- ◯ R$15.001 - R$20.000
- ◯ Mais de R$20.000

21. **Você possui o seu apartamento?** *
Mark only one oval.

- ◯ Sim
- ◯ Não

22. **Você está procurando um apartamento novo?** *
Mark only one oval.

- ◯ Sim
- ◯ Não

23. **Você já usou um óculos de realidade virtual antes? Se sim, para que?** *
Mark only one oval.

- ◯ Não
- ◯ Jogos
- ◯ Vídeos
- ◯ Other: _____

Muito Obrigado!

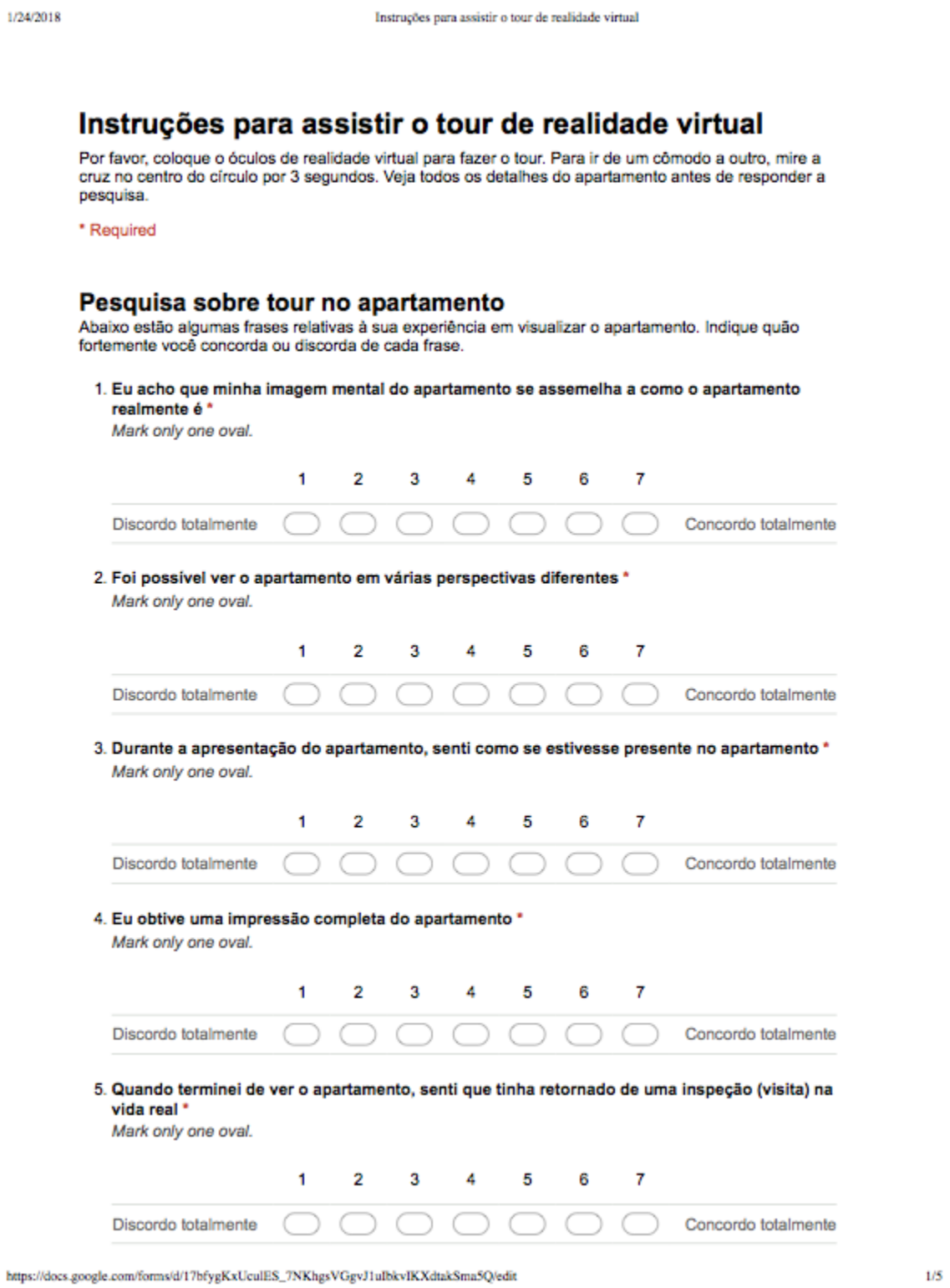
Nós respeitamos sua privacidade e todas as informações devem ser mantidas anônimas.

24. **Se você quiser os resultados deste estudo, adicione seu e-mail aqui**

_____

Powered by Google Forms

Figure A9: Instructions and Survey for Virtual Reality Tour



1/24/2018 Instruções para assistir o tour de realidade virtual

Instruções para assistir o tour de realidade virtual

Por favor, coloque o óculos de realidade virtual para fazer o tour. Para ir de um cômodo a outro, mire a cruz no centro do círculo por 3 segundos. Veja todos os detalhes do apartamento antes de responder a pesquisa.

* Required

Pesquisa sobre tour no apartamento

Abaixo estão algumas frases relativas à sua experiência em visualizar o apartamento. Indique quão fortemente você concorda ou discorda de cada frase.

1. **Eu acho que minha imagem mental do apartamento se assemelha a como o apartamento realmente é** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

2. **Foi possivel ver o apartamento em várias perspectivas diferentes** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

3. **Durante a apresentação do apartamento, senti como se estivesse presente no apartamento** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

4. **Eu obtive uma impressão completa do apartamento** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

5. **Quando terminei de ver o apartamento, senti que tinha retornado de uma inspeção (visita) na vida real** *
   Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

https://docs.google.com/forms/d/17bfygKxUculES_7NKhgsVGgvJ1uIbkvIKXdtakSma5Q/edit 1/5

6. **Eu pude controlar a visita do apartamento** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

7. **Tenho uma boa impressão do apartamento** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

8. **A forma como o apartamento foi apresentado ofereceu uma visão em que a informação era relevante e valiosa** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

9. **Para mim, o ambiente virtual tornou-se realidade** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

10. **Durante a apresentação do apartamento, tive a sensação de "estar lá"** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

11. **Ver o apartamento desta forma se assemelha a uma visita na vida real** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

12. **Quão interativo você classificaria a apresentação do apartamento em relação a habilidade para navegar por ele** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

13. **Eu senti que o apartamento foi apresentado de forma realista** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

14. **A forma como o apartamento foi apresentado me permitiu examinar minuciosamente o apartamento** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

15. **Eu sou capaz de imaginar os prós e os contras do apartamento** *
Mark only one oval.

	1	2	3	4	5	6	7	
Discordo totalmente	◯	◯	◯	◯	◯	◯	◯	Concordo totalmente

Informação Demográfica

Por favor, responda as seguintes perguntas ao melhor de sua capacidade.

16. **Idade** *
Mark only one oval.

- ◯ 20-30 anos
- ◯ 31-40 anos
- ◯ 41-50 anos
- ◯ 51-60 anos
- ◯ Mais de 60 anos

17. **Sexo** *
Mark only one oval.

- ◯ Masculino
- ◯ Femenino

18. **Nacionalidade** *
Mark only one oval.

- ◯ Brasileiro
- ◯ Other: _____

19. **Qual seu grau de escolaridade?** *
Mark only one oval.

- ◯ 1º Grau Completo (Fundamental)
- ◯ 2º Grau Completo (Ensino Médio)
- ◯ Especialização (Cursos Técnicos, etc)
- ◯ Ensino Superior Completo (Bacharel, Licenciatura, Tecnólogo...)
- ◯ Mestrado ou Doutorado

20. **Renda familiar (por mês)** *
Mark only one oval.

- ◯ Menos que R$5.000
- ◯ R$5.001 - R$ 10.000
- ◯ R$ 10.001 - R$ 15.000
- ◯ R$15.001 - R$20.000
- ◯ Mais de R$20.000

21. **Você possui o seu apartamento?** *
Mark only one oval.

- ◯ Sim
- ◯ Não

22. **Você está procurando um apartamento novo?** *
Mark only one oval.

- ◯ Sim
- ◯ Não

23. **Você já usou um óculos de realidade virtual antes? Se sim, para que?** *
Mark only one oval.

- ◯ Não
- ◯ Jogos
- ◯ Vídeos
- ◯ Other: _____

Muito Obrigado!

Nós respeitamos sua privacidade e todas as informações devem ser mantidas anônimas.

24. **Se você quiser os resultados deste estudo, adicione seu e-mail aqui**

_____

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Figure A10: Virtual Reality Headset and iPad used for experiment

Figure A11: Equirectangular representation of 360 images taken to create virtual reality and video content

Entrance

Family Room

Kitchen

Bedroom

Bathroom