Designing in Virtual Reality: Tools with the Human Field of Vision

by

Joie Z. Chang

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Author _____
Department of Architecture
May 19, 2017

Certified by _____
Takehiko Nagakura
Associate Professor of Design and Computation
Thesis Supervisor

Accepted by _____
John Ochsendorf
Professor of Building Technology
Director of the Undergraduate Program, Department of Architecture

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Abstract

Virtual reality, or VR, will be the next common medium for digital visualization. The purpose of this thesis is to explore how designers will use and discover new design methods with the representation in virtual reality. How do computational design tools such as CAD and VR, which are digital representations of the physical, affect our designs of physical space?

In this thesis, I explore the benefits and shortcomings of VR as a design medium. My first hypothesis claims that VR will excel in representing site context, depth, and scale, in comparison to CAD. The second hypothesis says that VR will encourage a preference for monumentality and open spaces in comparison to a higher packing density of objects in CAD. The third hypothesis claims that designers will prefer 3d models with realistic rendering textures in VR, more so than CAD. The fourth and final hypothesis is that architects, familiar with CAD, can design immersive views just from a 3d omniscient plan without immersion, unlike novices.

The first part of the research is the creation of a proof-of-concept virtual reality design review tool that can be integrated easily into existing design practices. The VR tool allows a user to explore their 3d modeled spaces with full locomotion and visually records their experiences in the space. This VR tool integrates virtual reality into the process of iterative design. Through subject testing, we explore our understanding of how our spatial perception interacts with simulated virtual space and thus affects our manners of designing.

The results led us to several different conclusions. First, intuitive perception of scale and other spatial relationships is easier in VR. Secondly, VR, despite its intimate relation to the human scale, does not promote a preference for large spaces and monumentality. Thirdly, designers slightly prefer realistic rendering textures in VR. Finally, those with architecture training perform slightly better than novices in visualizing 3d immersive views from plans.

This project illustrates where virtual reality's value and flaws as a digital visualization medium. It examines what manner the mode of representation affects and limits the process of designing and making.

Thesis Supervisor: Takehiko Nagakura
Title: Associate Professor of Design and Computation

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Abstract

Acknowledgements

I.   Introduction

In modern architectural processes of making, designers and architects preview, manipulate, and derive knowledge about their project space through a computer's digital visualization. The simulation of three dimensional modeling on a two dimensional screen is a method of representation that harkens back to the perspectival and axonometric physical architecture drawings. These representations have become codified within the conventions of architectural design, yet, as with any three dimensional object rendered in two dimensions, they can be limiting, reductive, or downright falsified.

Technology has long been one of the great drivers of architectural innovation, from the wide spread switch to CAD to developments in digitally based fabrication tools. The development of these new design tools have gone hand in hand with the evolution of the discipline. Often the trajectory of a developing technology is guided by not only its far reaching possibilities but its ability to integrate and transform itself to new methods of making and designing. In 1963, Coons wrote "An Outline of the Requirements for a Computer-Aided Design System" as a reflection not only on the current capabilities of the light pen CAD system but as a reflection on the relationship of computation and design. The manner in which design became codified in the manipulation of primitive objects into larger forms came from a virtual representation in CAD. Fast forward fifty years and CAD is the preferred medium for 3d representation, quickly overtaking traditional craft models.

Now, virtual reality, or VR, proves promising as the next common medium for digital visualization. The purpose of this thesis is to explore how designers will use and discover new design methods with the representation in virtual reality. Similar to how designers explored and theorized about the manner in which CAD could be developed and used as a medium for architectural design,

now VR requires a similar treatment. Precedents for this research include Joshua Choi's thesis, *Merging Three Spaces: Exploring User Interface Framework for Spatial Design Virtual Reality* in which he designed a number of spatial experiments to prove the fidelity of spatial perception of VR to the real world. Choi then used these results in order to theorize about a UI framework for modeling and spatial editing in VR.

Expanding from his confirmation that VR offers a unique and worthwhile medium to perceive architectural space, I sought to investigate VR and its possible relationship with the architectural design process. How do computational design tools such as CAD and VR, which are digital representations of the physical, affect our designs of physical space?

I wish to demonstrate how current CAD design metaphors are insufficient and unwieldy in their spatial representations. Design tools are not objective in how they affect our manner of making and often embody philosophies or ways of working little considered by the designer themselves. The purpose of this thesis is thus two fold.

The first purpose is to create a proof of concept virtual reality design tool that could be integrated easily into existing design practices. I aimed to prototype an architectural virtual reality tool that allowed a user to explore their 3d modeled spaces with full locomotion and visually record their experiences on the site. By integrating virtual reality into the process of iterative design instead of as a separate experience not concerned with making, I wished to repurpose the VR medium as not just a consumptive tool but as a mode of critical creation.

The second purpose is to examine hypotheses in order to better understand how our spatial perception interacts with simulated virtual space and thus affects our manners of designing. I hope to ascertain where virtual reality's value as a medium of digital visualization lies, as well as its flaws. While I wish to postulate virtual reality as a new medium for architectural design processes, I would

also like to critically examine how the process of making becomes beholden to the method of representation. Neither medium is without its weak points and I would like to examine in what manner the mode of representation affects and limits the process of designing and making. By integrating virtual reality into the process of iterative design instead of as a separate experience not concerned with making, I wished to repurpose the VR medium as not just a consumptive tool but as a mode of critical creation.

II.   Hypothesis

This thesis aims to examine the differences in how designers work spatially between a 3D simulating viewport and an immersive virtual reality environment. The purpose of this experiment is to test how egocentric versus allocentric spatial processing affects creativity and the process of making in 3D modeling. The relative youth of virtual reality technology combined with their lack of application to architectural design disciplines meant coming up with new methods to integrate VR into an iterative design process. Thus, this thesis also takes on the second dimension as a proof of concept design for a VR design tool.

I argue that in the current CAD convention, the two activities of "visualizing" and "making" have built in limitations. Designs within the medium of CAD often express these limitations and affect the humans' understandings of their own spatial designs. In simulated 3D in 2D, the omniscient perspective in design causes difficulties in perceiving scale, depth, and contextual elements. The designer favors abstract over realistic representations, partially because of the ease of manipulating reductive elements and partially because of the formalism applied and inherent in CAD modeling. The strengths of human spatial perception lie in their ability to intuitively grasp issues of scale, context, and depth while in relation to themselves, causing spaces designed solely in CAD to unnerve a human inhabitant.

My claim is that the process of design can be expanded or limited by the mediums of representations. The current system of CAD design metaphors run counter to many of the intuitive tools given to designers by their natural human spatial perception. Thus, I believe that virtual reality contains the possibility in compensating for these pitfalls and evoking a more natural process of "visualizing" and "making". I hypothesized that, within VR, designers would create more organic and non-rectilinear geometries as a result of an egocentric spatial processing. Designers would favor

wide open spaces and weaker hierarchal alignments because their perception of these elements would be hampered by their own body relation. Finally, the blend of abstract forms with rendered objects is necessary for creating the immersive metaphors of virtual reality as a totally abstract white environment by nature dominates and unnerves the designer's senses.

Hypothesis 1: If the designer makes a space in a 2D screen environment, they will consistently misjudge the scale of objects and their spatial relationship to the human body. Designers will find it easier to perceive and judge site context, depth, and scale in virtual reality than in CAD environments.

Hypothesis 2: A designer in CAD will intentionally create higher packing density of features within CAD. In the virtual reality environment, a designer will prefer open spaces and landscape features positioned in more in relation to the body.

Hypothesis 3: Designers will show greater preference for abstract and geometric forms in CAD but, in VR, realistic rendering textures on 3d models will be more desirable.

Hypothesis 4: Designers with an architecture background training will be better at visualizing and designing immersive views that satisfy their own design intentions from a plan perspective than novices.

III.   Methodology

i. Experiment Design

To test my hypothesis, I created a design game based off Habraken and Gross' Silent Game to examine the ability to convey intent by a single designer between different mediums. The game simulates the challenges of architectural spatial design in a controlled environment. The goal of the design experiment was to design a sculpture garden with a circulation between two points of entry.

The subject is given three prefab objects to work with: walls, water, and trees. Subjects are given complete freedom to manipulate the number, scale, position, and orientation of these prefabs. The choice of these three landscape design objects is due to their distinct effect in manipulating and dividing space. Walls divide space and view. With their white material recalling the formalistic aesthetic of architectural education convention, the walls are a material of the architectural abstract. Their usage is intended to correlate with a design process in abstract. In contrast, the rendered models of the tress and water place them in the realm of mimetic reality. Trees divide view but often still allow for a permeable movement through them. Water does not divide view at all but divides space, as one cannot cross water physically.

There are six sculptures within the garden space that cannot be moved. Four of the statues are placed on the axis points of a 3x3 grid and the final two are placed on the lengthwise axis in the center of grids. The subject is given the instruction to create a circulation that would allow a person traversing the garden to see all six sculptures. The garden space they were allowed to design in had a rectangular perimeter wall of three meters, with two entry points on the southern side.
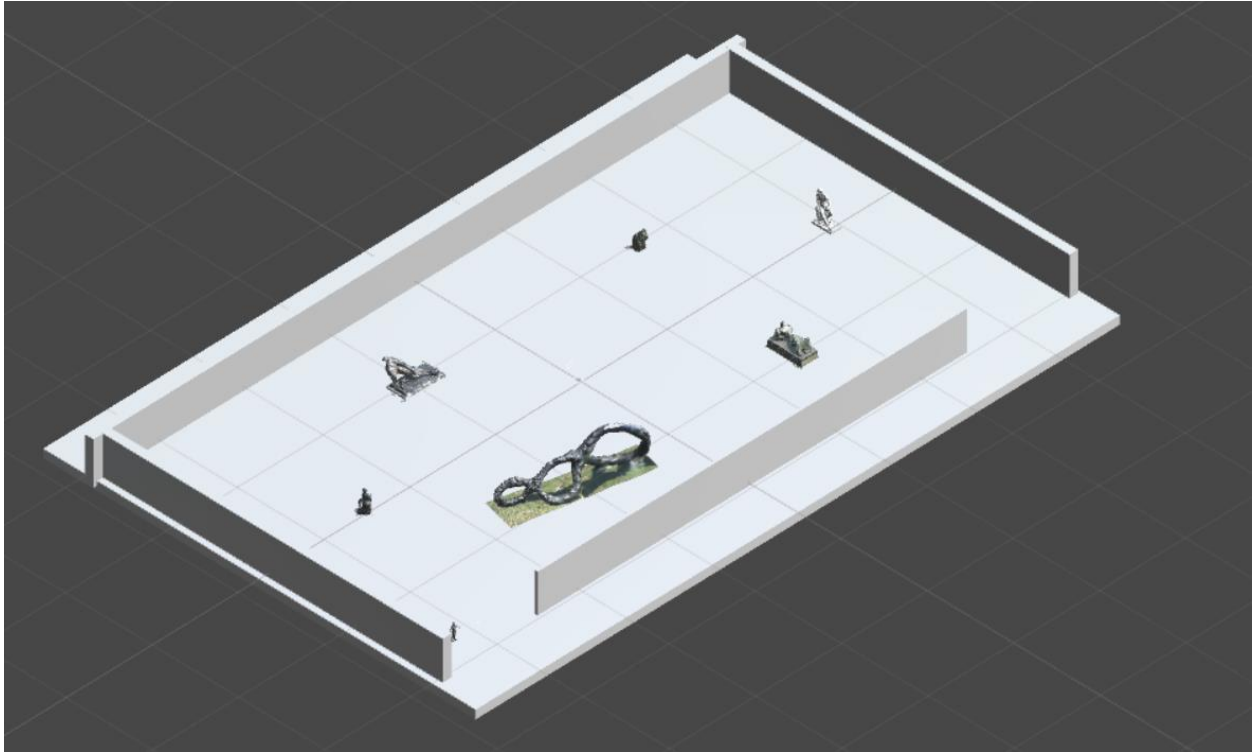
Figure 1: Blank Sculpture Garden Template
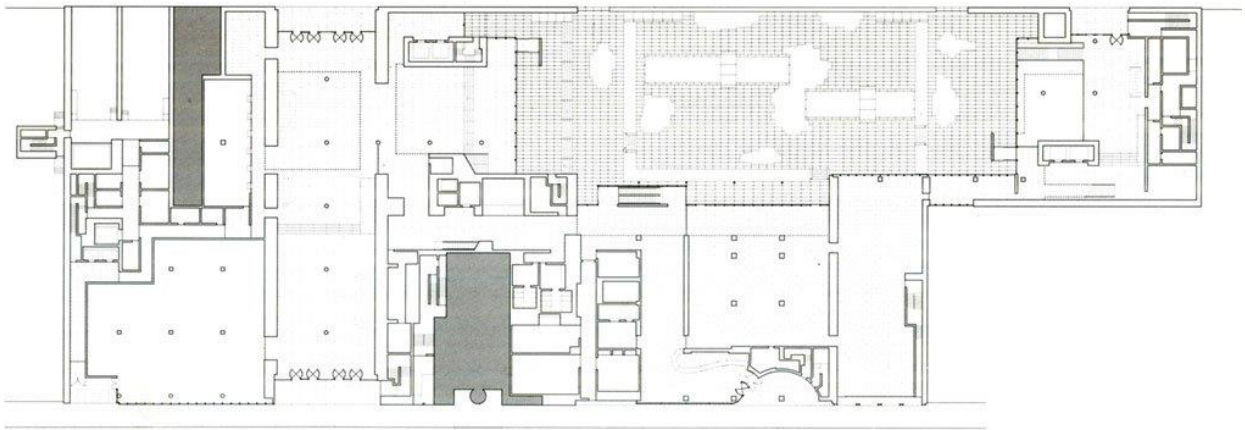
ii. Precedents

Figure 3: MOMA entry level plans © Taniguchi & Associates

Figure 4: MOMA Abby Aldrich Rockefeller Sculpture Garden Panorama (Photo by Steve Guttman)

When creating the template for the sculpture garden, I referenced the Abby Rockefeller sculpture garden within the New York MOMA. The current landscape design comes from the 2004 renovations by Yoshio Taneguchi. The original design by Phillip Johnson from 1953 was renovated and enlarged as the heart of the museum. I chose this site for two reasons. The first, by referencing an existing sculpture garden's dimensions, I could compare the digitally modeled designs by the subjects to a physically built, existing environment. The Rockefeller sculpture garden is semi-permanent, where its landscape design and sculpture offerings have changed drastically over the course of its history. Having a history of multiple redesigns helped illuminate all the flexibilities of a space with these perimeters.

The second was because of the scale of the Rockefeller sculpture garden meant moving through the garden was an absolute necessity for a human-scaled viewer to see all the objects. Yet the space was constrained enough for the limit of the experiment. The rectangular perimeter of the garden suggested an axial organization of space that could then be fulfilled or subverted by subjects. The rotating sculpture designs, abundance of foliage, and mostly level ground material as opposed to an open grass park allowed me to approach the experiment as architecture. Having a physical

sculpture garden precedent helped ground me into a physical scale and space given the virtual nature of the project.

iii. Equipment

In order to carry out my experiment, I used a Google Cardboard coupled with an Android phone as my VR headset. I wanted a headset that designers today could already have access to without exorbitant cost or steep learning curves in usage. The choice of Google Cardboard over other VR hardware was to maximize the possible audience of

Figure 5: VR Review Experiment Setup with Google Cardboard and Bluetooth Controller

the application. Instead of expensive and technology locked hardware, by prototyping this experiment on the Google Cardboard, I hoped to demonstrate the flexibility and power of the low-end range of virtual reality and promote a compatibility with a wide range of design processes and techniques. I hoped to demonstrate that VR could be integrated successfully into the design practices of now and not just the far-flung future. In order to facilitate locomotion and input through the VR space, I paired this with a Bluetooth video game controller. Finally the environment used for the design in 2D CAD as well as to load the VR program was the Unity 3d game environment.

iv. Design Participants

Participants for this experiment were divided into two groups: those with architecture training and those who were novices. Experience with virtual reality was not necessary although some subjects came with prior experience. All participants had some prior experience with 3d modeling on the desktop and had some familiarity with the GUI. A total of ten subjects participated in the experiment.

v. Design Task

The experimental game has two stages. The first stage is performed in a CAD environment on a PC screen. The subject will be able to view the sculpture garden space in simulated three dimensions, within a perspective view. The subject will have full control of their camera angles in order to replicate the degrees of camera freedom in most conventional CAD 3d modeling software. Thus the subject will be able to replicate 2D viewpoints or approximate human eye elevation perspectives by manipulating the camera if they so choose. They can manipulate the game objects either through the drag-based GUI or through numerical input, giving them a fine level of precision. The Unity environment was locked such that they would only be able to duplicate and manipulate the prefabricated game objects. Afterwards, I would conduct interviews to ascertain their design intention, how they would self-evaluate their design, and given more time, what would they like to explore further.

The second stage is performed in an immersive virtual reality environment with Google Cardboard. The subject will view the space they designed and their perspective will be simulating a standing human's vision. Their viewpoint will be keyed to the movement of their head and they will be able to move through the space through a joystick controller input. The subject will be able to maneuver and look all around the model of their space. Their designed model will be loaded onto an

Android phone and then placed within a Google Cardboard head mounted set. The controller will also have a second function. When the participant presses A on the controller, the headset will take a photo or screenshot of whatever the participant is viewing. Given this photo function, I ask participants to take two types of photos:

1. Record what you liked and found successful about your design.
2. Record what you disliked and would like to change about your design.

Afterwards, I would conduct interviews to see how their design intention has been affected by their VR review, the commentary and rationale behind their photos, what would they like to explore further, and finally to reflect on how VR can be applied to the design process.

vi. Experiment Process

Part I: Design in CAD-space

1. The subject would be given the empty garden site with the prefabs on the side in the Unity environment. They would receive the instruction about the design task.
2. Subject would have 20 minutes in order to manipulate the prefabs to create a design. I would be recording their screen.
3. Upon finishing their design, I would save their model.
4. I would then conduct the post-interview with the subject.

Interview Questions:

1) "How familiar are you with CAD and 3d modeling?"
2) Did you find any difficulty or disparity between the design you envisioned and the design on the screen?"

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3) "Can you quickly walk me through your space and let me know the intention behind your design?"

4) "Given more time and iterations, would there be anything else you would like to explore in your garden design?"

Part II: Review in Virtual Reality

1. The subject is given a virtual reality demo app in order to test out the Google Cardboard. They had to complete a small look and find exercise in the VR environment.

2. Next I would load the model they had created in CAD onto the Android phone.

3. The subject would be given instructions to take photos and explore their model space.

4. The subject would have 15 minutes to explore the space and complete their assignment. I will be recording their screen.

5. Afterwards, I would then conduct the post-interview with the subject and review their photos.

Interview Questions:

1) "Was this your first time using a virtual reality HMD? Can you please describe any difficulties you had adjusting to the display or the controls?"

2) "In the event you were to further refine your design after this, was there anything useful or interesting about the VR display? Was there anything frustrating or unhelpful?"

3) "Let's take a quick look at your photos that you took. Please point out what you were thinking when you took each photo."

4) "Did you move through your intended circulation when you went around your garden space? Did you move in a manner similar to how you would move through a physical garden? Why or why not?"

5) "Could you see yourself using Virtual Reality in your design projects? To what capacity? Where in the design process and, as a supplemental viewing tool, or to manipulate objects in the environment directly?"

IV. Results

i. Overview

Figure 6: Garden Designs and VR Photos from All Subjects

I ran the experiment with ten different subjects. Six of them had architectural backgrounds and training while four of them were novices from assorted backgrounds, including mechanical engineering and computer science. Four subjects had used VR before to varying degrees, from playing games to prototyping in VR. Even those never exposed to VR found little to no difficulty in getting adjusted to the virtual reality set up and controller. Altogether, I collected 109 photos and comments from the VR review with a 50-50 split of liked versus disliked. The average subject took about 10.7 photos, giving me a good breadth in commentary and views for each design to analyze.

Figure 7: Subject 10's Sculpture Garden Design with Bridges and Plinths

I noticed some larger overall trends in the subjects even as each subject brought a unique design intent to the problem. These behaviors occurred throughout the subject pool, regardless of a subject's background in architecture.

The first was that subjects, in the CAD portion of the design activity, tended to 'settle' in a view to manipulate the design elements. They would manipulate all their elements from this view, be it plan, axonometric, or somewhere in between, and change their perspective infrequently. Secondly was every subject used multiple trees and at least one or more water features in abundance. All subjects excepting subject 5 included at least one wall as well. While people scaled trees and water, only subject 10 scaled the height of the walls or attempted to transform the walls into a different feature – seen here, they turned the walls into bridges and plinths.

Each of the subjects had a post CAD and post VR interview to comment on their CAD design. The length and detail of how they would further explore their design greatly increased in the post VR review. Most comments in the post CAD interview tended to be related to the manipulation of specific elements, like "playing with moving the sculptures, elevation changes, adding more trees" (Subject 2) or "would move the wall in the middle further from the statue and another water feature" (Subject 7). Comments in the post VR interview on the other hand ended up in two different categories. The photo commentary found an abundance of comments in relation to the personal experience of the subject. For example, subjects said things like "[I] didn't like being able to where you came from. [I would put] a wall here so you don't see back to the sculptures in the first half". Subject 2, even while making comments about adding elements, related the action back to a personal ability to view the sculpture. Comments after the post-VR interview also tended to speak about space and scale related to their personal experience and perception during their review. These types of comments are consistent across both architecture and novice subjects.

Thirdly in the VR review and the photo commentary, the most common comment about elements was calling for the addition or manipulation of more tree elements. Water was also positively regarded with all comments about water being the addition or extension of water. Walls were more controversial, with comments for the addition, deletion, and editing of walls.

Subjects remained disparate in their opinions of how VR could be used in various design processes and while some subjects' opinions were favorable, others remained skeptical even after using the VR review device. Subjects also perceived their relation to reality while in VR to varying degrees. Some subjects, without prompting, referred to virtual reality as the 'actual' despite virtual reality being a virtual representation medium and not the physical garden space. Others remained aware of virtual reality as another medium and critiqued or praised it as such. These trends cannot

be generalized to a body of subjects and reflect how using VR becomes an intensely personal experience for each and every subject.

ii. Case Study: Subject 9

"I see a large amount of water, sky, trees... [I like] a small thin line of concrete and sculpture... [it's] concrete and art"

"the distance is all wrong...too empty"

"I like this picture because of the perspective it gives..."

"...too empty...too much concrete"

"I dislike this one because it was too empty."

"I liked this picture...the layering of elements that were arranged."

"[In contrast to the one before]...similar points of view but less empty...slivers of space"

"I did not like this...this area seems to be really empty..."

"This space is the size of the Rockefeller Moma Sculpture Garden."

"Really? ... It's about vision, not VR, about the **wrong sense of scale**..."

"I liked the picture... it confirmed the idea I had when drawing in 2D...the line of water guides your entrance"
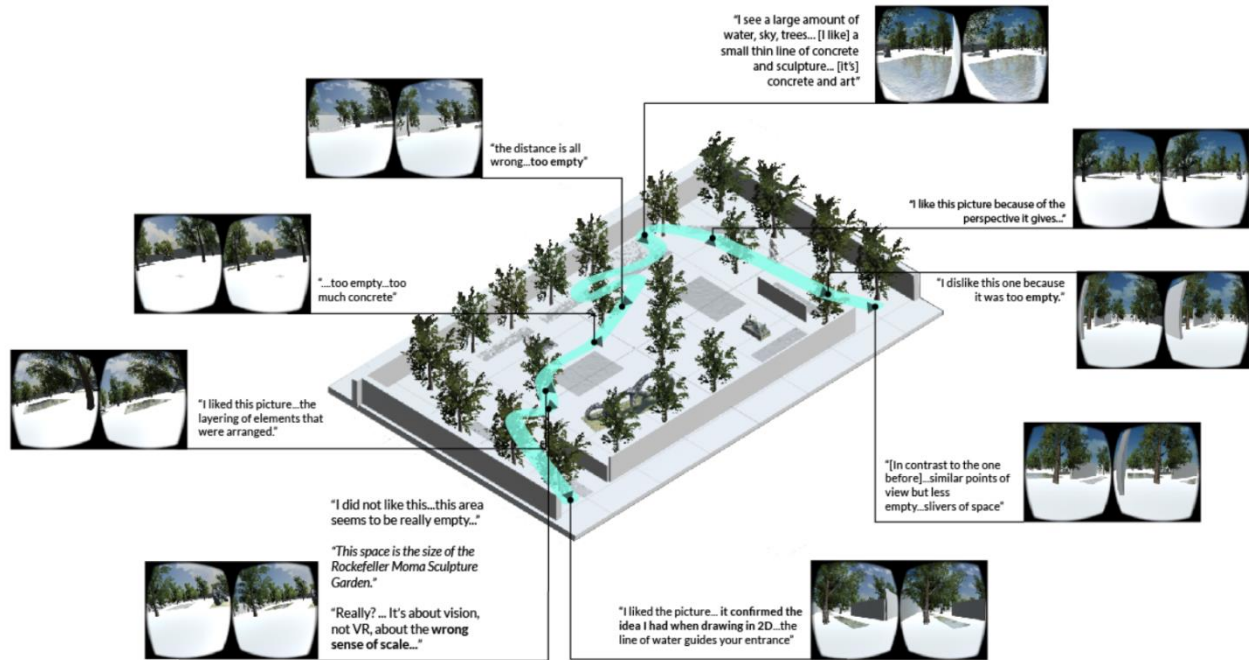
Figure 8: Subject 9's Sculpture Garden Design with VR Review Photos, Route, and Commentary

Subject 9 is an architecture student who had never used VR. Their background is in architecture, but they also have experience in design and computation research, giving a different kind of depth in their commentary. When designing within CAD, they created a branching circulation with an abundance of trees, water, and two walls. They stated their design intention was to lead the audience through the circulation with these small water strips and use the larger bodies of water as central areas that could be related to the sculptures. They also covered the perimeter wall with trees in order to evoke a greater garden appearance. When they designed their space within CAD, they mostly stayed within a plan perspective to manipulate the elements.

In the post CAD, pre VR interview, in response to my question about what they would like to explore further given more time and more iterations, they specifically mentioned curating the specific moments in the space. The subject said they would like to test the appearance through going into specific views as if in real time and double checking the trees and wall distances. They also made commentary on the CAD framework itself, expressing a frustration at the disconnect between the act of designing and the mouse and GUI click and drag/numerical scaling in CAD. Notably they are the only subject to express such frustrations between the ideation of a design and its translation into the computer environment.

When going through the experience in VR, they took a total of 9 photos with 5 positive photos and 4 negative photos, making a number of interesting comments. At the entrance, they saw the VR confirmed what they imagined as a water feature leading you into garden. Upon getting into the main space of the garden however, they found the scale they expected to find was different than the enormity of the garden. The following exchange was recorded below about the following photo:
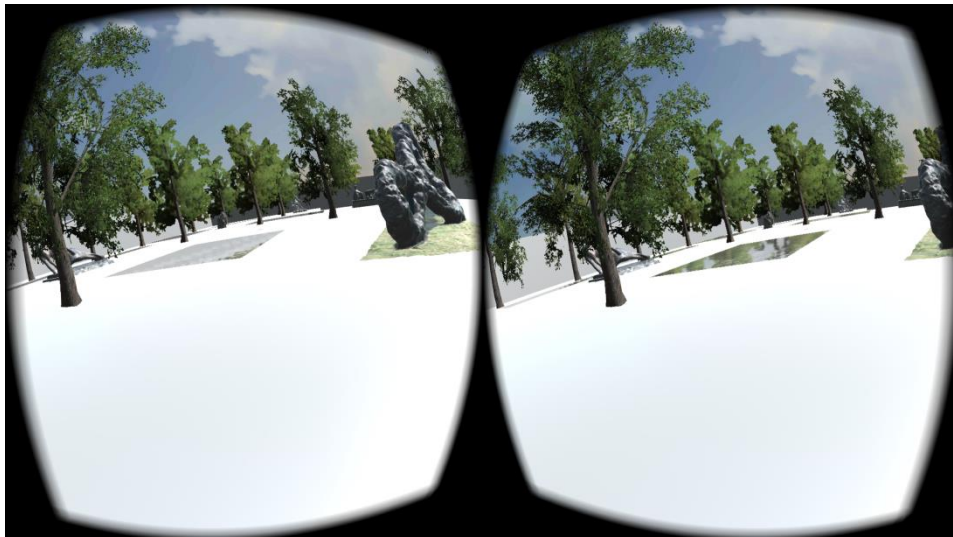

Figure 9: Subject 9 Photo no. 3047

Subject: "[I] did not like, it's so empty ... this area seems to be really empty, is it because of the camera perspective or I made it that empty?"

Researcher: "This space is the size of the Rockefeller Moma Sculpture Garden."

Subject: "Really?"

Researcher: "Is that surprising to you?"

Subject: "Yes…It's about vision, not VR; about the wrong sense of scale… vision is full of illusions. [When you increase the] layers of what you see, you increase the amount of illusion."

It is interesting of note that they came to the conclusion that vision fundamentally is a faulty tool with many illusions and tricks. Continuing on their journey- they moved in a fashion that no physical person would, skimming across bodies of water in order to check certain views, hinting at a disconnect between how the body moves in virtual reality as opposed to physical reality. The subject also viewed most of the sculptures from a limited degree of perspective, choosing to move close to the sculptures in the north side but viewing south side statues from afar. Most of the photos they disliked came from dissatisfaction with the emptiness of the space. Emptiness of space in this case referred to the abundance of no textured ground space. On the other hand, the perspectives they liked included many objects with realistic rendering textures often layered together within a view.
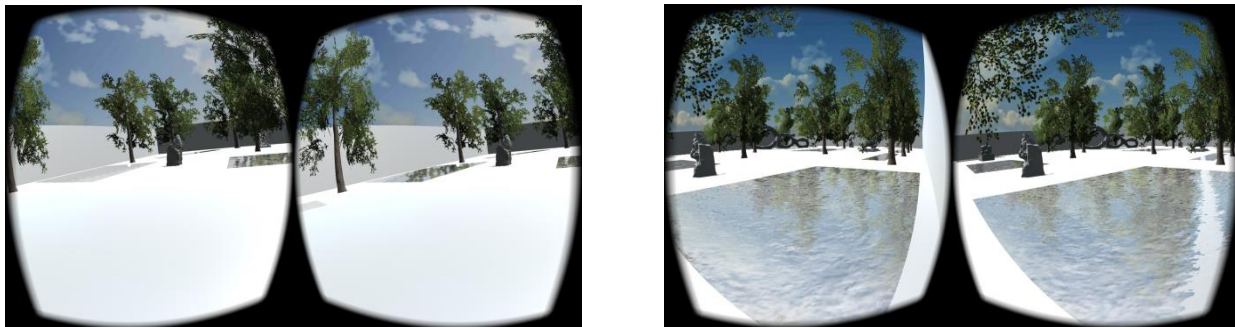

Figure 10: *Photo Captures from Subject 9*: (left, no. 3865) "the distance is all wrong… too empty",
(right, no. 4329) "I see a large amount of water, sky, trees... [I like] a small thin line of concrete and sculpture... [it's] concrete and art"

In their post VR interview, they said they would redesign many parts of their design as the sense of scale was far more realistic and they couldn't realize the actual measurements of spaces while designing in plan. They found value in the scale of the space and context, especially in considering materiality. Some feedback they had in the application of VR includes the possibility of making measurements in VR in order to control space and alignments. For their evaluation of VR as a design tool, they considered VR as a promising medium in order to evaluate large scale projects, materials, and the scale of space and context, among other things. They still say that 2d drawing has merits in order to enforce regularity, alignments, and measurements. As for digital modeling while in the 3d environment, the subject brought up the possibility of manipulating the digital model in augmented reality. Their rationale that augmented reality would be easier to edit in also belies a sense of VR being a difficult medium to edit directly into.

Overall, subject nine's journey from their original CAD design to their VR review contained the same kind of perspective shift and new discovery in VR that many other subjects experienced. Perhaps due to their design and computation research background, they commentated thoughtfully about how their own understanding of their design evolved upon using virtual reality.

V.   **Analysis**

Through the research conducted, I collected a number of sculpture design models, interview answers, recorded design and review processes, subject-captured photos, and photo commentary. Each hypothesis required a different pool of the data and, in order to extract meaning, careful attention was given to each different method of analyzing the data.
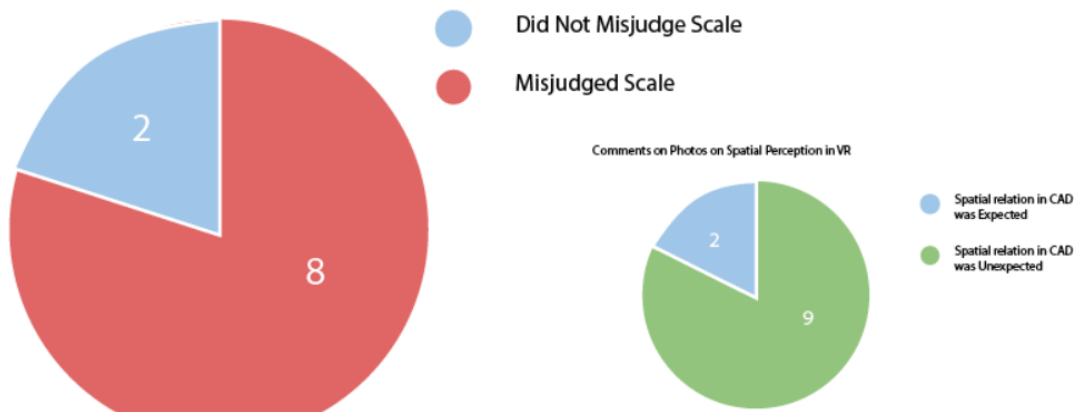
i. Hypothesis 1: If the designer makes a space in a 2D screen environment, they will consistently misjudge the scale of objects and their spatial relationship to the human body. Designers will find it easier to perceive and judge site context, depth, and scale in virtual reality than in CAD environments.

Hypothesis 1 is all about the perception of the human scale in VR and whether or not people would find it easier to perceive scale in an egocentric view. Overwhelmingly subjects responded with surprise and dismay during the VR portion as to their faulty sense of scale, both through their photos and also their post VR interview. In the post VR interview, many subjects had commentary such as:

"[Virtual reality is] actually really useful, it's hard to envision the ground to scale, even if you put a human, it's not the same as seeing it. So I found it way more useful than seeing it from above or the scaled human. A lot of perspectives surprised me and I liked and also a lot of them were poor and I would like to redo it." (Subject 2)

"[In VR, I] get a better sense what the sculptures were. [I] couldn't tell from the model… a sense of how big the trees were. [I] mainly worked from a plan view so being able to see through the trees meant a different in density expected. Looking in virtual reality, the [tree] sparseness without extra landscape features made it really sparse." (Subject 7)

In the VR post interview, which subjects commented on scale?

Did Not Misjudge Scale

Misjudged Scale

2

8

Comments on Photos on Spatial Perception in VR

Spatial relation in CAD was Expected

Spatial relation in CAD was Unexpected

2

9

Conclusion: Intuitive perception of scale and other spatial relationships is easier in VR than CAD.

Figure 11: Diagrams: (left) Post VR Interview Mentions of Scale, (right) Comments on Photos on Spatial Perception in VR

Only two out of eight subjects did not mention scale directly in their VR post interview, but still spoke about the spatial relationships and planning they would explore in their later iterations. In comparison, in the post CAD interview, only two people commented that they were unsure or insecure about the scale they were designing in. Across all subjects, a total eleven photos were taken that had commentary about spatial relationships between objects or between the object and the subject. Two of them were commenting on an expected relation while nine of them, the overall majority, were photos they were dissatisfied with and expressed surprise and dismay over overly large spaces.

The speed and consideration a designer can give to the scale of their space is both more efficient and intuitive in the personal self-centered perspective of VR in comparison to the omniscient perspective of CAD. Our final conclusion is that our research supports our hypothesis: intuitive perception of scale and other spatial relationships is easier in VR than in CAD.

ii. Hypothesis 2: A designer in CAD will intentionally create higher packing density of features within CAD. In the virtual reality environment, a designer will prefer open spaces and landscape features positioned in more in relation to the body.

Hypothesis 2 was about the spacing of elements in relation to the human body and the likelihood that having a god perspective such as in CAD would promote more cramming of elements. The premise of this hypothesis had to do with the belief that having allocentric spatial processing, or spatial processing relating object to object, would lose the human element in relating to a spatial order. In order to test this hypothesis, we looked at the way that subjects interpreted the layout of their designs.

"[This photo] is also empty. Space felt bigger when you were in it than when you were on the computer." - 5

"[There is] so much empty space. There needs more level changes in the ground. I totally underestimated the amount of space in this area..." - 10

VR Photos Commentary on Open Spaces

Supports (preference for open spaces)

Disprove (against open spaces)

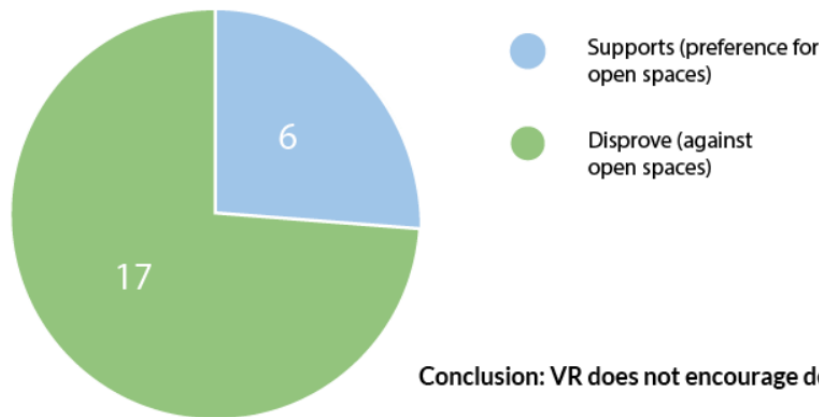Conclusion: VR does not encourage designs with open spaces.

Figure 12: Diagrams: VR Photos Commentary on Open Spaces

In the post CAD interview, six out of ten subjects said if they were to take their designs further, they would add to their design, be it trees or water elements. Once in VR, we found that line of thinking to be consistent with 23 photo comments of all 109 comments relating to critiques of

emptiness and open space. 17 of those comments were against open space while 6 of them were in support. White, no textured, empty ground was viewed in the photo commentary as something to be changed or added to with trees and water in order to 'fix' it. The six comments in favor of open space characterized the open space as allowing for a view and in Subject 3's case, an utter disdain for walls due to their blocking of the view. Thus the VR perspective actually completely overturned our hypothesis that VR with its intimate relation to the human scale would actually promote favorable choices to large spaces and monumentality.

iii. Hypothesis 3: Designers will show greater preference for abstract and geometric forms in CAD but, in VR, realistic rendering textures on 3d models will be more desirable.

Hypothesis number 3 looked to see if there was a preference for certain textures. This hypothesis came from the question of VR's suitability for abstract, no texture modeling. This formal massing design preference currently exists in CAD where material and texture is a finishing gloss on the overall form of the element instead of an inherent property of the object. Whether it is desirable to have a medium that has preference for textures versus no textures, with or without material encoding is a debate in design that has only been enabled by the design tools we use. If the modeling medium we use biases our representation of our models in a certain direction, there are consequences that manifest in our design process and our consideration of form and materiality.

I took two photos from each subject in which there was commentary as to their appearance based on materials and analyzed the amount of rendered texture and no texture in these photos. I included the sky, trees, water, and sculptures as 'rendered' texture and the white ground and walls as 'no texture'. One photo was a liked and favored photo and the other one was a disliked photo. In comparing the amount of rendered and no texture between liked and disliked photos, I hoped to demonstrate the unconscious preferences towards texture.

Subject Number	Liked Photos no. (mentioning textures)	White Space	Total Pixels	No Texture Percentage	Disliked Photos no. (mentioning textures)	White Space	Total Pixels	No Texture Percentage
1	5917	902653	1840320	49.05%	9062	1037065	1840320	56.35%
2	5278	975863	1840320	53.03%	4564	788300	1840320	42.83%
3	5378	579508	1840320	31.49%	9942	868923	1840320	47.22%
4	8548	638745	1840320	34.71%	7871	1265525	1840320	68.77%
5	5038	278924	1840320	15.16%	8917	731435	1840320	39.74%
6	3892	800317	1840320	43.49%	6444	802487	1840320	43.61%
7	7428	771824	1840320	41.94%	2970	1082428	1840320	58.82%
8	6379	797595	1840320	43.34%	6563	753704	1840320	40.96%
9	1403	793243	1848960	42.90%	3047	877171	1840320	47.66%
10	2423	535198	1840320	29.08%	3850	624671	1840320	33.94%

Figure 13: Table of Percentage of No Textured elements in Liked and Disliked Photos

In average, for the liked photos, there is 61.9% rendered texture and 38.4% no texture in the photo. For disliked photos, there is 52% rendered texture and 48% no texture. Just from the photos, there is a slightly higher percentage of rendered textures in liked photos, although the gap is but about 10%.

Texture Distribution On Models In:

Liked Photos — 38.4% No Texture, 61.6% Realistic Rendered Textures

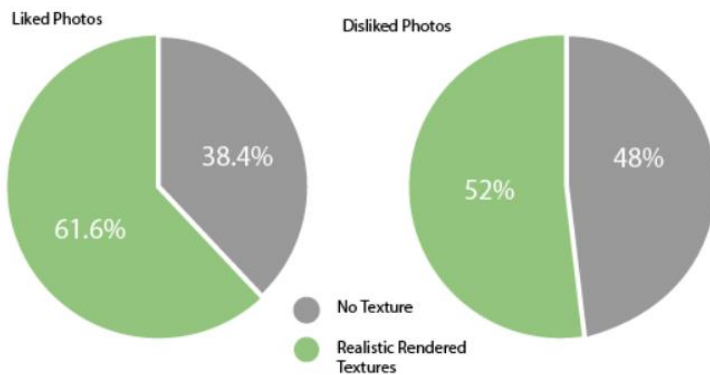Disliked Photos — 48% No Texture, 52% Realistic Rendered Textures

Photo Commentary Word Analysis:

- 13 out of 15 comments on emptiness as critiques within Disliked Photos

- 15 out of 17 comments calling for "more trees"

- 27 out of 32 comments on water calling for "more water"

- 14 out of 20 comments on wall suggesting "removal of wall" or editing the walls

Conclusion: Realistic Rendered textures are slightly more desirable than no textures when viewing in VR.

Figure 14: Diagram: Texture Model Distributions on Liked and Disliked Photos and Photo Commentary Word Analysis

Aside from the photo analysis, the photo commentary also proved illuminating. As mentioned earlier, the concept of emptiness in the sculpture garden design is in fact no textured ground. Thirteen out of fifteen comments on emptiness were negative. Out of the seventeen comments about trees, fifteen called for more trees. Other realistic rendered elements also received this treatment. 27 out of 32 comments about water called for additional or expanded water. In contrast, the no texture walls had 14 out of their 20 comments calling for either a removal or repurposing of the wall. From this photo commentary analysis, subjects suggested a desire for more realistic rendered texture elements and the exclusion of no texture walls. Thus in conclusion, I would deem hypothesis number 3 is supported by subjects slightly desiring realistic rendering textures in VR.

iv. Hypothesis 4: Designers with an architecture background training will be better at visualizing and designing immersive views that satisfy their own design intentions from a plan or non-immersive perspective than novices.

My fourth hypothesis was to compare the 3d visualization abilities between architects and novices. One would think that with architects with training from reading plans and translating them into 3d spaces that they would perform better at creating 3d views from 2d than novices. In this hypothesis, we treat the VR 3d immersion perspective as a tool to confirm their design intent.

Subject Number	1	2	3	4	5	6	7	8	9	10
Architecture/Novice	Arch	Arch	Novice	Novice	Arch	Novice	Arch	Novice	Arch	Arch
Liked Photos	7	5.5	4	4	2	2	1	3.5	5	9
Disliked Photos	2	6.5	7	9	5	8	5	1.5	4	15

Figure 15: Table of Liked and Disliked Photos between Architecture and Novice Subjects

Architects

"[The] sense of scale was far more realistic. [I] couldn't realize the actual measurements of the spaces I was designing in top view."

Novices

" I did not want to view the sculpture from this angle. I was trying to encourage the person not to look at [the sculpture] but [the trees and walls] didn't actually do anything."

Number of VR Review Photos by:

Architects

Non Architects

37.5   29.5

25.5   13.5

● Liked Views
● Disliked Views
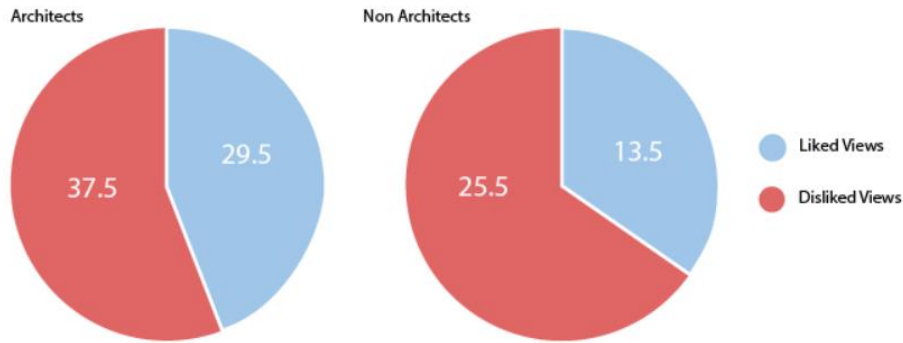
Conclusion:
Architects do not perform significantly better than Novices in visualizing 3d views from plans.

Figure 16: Diagram: Number of VR Review Photos by Architects and Novices

In total, there were four novice and six architecture subjects. By looking at the ratio of comments about views and design intention, we notices the subjects that are architects had about 56% dissatisfaction with the views they had and novices had about 65% dissatisfaction. Most of the dislike comments are along the lines of surprise and dismay over an intentional creation gone wrong. Of course, it is difficult to evaluate what constitutes a "better" view without personal prejudices. In order to compensate through this subjective evaluation, it is possible to see that there is only a small difference of nine percent between novice and architecture subjects' ability in imagining what is like to inhabit their designs. Therefore we conclude that architects slightly better better than novices in visualizing 3d from plans.

VI.   Further Research and Conclusion

Through the development of the virtual reality tool and the experiments to understand its effects as a design tool, we were able to better understand the VR medium as a method of critical creation. I believe I demonstrated viability for an architectural VR review tool as well as challenged some of the design practices enabled by CAD-space modeling.

The subjects demonstrated the fallibility inherent in different virtual representations, be it CAD or VR, and through examining their design processes, we can better understand how CAD and VR affect perceptions of scale, object relationships, materiality, and open spaces. VR naturally supports better intuitive understandings of scale and object spatial relationships, but does so in an experiential manner. CAD provides illusions to questions of scale, density, and immersion. Both no texture and realistic rendered textures can be deployed in VR, with a slight preference for realistic rendered textures. Finally architects and novices, when self-evaluating their immersive 3d spatial imagination from a plan, perform almost the same, with architects performing slightly better. These conclusions demonstrate a space for VR as a unique and worthwhile new medium for architectural design.

The experiment also allowed for some brainstorming and possibilities of future VR applications. Different subjects weighed in with the various uses of VR. One particularly interesting proposition was to design from the perspective of those who are not currently considered, such as views for children or for wheelchair users that have different lines of sight. Some found VR as a helpful tool. but not a replacement for traditional CAD modeling and there were many different opinions on its place and role in the design pipeline.

On the broader scope, the next step for this project and this research would be to evolve the VR review tool into the VR editor tool. By taking the VR proof of concept and develop it into a full

VR editing environment, we could make a more comprehensive comparison between designs in CAD and designs in VR. The beginnings of this research was interested in this possibility but the difficulties in creating flexible VR metaphors to edit space proved to be quite the challenge. One example of such a difficulty was how objects could be moved and manipulated far away from the body. The question of whether the user would have to move with the object in order to place it was one out of many object manipulating concerns. The metaphors that enable modeling would have to be reimagined for an immersive virtual reality environment. Doing so would transform design and the act of making and architectural modeling in virtual space.

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　　　July 2015. Web.

IV. Appendices

i. Subject Interview Responses and Designs

Subject 1

Architecture
CAD Familiar
VR Unfamiliar

Part 1: Design in CAD-space

Design Intention:

    Defined path to follow, assumed no water walking
    Little bottleneck areas to see where you're going with water

Further Exploration, part 1:

    More trees as space filler and path direction

Design Axonometric View:

Part 2: Virtual Reality Review

VR Ease of Use:

       Unused to Anti-Aliasing, Locomotion Easy

Total Number of Photos:

       Liked: 7
       Disliked: 2
       N/A: 1
       Total: 10

Further Explorations, part 2:

       The sculptures way bigger than expected, now that I have seen the actual…
       Different immersion than 2d or 360 renderings
       Moved with reference to choreographed movement versus free locomotion,
       VR use to check the moments when designing

Relation to Reality:

       similar movement, less focus on moving around sculptures

VR Applications

       would use if available, early in the design process

Selected Photos:
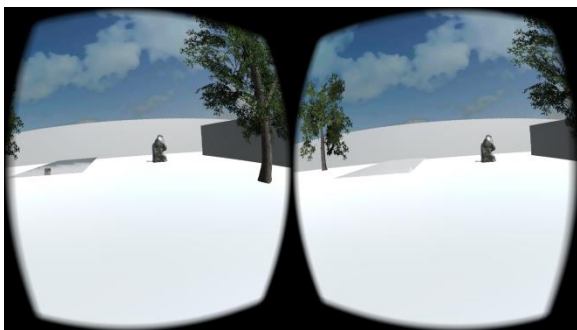
No. 9062
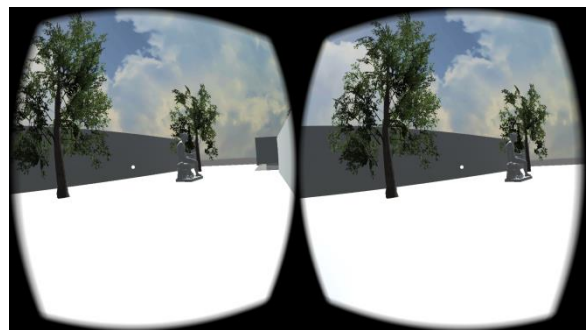
No. 10862

Subject 2

Architecture
CAD Familiar
VR Familiar

Part 1: Design in CAD-space

Design Intention:

'Miesean', bring the person in with tree line
white floor and ponds are spaced to give a viewing point for each sculpture, creating a view

Further Exploration, part 1:

playing with moving the sculptures, elevation changes

Design Axonometric View:
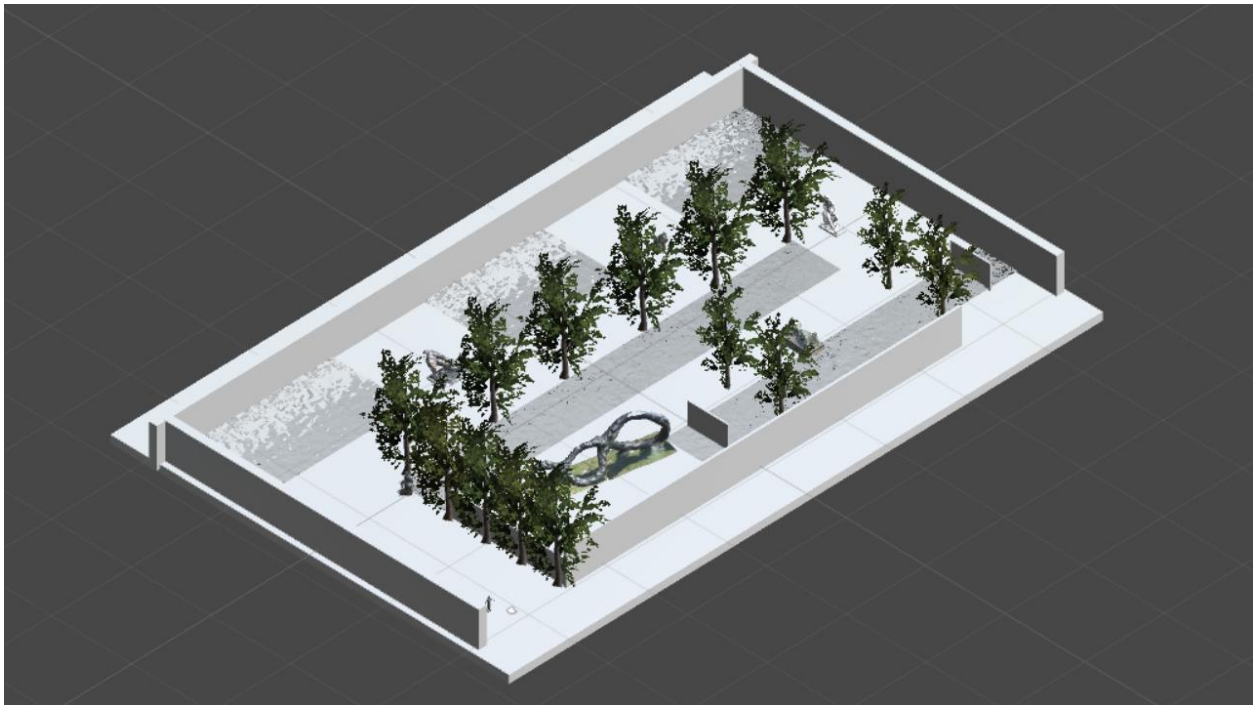
Part 2: Virtual Reality Review

VR Ease of Use:

Easy, Speed of movement could vary more

Total Number of Photos:

> Liked: 5
> Disliked: 6
> N/A: 1
> Total: 12

Further Explorations, part 2:

> nicest to look at sculptures up close,
> masterplan too far away, different approach, composition,
> designing in terms of place, primary view of the vertical plan

Relation to Reality:

> Followed circulation
> Realized going under the sculpture as a possibility

VR Applications

> manipulation within the environment, distance versus proximity, checking but after desktop design

Selected Photos:
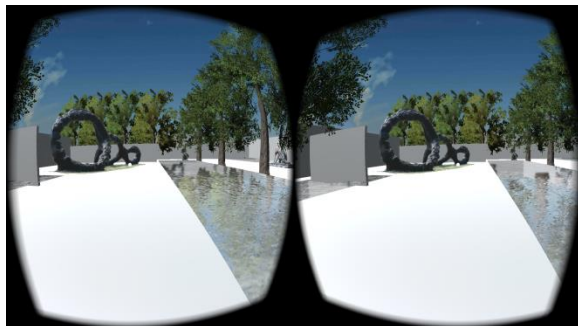
No. 4677
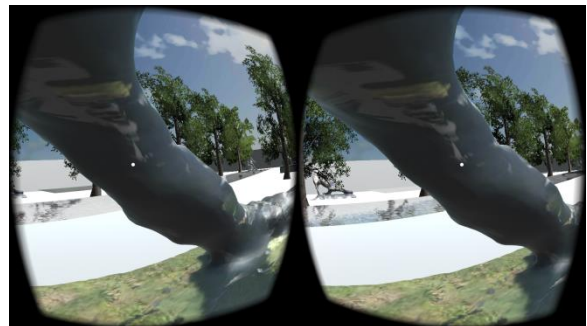
No. 5466

Subject 3

Novice
CAD Unfamiliar
VR Unfamiliar

Part 1: Design in CAD-space

Design Intention:

> Sees a predetermined order of sculptures
> Walls things off to make one path

Further Exploration, part 1:

> longer water bodies, difficulty envisioning the ground, ground too vast, cannot tell scale

Design Axonometric View:
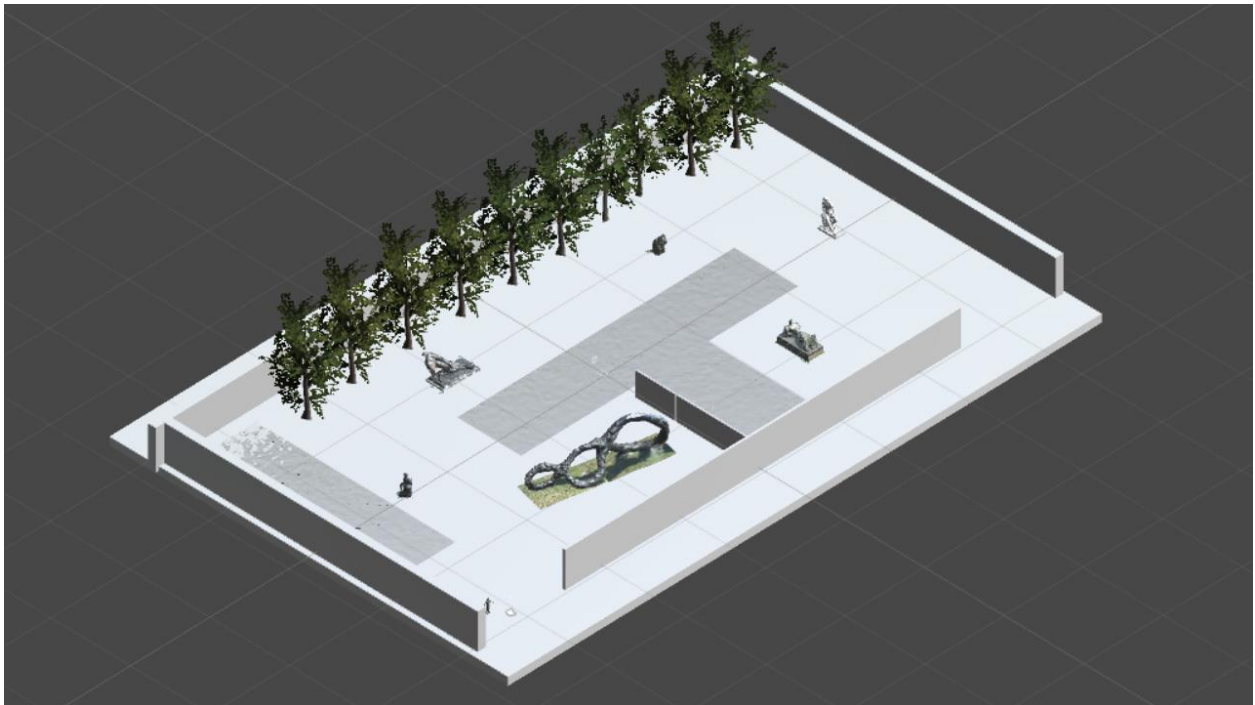
Part 2: Virtual Reality Review

VR Ease of Use:

> Easy

Total Number of Photos:

Liked: 4
Disliked: 7
Total: 11

Further Explorations, part 2:

"it's actually really useful, it's hard to envision the ground to scale, even if you put a human, it's not the same as seeing it. So I found it way more useful than seeing it from above or the scaled human. A lot of perspectives surprised me and I liked and also a lot of them were crap and I would like to redo it."

Relation to Reality:

I tried my best at the beginning... then I started thinking as an actual tourist, I would never stick to the path, to see the other perspectives, if you stay on the path it looks decent, if you don't stay on the path, looks pretty crappy. Getting off the path helped me figure out more design.
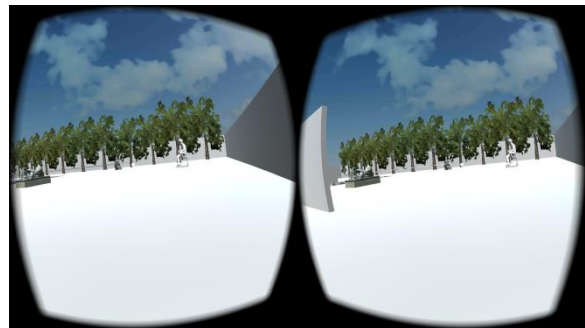
VR Applications

I imagine it is difficult to create new objects and place them down...especially in complicated modeling, but once you have the shapes, I think setting them down and designing the place would be easier in VR than just seeing it in a computer.

Selected Photos:
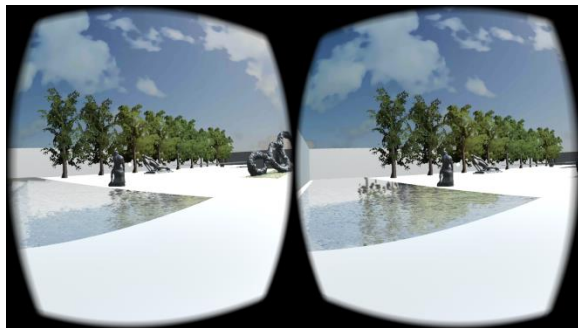
No. 5372

No. 9942

Subject 4

Novice
CAD Familiar
VR Familiar

Part 1: Design in CAD-space

Design Intention:

first outside circuit, with a slower wandering path for an inner space

Further Exploration, part 1:

Tree placement

Design Axonometric View:

Part 2: Virtual Reality Review

VR Ease of Use:

Easy

Total Number of Photos:

Liked: 4
Disliked: 9
Total: 13

Further Explorations, part 2:

viewpoints allow too far sight at certain points
enclosed space was not visually closed
question of exiting without completing the rest of the loop

Relation to Reality:

would move in the grove in real life, other movement was to see the angles
to go around with a camera to step in the grove is natural

VR Applications

"I am totally in favor of virtual reality as a design tool. I've not used it as a design tool
before, but I've talked with architects who have. I'm very excited for 3d modeling packages
for virtual reality stuff... really appreciate the affordance VR give you...cardboard... that's
more of a viewing thing... being able to manipulate stuff in 3d space without having to map
it to a 2d screen and mouse"

Selected Photos:
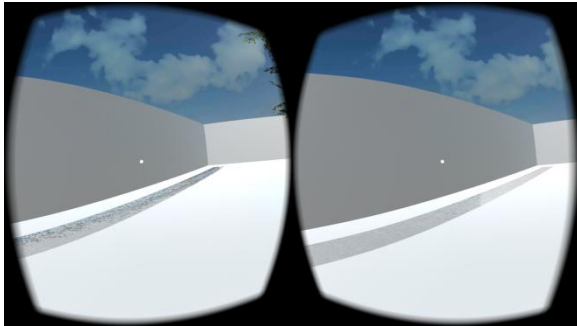
No. 7871
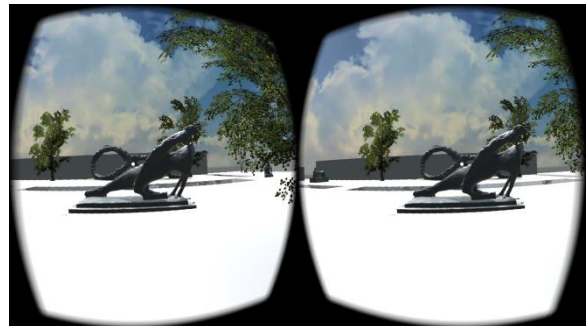
No. 8548

Subject 5

Architecture
CAD Familiar
VR Unfamiliar

Part 1: Design in CAD-space

Design Intention:

    water to block and guide background of nature, groups of three

Further Exploration, part 1:

    framing the views more, currently more open ended, the orientation for sculpture

Design Axonometric View:

Part 2: Virtual Reality Review

VR Ease of Use:

    Easy

Total Number of Photos:

Liked: 2
Disliked: 5
Total: 7

Further Explorations, part 2:

"it was helpful ... it was easier to maintain human height position and look at the different angles... it would be very helpful to look at the view... how you actually see the sculpture... very hard in unity... difficulty in panning... felt more freeing"
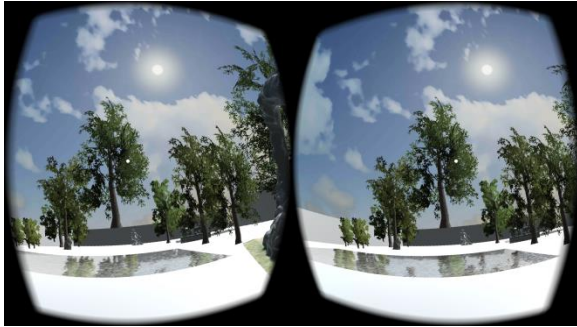
Relation to Reality:

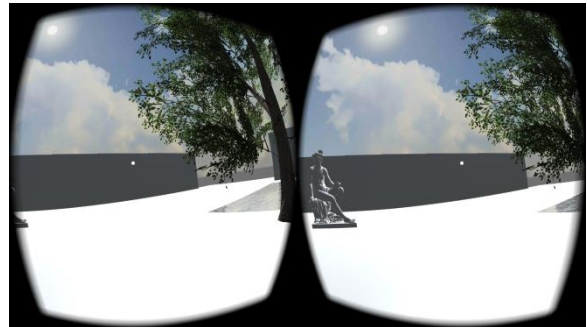intended circulation, real life not so close to the statue, couldn't back up into the statue

VR Applications

"if we were at the point, would have been nice to move the tree to move it down, but not at the beginning of the design process. VR design in the middle of the road process"

Selected Photos:

No. 5038

No. 8917

Subject 6

Novice
CAD Unfamiliar
VR Familiar

Part 1: Design in CAD-space

Design Intention:

using body of water in interesting shapes, using elements they liked

Further Exploration, part 1:

doing more things with water

Design Axonometric View:

Part 2: Virtual Reality Review

VR Ease of Use:

Easy

Total Number of Photos:

Liked: 2
Disliked: 8
Total: 10

Further Explorations, part 2:

"it was really useful to see how things were looked at from the audience perspective... this is in part due to my newbiness with Unity... but I didn't see this with my bird eye's view... in the VR perspective can see the sculptures and how you're supposed to look at them so you can see what your background is actually supposed to look like"

Relation to Reality:

"I followed it for the most part expect for when I was exiting... feeling nauseous so I cut through the trees to get to the exit... but can't say with 100% certainty, had trouble having a good sense of direction"
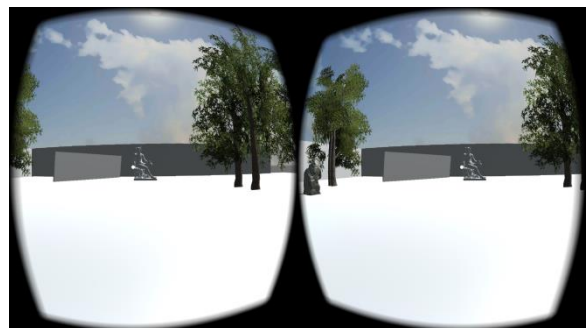
VR Applications

"I think of using it as part of the final product... the end goal is making a VR experience... I also think VR manipulation of objects is cool"

Selected Photos:
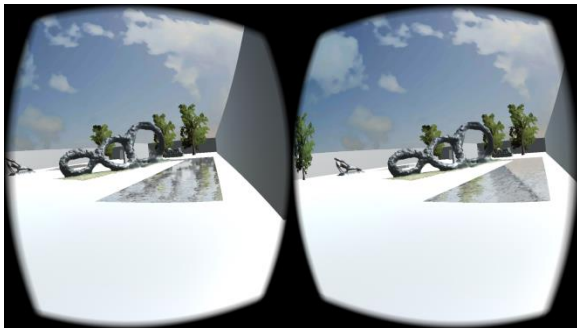
No. 3892

No. 6444

Subject 7

Architecture
CAD Familiar
VR Unfamiliar

Part 1: Design in CAD-space

Design Intention:

>   creating semi private and private spaces for the first and last sculpture, can go through
>   entrance to exit, water features in the middle serve as separations between the middle
>   statues, tree serves as a marker to go around the wall to see the last statue, general idea to
>   push to the exit and a look back to see the last statue

Further Exploration, part 1:

>   would move the wall in the middle further from the statue and another water feature

Design Axonometric View:
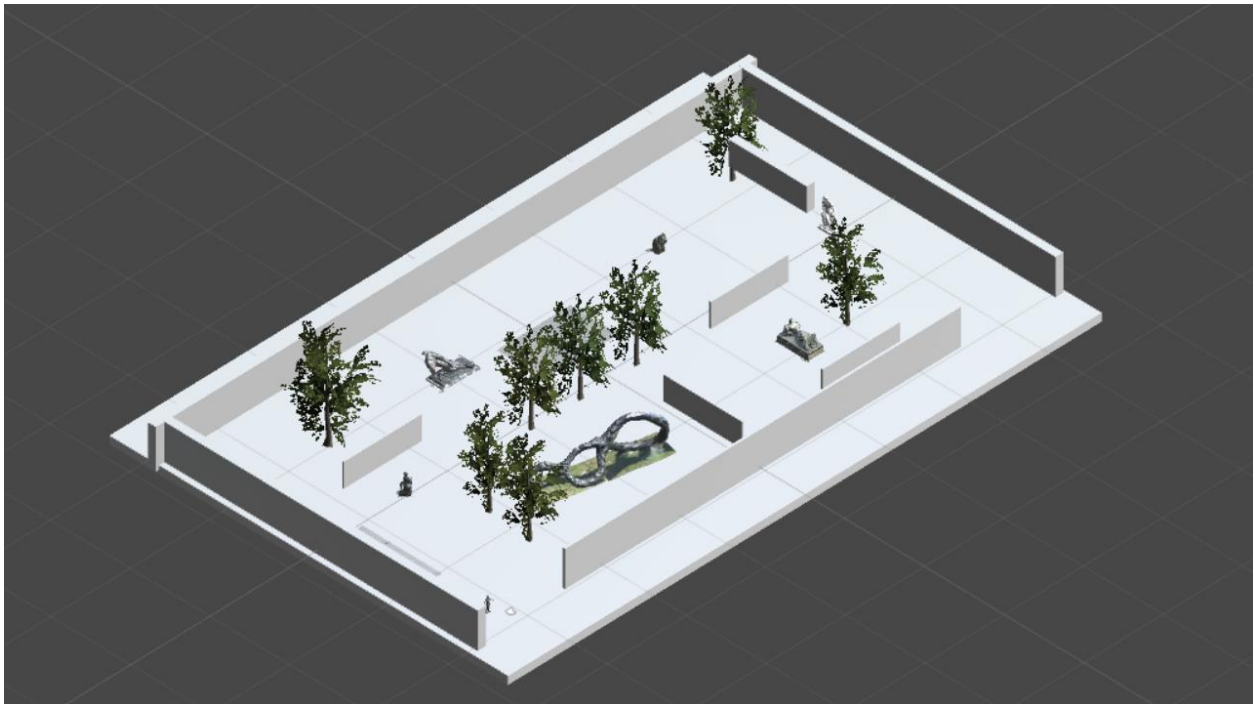
Part 2: Virtual Reality Review

VR Ease of Use:

Easy

Total Number of Photos:

Liked: 1
Disliked: 5
Total: 6

Further Explorations, part 2:

get a better sense what the sculptures were, couldn't tell from the model, get a sense of how big the trees were, mainly worked from a plan view so being able to see through the trees meant a different in density expected. Looking in reality, the sparseness without extra landscape features made it really sparse (could tell from plan but didn't notice at first)

Relation to Reality:

"yes the way I walked is the way I physically walked... not how I would walk based on my plan.. went to the blank corners first, the flaws"
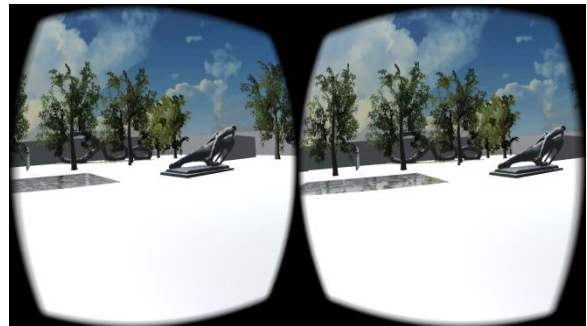
VR Applications

probably not use VR, design in 2d best way, used at the end to catch potential conflicts, whole thing in plans, sections, don't want to model in VR (relation to Revit), BIM experience, idea for it as a client tool not necessarily for design

Selected Photos:
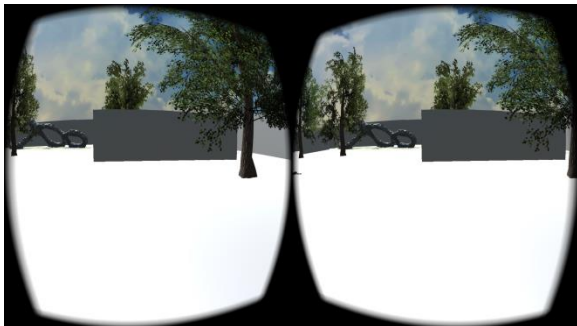
No. 6968

No. 7428

Subject 8

Novice
CAD Unfamiliar
VR Unfamiliar

Part 1: Design in CAD-space

Design Intention:

> "so I wanted the connectivity to be going through the two entrances... framed by the trees and the water...the sculptures at the forefront with the trees and the water at the back of it, surrounding the sides"

Further Exploration, part 1:

> "maybe being able to move the sculptures into different configurations...that would allow for more complex path through the garden"

Design Axonometric View:

Part 2: Virtual Reality Review

VR Ease of Use:

Easy, walking and moving head together can be nauseating

Total Number of Photos:

Liked: 3.5
Disliked: 1.5
Total: 5

Further Explorations, part 2:

"I thought it was a pretty cool way to have a 3d experience...while I was doing the garden on the screen, I didn't know it would I would have the effect of the wall and being able to see the entire garden on the right portion but not on the other side"

Relation to Reality:

yes followed the path, no reason I stayed on the path but I did

VR Applications

a really cool supplemental tool, if you want to design sees it and not goes through the fabrication, any adjustments before the final version of it

"definitely wouldn't have imagined possible a couple years ago...in terms of having motion...being able to see the trees, the leaves move or water ripples would be cool...30-40% accurate representation of what it would look like"

Selected Photos:
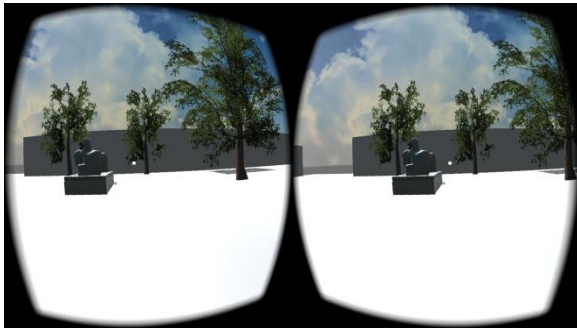
No. 6379

No. 6563

Subject 9

Architecture
CAD Familiar
VR Unfamiliar

Part 1: Design in CAD-space

Design Intention:

> "the first thing I noticed...thought of was that I had these trees... decision was to cover these barriers with trees to make it look like a garden space...make a circulation parallel to the water...that's why I made these strips...I made wider areas I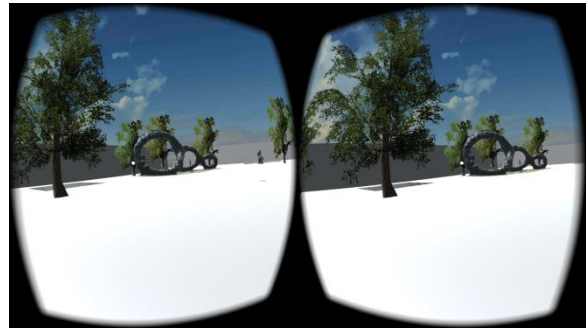 wanted to located some wider areas... some areas of water...some more central areas to related them to the sculptures. Also the entering and exiting points were very critical in this process

> *hard to envision the design without designing, process was limited by having to use the GUI and mouse controls*

Further Exploration, part 1:

> GUI to be more flexible in POV, go through the real time model, possible location and test appearance, distance between trees and walls

Design Axonometric View:

Part 2: Virtual Reality Review

VR Ease of Use:

> Easy, Controller Helped

Total Number of Photos:

> Liked: 5
> Disliked: 4
> Total: 9

Further Explorations, part 2:

> sense of scale was far more realistic, couldn't realize the actual measurements of the spaces I was designing in top view, I would redesign many parts of my design if I had the VR option

> "what would be super helpful would be able to make measurements in real space in VR, what you want to be able to control in top view is the alignment... trees add space with stuff"

Relation to Reality:

> I guess, yes, movements of turning broke the continuity...
> continuous movement to focus on what I liked or didn't

VR Applications

> with large scale projects, materials, different functions, many aspects, scale of space and context, maybe manipulating object AR would be more effective, 2d drawing still has merit, AR to navigate digital model, difficulty in commands?

Selected Photos:
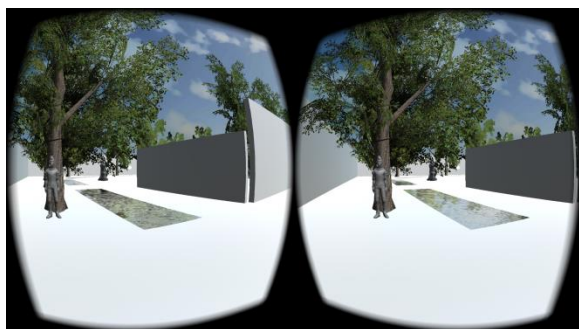
No. 1043
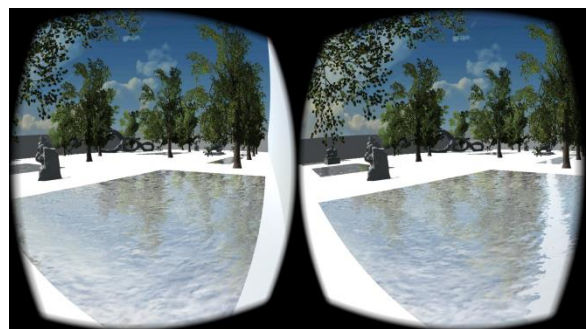
No.4329

Subject 10

Architecture
CAD Familiar
VR Familiar

Part 1: Design in CAD-space

Design Intention:

> long view and see the water, the bridge steps over the water, sees the sculpture in a controlled view, the separation of sculptures, a sculpture relaxing in a pool, creating different viewing platforms, a lot of walls intersected on purpose in order to create more interesting things with concrete walls

Further Exploration, part 1:

> view things more closely instead of in a perpendicular angle, create more personalized turns

Design Axonometric View:

Part 2: Virtual Reality Review

VR Ease of Use:

Difficulty in moving head + controller

Total Number of Photos:

Liked: 9
Disliked: 15
Total: 24

Further Explorations, part 2:

"especially when you're trying to pocket moments, actually seeing it in 3d is a lot more helpful... ground level, better sense of scale and depth ...also not a good sense of space while editing in 2d, dissatisfied with the size of objects like water features that seemed big in 2d but small in VR"

Relation to Reality:

No comment.

VR Applications

"... it's nice to take photos to know how to edit but I guess switching between 3d and 2d continuously to modifications is annoying. ideally I would push around in VR mode. "

"as a pre-rendering, you could check it out in VR... right now you have the rendering view in Rhino but it's not a full body experience. and nice to have something on human head level. Like how we design for kids... Disney designs on a whole different scale. Kid eye view! Some presets for sitting, standing… good to step into the shoes of your client, designing for special cases"

"it's really cool... if when you're trying to cut sections in our 3d model process, like on Google Street View to drop a person on the map, if we could do that when we're trying to cut our sections. drop a pin down to see... to see the what our sections are cutting"

Selected Photos:
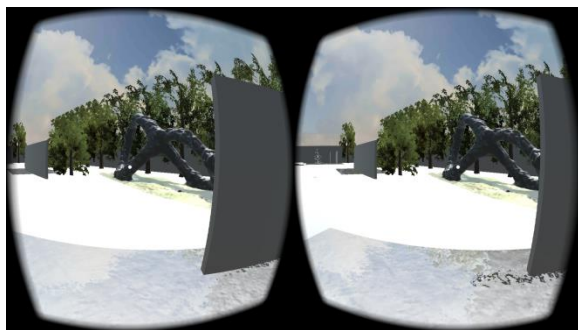
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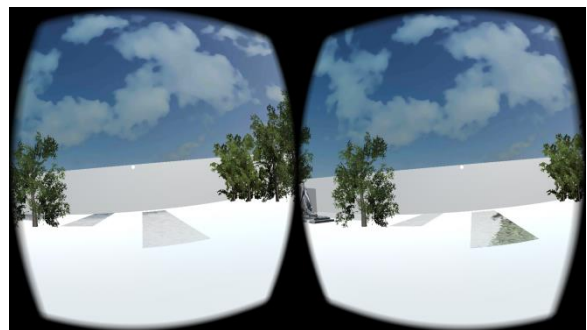
No. 3805

ii. Subject Photo Record and Commentary

Subject Number	Photo No.	Photo Commentary	Liked (L) / Disliked (D) / Mixed (H)
1	3671	liked three sculptures in the view, barriers set	L
Arch	5121	took it because of the trees, kind of in a row, looked better in VR than on top, ?	H
	5917	didn't realize it was symmetric, a surprise, a nice unexpected surprise	L
	6272	open straight back, there's water there, but open straight back, tree forward a little might be better	D
	6890	I liked that I could see the exit, but you can't cross the water, can see it but can't get there yet	L
	8536	Liked because you can see three of them, can't get to one yet,	L
	9062	Didn't necessarily like, more open but the sculpture was kind of just sitting there, not that not having surroundings is a bad thing, needs a tree or something, empty	D
	10862	think I like this because there were two trees on either side to look straight, head on	L
	12236	Looking from the exit back into the space, liked to see one of the sculptures across the water	L
	12826	same as last one, one where you could see the far one and one you could see the close one, couldn't get all three in the view	L
2	2064	I like this view, pretty successful to see statues and the wall	L
Arch	2363	thought nice for the symmetry there	L
	2510	strange human avatar character (not relevant)	D
	3157	mixed about this, nice view of the statue there, but the second half shouldn't be seen right away, had a wall along here too	H
	3527	nice view looking back to see the statues between the two pools here, wish it was bigger, fill more of that space	H
	4245	this worked pretty well with the near ground statue and the one in the distance	L
	4564	water above the ground level clipping	D
	4677	liked the view of the statue but annoyed that stuff here isn't quite lined up with when you come in, at this point you shouldn't be thinking about the path you took to get in anymore	D
	5278	the walls make a nice solid line there and the tree spills over it	L
	5466	I like the ability to walk through this sculpture, almost wished I forced you to walk through it	L
	6222	didn't like being able to where you came from, a wall here so you don't see back to the sculptures in the first half	D
	6898	maybe place a wall here to not let someone look back	D
3	5310	I hate this wall, I really like open spaces, I put the wall to corral people into one path, with the water we could do that and it feels weird to	D

		have a statue with holes of darkness behind it	
Novice	5378	I liked this, I like seeing statues over water with trees behind it, needs more foliage	L
	6218	this is me discovering I like open spaces, the garden is way better without the wall, I liked one straight body of water with statue, very French	L
	6737	I liked seeing statue across the body of water, with a nice reflection, hates the wall next to it	L
	7454	Liking statues over water in front of foliage, didn't put enough trees in other places	L
	8320	I like being able to see several statues of once with other pieces of nature in it, would be a nice view with grass, trees, more natural	L
	8950	More statues with trees and water	L
	9274	the opposite view down the water, couldn't figure out if they were centered on the ground, but would create a very beautiful symmetry	L
	9328	the pain over the wall and limits the view of the statue, only a view on the right, wished gave the statues more angles to view it	D
	9638	too much open space, extend a body of water over, more trees on the right hand side, struck me how much space there was	D
	9942	blank space, trees on the right hand side would have done so much for this	D
4	2492	nice photo but also the field of view is narrower than expected, especially in contrast to unity wide screen "I did not plan to have this stuff not visible"	D
Novice	7743	I did not want to view the sculpture from this angle- I try to encourage the person not to look at it but didn't actually do anything	D
	7871	too empty, not much there, shrunk down trees to make them look like bushes, more reasonable	D
	7985	the two statue looking at each other across the water effect was nice	L
	8548	unexpected consequence, with the trees in the back you could go back to the trees to be able to look at the other statues, the grove in the back on the outskirts	L
	8943	I took the picture to see how the sculpture looks at this angle	
	10158	One that I took to show how the reflections look...both eyes are seeing different things in the water	D
	10238	made the enclosed space even smaller because you can't see the water blocking it off at the end	D
	10433	looking like you were meant to exit out there through the closed space without going around... which was fine... a full experience... not what I originally intended	D
	10677	a great view ... you don't get to see if you go through the closed space	L
	10730	Another great view, "	L
	10880	seeing there is a full vantage of all the statues is what I was thinking when I made it but the field of view cut it down to 4-5 statues	D
	11411	I like ...the welcoming feel at the exit, can go either direction. If you completed the long loop run, it gives you one last chance to explore it. Unintentional design consequences.	L

5 Arch	3721	didn't like the emptiness	D
	4078	liked this side of it	L
	5038	liked that it looked like a forest	L
	6236	floating tree from scaling the tree	D
	7234	didn't like the alignment of the water and the tree	D
	8359	empty disjointed	D
	8917	also empty, space felt bigger when you were in it than when you were on the computer	D
6 Novice	3362	the floating tree in the sky	D
	3892	liked the water in an L around the sculpture	L
	4669	more water and trees, no frame	D
	5847	no framing	D
	6066	would like to delete the wall as it disrupted the view	D
	6444	shouldn't have put in the diagonal wall, "	D
	6700	The wall again, should not be there	D
	7383	like the placement of the water	L
	8022	view of the sculpture is not the main view	
	8662	nice background, more water, trees	
7 Arch	2970	bare corner, did not like that, would have put a water feature to fix this	D
	5058	wall is in the air	D
	6968	on this side, the wall needs something, the tree is not right, probably needs more trees or the water feature with trees, better space, relationship of bare wall to tree and the other sculpture is not a relationship	D
	7428	this one I like, the trees give some coverage to the larger one... the water...the connection to the one in the foreground	L
	9745	lacking something. the water needed to be little longer, the space between the sculpture and the water not right.	D
	11678	the sculpture facing the wall	D
8 Novice	3733	Liked the clear path and the open space	L
	4027	nice space to wander around to go into the trees, closer to the sculpture	L
	5107	show the walls block off a portion, don't know what's happening over there	H
	6379	[i like] maybe how the trees are framing the sculpture, if I did it differently, I'd add one more tree	L
	6563	this space is empty or could be more interesting, either put more distance between the trees, or put one of the long vertical water spaces	D

		to make an L shape	
9	1403	liked the picture..."it confirmed the idea I had when drawing in 2D, the line of water guiding your entrance"	L
Arch	3047	did not like, it's so empty ... this area seems to be really empty, is it because of the camera perspective or I made it that empty ... I still find it empty ... "this space is the size of the Rockefeller moma sculpture garden" "REALLY?" "is that surprising to you?" "it's about vision, not VR, about the wrong sense of scale" "when you see things...vision is full of illusion...increasing layers of what you see stuff, you increase the amount of illusion"	D
	3518	i liked this picture, layering of elements that were arranged	L
	3744	I didn't like this picture, too empty, too much concrete	D
	3865	Again, too much concrete, too empty, the distance is all wrong	D
	4329	I see a large amount of water, sky, trees, a small thin line of concrete and sculpture... I like this ... concrete and art	L
	4686	I like this picture because of the perspective it gives, all of them seem more empty	L
	5193	I disliked the previous one because it was empty	D
	5298	but I like this one, similar points of view, but less empty, sliver of space	L
10	1341	kind of like it, lots of fragments of wall, water, sculpture in the view, kind of want to move closer to explore them	L
Arch	1694	wanted a waterfall but dissatisfied	D
	1757	view next to the waterfall wall, shows fragments of various works, liked that	L
	1857	I didn't like how the statue was floating on top of the water instead of being immersed, and this side was kind of boring	D
	1964	a pocket view of passing by the wall as planned	L
	2127	nothing much here/accidental photo	
	2158	On the bridge	
	2342	on the bridge, crappy view, can kind of see other views, didn't like the empty space	D
	2423	when you peek around the wall to see hidden sculptures, to separate the view	L
	2508	didn't like this sculpture, didn't see the sculptures clearly in 2D and didn't notice the orientation, didn't look at it	D
	2746	a pocket of space, intended to have benches but ended up looking creepy, empty, a clearing without art intention	D
	2837	levitating objects, backwards view to see something to discover	
	3010	2 sculptures and a pathways and rooms	L
	3541	the 5 piece layering	L
	3672	so much empty space, needs more level changes in the ground, totally underestimated the amount of space in this area, but liked the statue reveal	D

	3805	really bare	D
	4032	extend the water further due to the statue's appearance	D
	4241	liked the landscaping and the pier	L
	4383	corners dull and awkward empty space in the garden	D
	5038	elevated pier, looking at the statue perspective new is nice	L
	5572	on the way out you see the statue as a buffer to the space, saying bye to you	L
	6048	you see fragments to look back and a completely different view from when you came in with statue reveals	L
	6231	bench area, where you can eat a sandwich, where you would nap	
	6269	zen resting area with an extra program, before you leave, viewed it as a separate area from the sculpture garden	
	6353	bench intended to wait for uber	L
	6398	ideally no sculptures, the wall to block the view	H