Using Virtual Reality as a Design Input: Impacts on Collaboration in a University Design Studio Setting

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Abstract: The use of immersive virtual reality as a design input tool has the potential to dramatically alter the way students approach the design process by providing students with improved spatial understanding of their design decisions. This paper presents the findings of a case study examining the use of immersive virtual reality to assist landscape architecture students in designing a micro park. The results of the study found that students found virtual reality to be a powerful design tool for helping them understand their design decisions and enabling them to rapidly prototype their design ideas. However, issues of scale and fidelity presently limit the ability to implement the use of immersive virtual reality as a design input tool in a widespread manner.

Keywords: Virtual reality, design process, technology

1 Background

This research evaluates the potential of immersive virtual reality (VR) to enhance the design process of landscape architecture students. Understanding the three-dimensional impacts of design decisions can be difficult for students, who are accustomed to working two-dimensionally on paper or computer screens. Even when working with digital 3-D models, students must work through multiple filters: the 2-dimensional nature of the display, working on a design from an external perspective, managing camera angles, and conforming to the constraints of modeling software. As a result of these constraints, students will often begin prototyping their designs 2-dimensionally before transferring design concepts to a 3d modeling program at a more advanced stage in the design process.

Immersive VR provides an opportunity to design in 3-D from the very beginning of the design process, unencumbered by many of these filters. Using immersive VR, students can digitally work in-situ, freely and intuitively expressing their design ideas. We theorize that utilizing VR will improve student's design abilities by fully immersing them in their design and providing greater spatial awareness.

2 Literature Review

Many definitions of virtual reality are put forth in the literature; however, for the purpose of this research, we utilize CASTRONOVO, NIKOLIC, LIU & MESSNER (2013), who define VR as computer environment that provides a "convincing illusion and sensation of being inside an artificial [digital] world." Such an illusion of reality has been attractive to researchers as a valuable way to visualize the complex concepts associated with landscape changes and design proposals (HORNE & THOMPSON 2008). In addition to defining VR generally, we also need to differentiate between semi-immersive and immersive VR. For the purpose of this

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research, semi-immersive VR is an environment in which the user is not fully surrounded by the virtual world, either visually, audibly, or physically, or the user is not able to actively interact with the virtual reality. An example of semi-immersive virtual reality would be a virtual reality theater, with imagery from the virtual world projected onto multiple screens in front of the viewer only. In this research, we define immersive VR as a computer-mediated environment in which the user is fully surrounded visually, audibly, and physically and in which the user is able to interact with and manipulate the virtual world (SLATER & USOH 1993). Immersive virtual reality is not simply the passive viewing of a simulation, but rather is an engagement of the senses and an interaction between the imagined world and the user (GRAU 2003). An example of immersive virtual reality would be a computer-connected VR headset.

Design education programs have utilized VR for several decades, mainly in the form of a semi-immersive VR theatre, comprised of a series of screens upon which a virtual world is projected. The large majority of VR research in the design fields focuses on utilizing VR as a comparatively passive viewing platform to assist in visualization, rather than design creation. In their review of VR research, PORTMAN, NATAPOV, and FISHER-GEWIRTZMAN (2015) noted that the use of VR in landscape architecture has focused on visualizing landscapes. In their assessment of VR research in the field of architecture, FREITAS and RUSCHEL (2013) found that while nearly half of published research considered the use of VR in some stage of the design process, nearly all examined VR as an evaluative tool.

CASTRONOVO et al. (2013) found that VR systems were effective tools for evaluating designs with immersive and semi-immersive systems because of the wide field of view and a perceived high level of immersion by the user. BULLINGER, BAUER, WENZEL, and BLACH (2010) successfully used a series of semi-immersive VR-based “evaluation sessions” to evaluate a design at several different stages in the design process in order to positively impact the design outcome. Immersion in VR also extends to human interactions, as DUNSTON, ARNS, and MCGLOTHLIN (2011) found that VR enables users to experience and assess all aspects of a design by virtually interacting with design elements. GU, KIM, and MAHER (2011) concluded that VR was effective for digital collaboration when used in non-immersive manner.

VR’s ability to improve spatial awareness is noted by several researchers, including CASTRONOVO, et al. (2013), RAHIMIAN and IBRAHMI (2011), and PORTMAN et al. (2015). GEORGE (2016) found that immersive VR provided students with sufficient spatial awareness of a site to accurately conduct a site analysis. However, when utilizing a semi-immersive VR system, BULLINGER et al. (2010) questioned whether the spatial experience was sufficient for making design evaluations. Furthermore, GILL and LANGE (2015) criticize the use of VR for separating designers from the actual site, potentially creating false spatial impressions and conflicting interpretations (LANGE 2011).

CHAMBERLAIN’S (2015) work comes closest to designing in VR by utilizing gaming applications to enable students to create fictional urban landscapes, but overall the present body of research does not provide an example of truly immersive design within VR. However, the research demonstrates the value of immersion and interaction in VR, both of which should be valuable to a student utilizing VR for design creation. We believe the immersive spatial-component can make VR a valuable mechanism to facilitate the ability to design.

3 Methodology

This research was conducted in a landscape architecture studio (n = 29) focused on recreational design at a public university. The cohort was primarily composed of third-year undergraduate students (n = 24), with 12 male and 12 female students. There were also two male and three female graduate students in the cohort. A qualitative case study approach was utilized in this study (YIN 2008). Within collaborative groups, students used an HTC Vive immersive virtual reality headset and the 3-dimensional drawing program Tilt Brush to design a micro-park in virtual reality. The design brief for the park drew inspiration from the Park(ing) Day movement, wherein parking spaces are temporarily repurposed as an urban micro-park. The site for the park was flat, and included a 3d model of several parking stalls and a car.

Students worked in teams of five to six students to create several design concepts. Each student used the headset for approximately 20 minutes to create a single design concept, while his or her peers monitored the design progress on a large monitor and vocally offered input on the design. The researchers recorded video as the students worked to analyze the discussion of the students in order to identify the specific affordances and constraints of using VR to design, and the impacts VR has on the design process. Following the design project, a semi-structured reflective discussion was held to explore the adjustments that students perceived making to their process as a result of using VR, their general reactions to utilizing VR to design, and their self-assessment of the efficacy of VR in their individual creative/design processes.

4 Results

Several key findings resulted from this study. First, the learning curve for the students was surprisingly accessible. The most difficult part for students was changing their mindset that drawing does not have to happen on a flat, 2-dimensional plane, but that they could draw on any axis. Students found the actual act of drawing, utilizing the hand controllers, to be intuitive and easily adopted. This is because the motion of drawing with the VR controllers is very similar, if not identical, to physically drawing – save a lack of the tactile feedback of pencil on paper – and the highly accurate motion tracking of the VR controllers accurately reflected the gestures of the students, and enabled the students to be highly precise in their drawing. The most difficult part was mastering the program interface, but nearly all the students reported that they were comfortable with the interface within a couple minutes of using the software.

Secondly, the students reported that collaborating on a design was less effective than hoped, primarily because the students outside the VR could only verbally communicate with the student in VR. The student designing in VR then had to confirm feedback from the group verbally and by focusing their gaze and gesturing within the VR, which could then be observed and confirmed by the remainder of the group.

Working in VR had several impacts on the students' design process. As expected, students reported that they were more cognizant of how their design decisions impacted the three-dimensional space. They observed that being able to quickly assess this was an improvement over the development of design iterations in 2-D, or the use of 3-D modeling programs on a computer. Students believed they had a greater freedom of expression working within VR and that working immersively led them to think about their design more holistically. Overall, students responded positively to using VR and would, if available, utilize VR to design with in the future.

5 Discussion and Limitations

The findings of the study suggest that VR could have a significant role in the future of designing physical places. The findings of this study confirmed that the improved spatial comprehension of VR in evaluative exercises identified by previous research extends to design-creation tasks. Designing in VR made students more aware of the spatial impacts of their design proposals and provided serendipitous moments where they recognized design opportunities because of the 3-D nature of their work that would have been less apparent when working 2-dimensionally. VR also had the apparent benefit of reducing the cognitive load on students by simplifying 3-D design, as the students had to exert less mental energy extrapolating their design ideas from 2d or working through the filters of traditional 3d modeling. As a result, the threshold for 3-D designing is significantly lowered by VR programs that accurately mimic the natural gestures of drawing. The ability to rapidly prototype a series of design concepts and iterations in one-to-one scale while immersed in the space can potentially provide students with a powerful way to essentially design in-situ. Such a transition could fundamentally transform the design experience.

Being able to design while spatially immersed can facilitate and encourage students to design three-dimensionally and to better evaluate the impacts of their design decisions in the early form-giving phase of design. This benefit was born out in many of the students' comments, in which they mentioned the benefit of VR in making them "much more aware of the space between the elements and the space they took up." Other students noticed that being in VR felt like being on a site and that they could design "by feel on the site" and they were able to "quickly create ideas to support what you are imagining in your head." One student even experimented with mixed-reality by having her peers place a stool in the location where she had created a bench in VR, in order to enable her to physically sit on her bench and experience her design from that perspective. Such on-the-fly designing in-situ particularly highlights some of the powerful affordances that VR can bring to the design process.

However, the current tools available are limited in their level of fidelity, meaning that VR designing is best suited to early conceptual design phases, and not for more refined or precise designing (Figure 1). Students complained of an inability to accurately measure distances and objects within Tilt Brush, which made it difficult to refine their designs to the level of precision necessary for a final design or for the creation of construction documents. Students also found that, while they were able to draw with a high degree of accuracy, they found the program tools limited their ability to graphically refine their design. Thus, while students found it easy to rapidly iterate design ideas and assess the feel of their designs using Tilt Brush, being able to quickly create a series of *partis* in VR, they found it unrealistic to advance those designs to the more refined stages of presentation needed in the later stages of the design process.

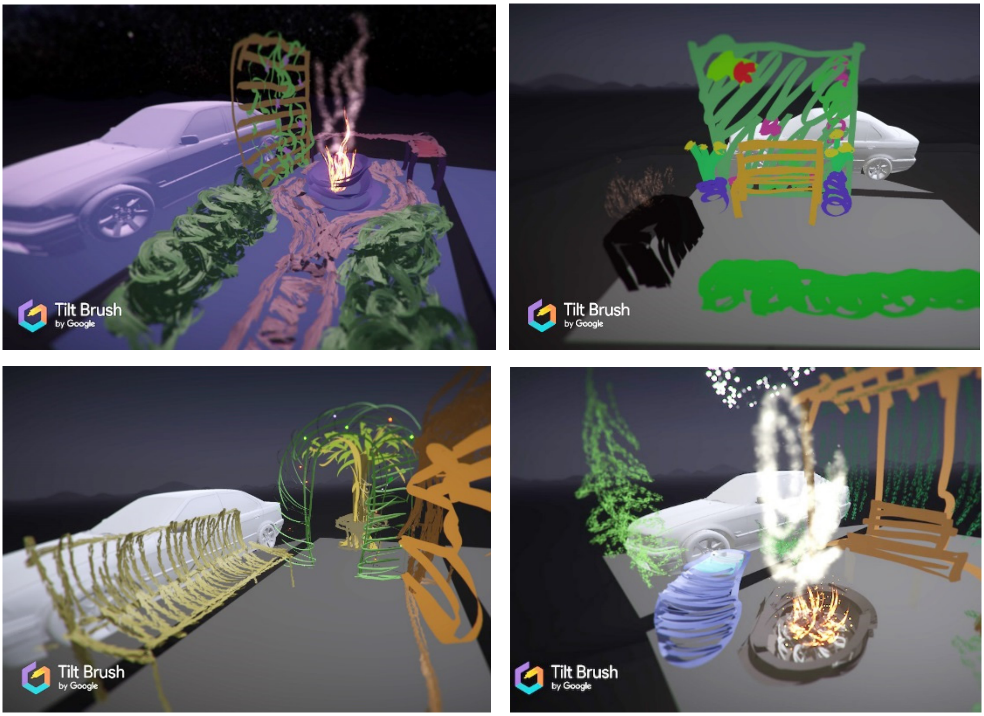

Fig. 1: Examples of the various design solutions explorations created by the students

Associated with this is the question of whether the use of VR constrained the students in their design decisions because of the nature of the technology. In this study, the students did not report such constraints to their thinking or process, and the broad array of design solutions created by the students suggests that the medium is quite versatile as a design tool. This is due to the open and flexible nature of Tilt Brush, which relies on fluid brush strokes as an input, as opposed to pre-set models or limited tool sets, which may constrain a student's design process and lead them to impose self-limits in their design process. However, because the students utilized immersive VR in the early, conceptual part of the design phase, the potential for students to self-limit while using the medium to design may not be fully apparent.

However, the ability to design while immersed within the design enables students to better understand their design decisions, and could enable students to advance to refining their design concepts more rapidly, but additional research is needed to assess if this theoretical benefit is borne out. Additionally, the tools utilized in this study would only be suitable for smaller sites. Multi-scale 3-D modeling programs are available (such as SculptrVR) that may enable the design of larger sites, however, additional research needs to be conducted to assess the effectiveness of designing in VR on larger sites. Sites with significant grade changes may also be challenging to design using current VR software, however nothing about the technology itself would preclude the use of VR as the software advances.

Additionally, within the VR design exercise, the VR technology presented some obstacles to group collaboration. The inability of all the students to interact simultaneously in the same space within VR caused some frustration, as the student in VR had to attempt to incorporate modifications suggested by their teammates by drawing based on the vocalized verbal descriptions (Figure 2). Simultaneously, it was frustrating for the students outside the VR because they could not simply take control of the input devices and visually demonstrate their ideas, but instead had to rely on their ability to describe their ideas verbally. In this way, the collaboration was hindered by a limited horizon of observation (HUTCHINS 1995), where the group was not able to adequately observe each other's work, and therefore had difficulties learning from each other's ideas. This finding runs counter to the conclusions of GU et al. (2011) and CASTRONOVO et al. (2013) that VR adequately scaffolds collaboration. However, it should be noted that neither of those studies utilized a VR headset, as in the study described in this paper.

Fig. 2: One student uses the immersive VR (left), while the others watch on a large monitor (not pictured) and offer verbal feedback

This experience runs counter to the acculturated practices of visually expressing and exchanging design ideas within the traditional design studio. Currently, traditional collaborative environments appear to be more effective for concurrent expression and exchange of design ideas. Consequently, in its current state of development, designing immersively may be best suited as an individual pursuit. However, this constraint did have an unforeseen benefit, as students were forced to vocally describe their design ideas in a precise manner in order to communicate design concepts, a skill students often neglect to adequately develop when they rely primarily on visual communication techniques.

Lastly, technical challenges to utilizing VR were also observed. The first is the technical proficiency required to operate the system. While the use of the VR itself is inherently intuitive, properly setting up and calibrating the equipment does require expertise, especially troubleshooting the devices. The amount of space required for operation of the VR must also be considered. The HTC Vive device utilizes room-scale tracking, meaning that its user is able to physically walk around inside the VR space. While this mobility was beneficial for 3-D drawing, it requires the dedication of an approximately 5 meter by 5 meter space, free of physical obstructions. Additionally, because the VR headset tracks its position in space using synched infrared emitted from a pair of base stations, reliably operating multiple VR headsets within 15m of each other without disrupting the tracking of the headsets is not possible, unless a physical barrier is erected.

6 Conclusion and Future Research

This study examined the use of VR during the concept development phase of the design process. Instead of using VR as a design-review device, students successfully utilized the technology for design-development. The proven efficacy of VR in this role, combined with the dramatic decrease in costs for VR headsets, suggests that VR could play a more prominent role throughout the design process. However, the success of this research highlights the need for future research on the use of VR in design generation. Further work is needed to develop the ability of students to effectively share the VR space while designing. This ability to interact within VR will be critical not just for collaborative designing, but also for critiquing of work by faculty, clients, and the public. Future research should provide a comparative analysis of the effectiveness of various VR software and systems in promoting facilitating collaborative design and assessing how VR technology can overcome existing challenges to design larger landscape. Research also needs to be conducted on the perception of scale within VR and if designers are able to accurately design to scale within the medium. Finally, research is needed to assess the impact of VR on the design process and the impact that it has on not only the design process, but also the impact on the quality of final design outcomes.

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