4-2019

Initial Evaluation of Accessibility and Design Awareness with 3-D Immersive Environments

Nicholas Rosasco
Valparaiso University

Alex Kaariainen
Valparaiso University

Jeffrey Will
Valparaiso University

Initial Evaluation of Accessibility and Design Awareness with 3-D Immersive Environments

Nicholas Rosasco* and Alex Kaariainen** and Jeffrey Will**
*Department of Computing and Information Sciences
**Department of Electrical and Computer Engineering
Valparaiso University
Valparasio, IN 46383
(219) 464-5193
nicholas.rosasco@valpo.edu alex.kaariainen@valpo.edu jeff.will@valpo.edu

ABSTRACT

This paper describes an effort to build and evaluate the effectiveness of an immersive 3-D visualization system to help increase the awareness that students have when designing software that has a high level of accessibility for the differently abled. The demonstration utilizes an immersive virtual reality (VR) environment in which we simulated two types of colorblindness in a generally familiar environment. We report on the initial trial of this tool and the results of student surveys designed to assess impact on student perception and understanding and demonstrate that the use of virtual environments can give students greater empathy for individuals with visual impairments.

INTRODUCTION

In the United States, the Americans with Disabilities Act (ADA) [1] and subsequent legislation defines a statutory requirement for accessible software in the private sector. Further regulations, including Section 508 [2], bolster these expectations for software and systems provided by the national government. Similar legal and regulatory structures exist in multiple jurisdictions, as shown through the European Accessibility Act, various Japanese regulations [3], and laws found everywhere from Europe to the People’s Republic of China, among many others. Globally, this standard is so general an expectation that an index for policies covering web-based systems alone is maintained by the W3C [4].

This legal expectation is paralleled by curricular, ethics, and policy guidance provided by and for the computing disciplines. The ACM/IEEE CS2013 [5] curricular framework provided by the combined professional and academic computing community includes multiple mentions of accessibility concerns. It is a foundational, core/tier one topic in “Human Computer Interaction”. Knowledge in this topic is also noted as a tier two area under the Social Context heading. Specifically, CS2013’s expectations on developer assumptions and accessibility are found in “SP/Social Context”: “Identify developer assumptions and values embedded in hardware and software design, especially as they pertain to usability for diverse populations including under-represented populations and the disabled.” Related concepts can also be found in the sections for “HCI/Foundations” and “HCI/Designing Interactions”:

• Define a user-centered design process that explicitly takes account of the fact that the user is not like the developer or their acquaintances.

• Discuss why human-centered software development is important.

• For an identified user group, undertake and document an analysis of their needs.

This doubled imperative – legal and professional - creates a need to effectively impart the significance of these requirements and expectations upon the students. Unfortunately, it is understood that not all topics listed may be covered, as detailed in the CS2013 “Principles” discussion as well as the Chapter 4 introduction.

In order to make the most of the time available, it may be possible to combine these areas with additional learning objectives. Specifically, these can be linked to the overall importance of design as a way to anticipate and solve problems. By doing this, the need for accessibility awareness can be articulated as functional and non-functional requirements. In turn, these requirements can be discussed as needs that must be met for any software or system a student may build as a working professional.

By recasting this issue into the context of an expectation, it is possible to concurrently touch on multiple CS2013 sections that refer to the design process, particularly with reference to user interfaces, including:

- Explain how user-centered design complements other software process models,
- Choose appropriate methods to support the development of a specific UI, and
- Use a variety of techniques to evaluate a given UI.

This also provides an opportunity to make this expectation a habitual, as opposed to an occasional, consideration – and to link it to good design generally. Similarly, the importance of effective design is emphasized both in the curricular guidance - and in the commonly accepted guidance for software engineering practice. While the fines or repercussions of failing to provide the differently abled will vary by jurisdiction, the use of software engineering solutions at the design stage is general. Similarly, the convention is that a mistake made becomes an order of magnitude costlier with each subsequent round (design, implementation, test, etcetera) in general [6][7].

BACKGROUND, CONTEXT, AND MOTIVATION

Various studies, including significant recent work from ongoing projects at Stanford [8][9][10], provide evidence that virtual reality environments can be used to foster empathy and understanding . Additionally, previous scholarship in teaching computer science and software engineering provides numerous examples for the teaching of accessibility issues, and fostering awareness [11]. Much of this instruction is placed in the context of a human-computer interface or other specialized elective course. The work of Shinohara et al illustrates that this is a general pattern for this topic across the United States [12]. This could imply that, for institutions without an accessibility specialist, or with the ability to offer limited electives, this topic is at risk of neglect. The same study indicates that curricular integration was still a central issue. To help meet this need to increase the awareness of accessibility issues, it was decided to add a CAVE system to the collection of examples and tools used for teaching this topic.

To meet that need, a project at Valparaiso University simulated two types of colorblindness in a generally familiar environment. We then used a student survey to assess the impact on the student’s perception and understanding and demonstrate that the use of virtual environments can give students greater empathy for individuals with visual impairments. The project sought to incorporate these objectives into a session that could be incorporated into required courses. This was considered especially important as the size of Valparaiso's program dictates a smaller breadth of electives than what would be available at a larger institution or from a larger department. It was felt that the best possible presentation would put the inclusion of accessibility into a larger narrative. By linking accessibility to design, and by making designing for accessibility a preemptive solution that could prevent an expensive retrofit or required corrective re-release, a narrative showing the power of thinking ahead can be built.

The project described and explained in this paper is intended to see if a memorable and suitable moment in a classroom can be built to accommodate those background factors. The expectation is that the use of an atypical technology can create an understanding and impression that can impact a student's thinking about design and accessibility. That experience was be built around colorblindness.

Colorblindness was chosen as a consideration to address because it is an issue found in a significant part of the general public [13], occurs in varying degrees, and is not externally apparent that someone has the physical issue [14]. For example, the National Eye Institute [13] notes that, "As many as 8 percent of men and 0.5 percent of women with Northern European ancestry have the common form of red-green color blindness." Also, in the United States during 2005, it is estimated that 1 percent or about 1.46 million men suffer from deuteranopia [15]. For the purposes of classroom use, this makes it likely that every student may either have or have a close connection to someone with this condition. Two forms of the condition, protanopia and deuteranopia, were chosen for demonstration and simulation. They are commonly referred to as red-green color blindness [13][16].

METHODOLOGY

Valparaiso University's Electrical and Computer Engineering Department owns and operates a commercially available CAVE Virtual Reality System ("VisCube") environment developed by Visbox, Inc [17]. This environment can immerse six to eight people simultaneously and is thus effective as an educational tool. The four displays are merged to create a seamless 3-D environment that makes use of the entire space, including the floor as well as the three front facing walls. This creates a similar experience to that of the more popular head mounted displays (HMDs).

For this project, protanopia and deuteranopia were simulated via a post-processing effect [18] using a 3D look up table (LUT) in the Unity Engine [19]. Three unique post-

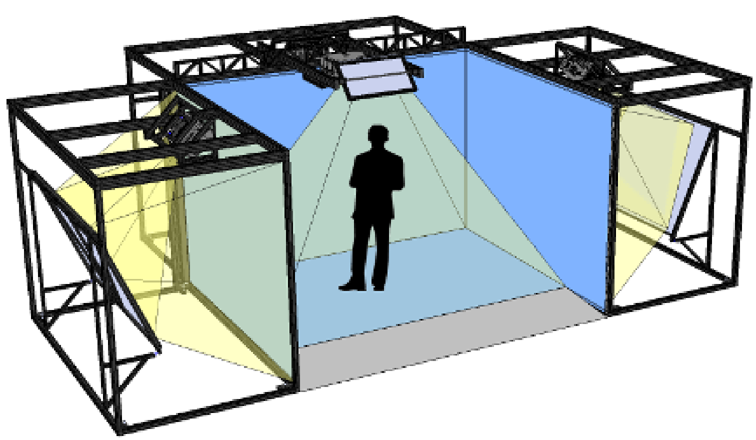

Figure 1: VisCube 3D Cave Environment [17]

processing profiles were used, two that illustrate colorblindness, the third for the 'unaltered vision mode' because various visual improvements were still necessary such as anti-aliasing and ambient occlusion. Switching between these three configurations, which can be triggered with a remote control, allow at run-time swapping between the post-processing profiles. Both instructor and students share the same VR experience. This quick-change capability, combined with a brief discussion meant that 24 students - a standard section size at Valparaiso University - were able to have an immersive and educational experience in the space of a 50 minute 'Carnegie hour' class period.

To test the impact of this exercise, Institutional Review Board approval was sought to use a pre- and post- exercise survey on current students as test subjects. For this initial study, students in the 'Seminar in Professional Practices' course were the participants. This course covers topics such as ethics, computing's impact on society, and other questions related to professional and academic practices. It is traditionally taken by upperclassmen, many of whom have had REU or internship experiences and most of whom have spent significant time developing software. Some students had participated in some initial rollout exercises of this same configuration, so had seen an earlier pilot edition of the overall sequence and presentation. For this initial trial, 14 students, approximately three quarters of a graduating class for Valparaiso University's Computer Science program, participated. For the first trial of the system and lesson, a set of pre-survey questions was given to the participants. As the development of this suite involved some exposure to the tools prior to the first structured, intentional test, a question about for prior experience was included. After that check and a request for explanation, the following questions were posed:

- Have you experienced simulated or actual colorblindness previously?
  (The remaining questions include Likert-scaled responses.)
- Your awareness of the need to consider colorblindness when designing software and systems. *
  1/Not at all aware, 2/Slightly aware, 3/Somewhat aware, 4/Moderately aware, 5/Extremely aware
- Your awareness of the need to design software and systems for the differently abled, in general (not just for colorblindness). *
  1/Not at all aware, 2/Slightly aware, 3/Somewhat aware, 4/Moderately aware, 5/Extremely aware
- Do you regularly consider the needs of the differently abled when coding or building applications?
  1/Never, 2/Rarely, 3/Sometimes, 4/Often, 5/Always

(Questions marked with an asterisk at the end were posed before and after the exercise.)

Once a group of students had completed the pre-survey, we asked them to accompany the instructor and enter the VisCube to immediately begin the demonstration. The demonstration begins in a rendering of a gymnasium. Various attributes were intended to create emphasis of color. For example, a basketball and a soccer ball were placed on the gymnasium floor as their colors are something that is familiar to most students. The first switch from 'unaltered' mode to each of the colorblindness modes was done in that space and used to start a conversation about perception. During the demonstration, the instructor leads a "walking and talking" discussion. The instructor then leads the group into several spaces configured for various STEM disciplines which are used to illustrate some challenges colorblind students may face in the classroom. For example, while in the chemistry classroom the instructor makes a point of the periodic table poster which relies heavily on color to convey various information. Then, several discussion questions – with the system set for the less and then the more challenging degree of colorblindness – are posed to move the discussion to a close. The final set of questions reframes the issues the students had have reading a specific item, the periodic table, as a factor in a high stress/high stakes situation like a test. The discussion is concluded as the group returns to the starting point, leaving the demonstration ready for the next group.

Students were then asked several questions as a post-survey and again asked to respond on a Likert scale:

- Your awareness of the need to consider colorblindness when designing software and systems?
  1/Not at all aware, 2/Slightly aware, 3/Somewhat aware, 4/Moderately aware, 5/Extremely aware
- Your awareness of the need to design software and systems for the differently abled, in general (not just for colorblindness).*
  1/Not at all aware, 2/Slightly aware, 3/Somewhat aware,4/Moderately aware,5/Extremely aware
- Will you regularly consider the needs of the differently abled when coding or building applications?
  1/Never, 2/Rarely, 3/Sometimes, 4/Often, 5/Always
- Did the immersive experience in the VisCube visualization system increase your knowledge of the need to build software with this issue in mind?
  1/No impact on me, 2/Minor impact on me, 3/Neutral, 4/Moderate impact on me, 5/Major impact on me
- Do you think you'll remember this experience longer term?
  1/Never-No, 2/Probably not, 3/Occasionally-Sometimes, 4/Lots-Usually, 5/Always-almost always

They are also given two additional comments that allow for more general comments and feedback:

- Any other comments or observations, generally?
- Any thoughts/observations on the demo, specifically?

RESULTS

Our initial trial included 14 student participants. While this is a somewhat small number, it approximates a graduating class from the Computer Science programs at Valparaiso University. Our sample population included some students with prior direct or indirect exposure to this demonstration for various reasons. To simplify conduct of the experiment, and to have a more reasonable sample size, these students were both identified and left in the aggregate data below. Additionally, a prerequisite course currently incorporates some mention of this in a lecture or two. Even allowing for this prior awareness, the results show a general strengthening of student awareness.

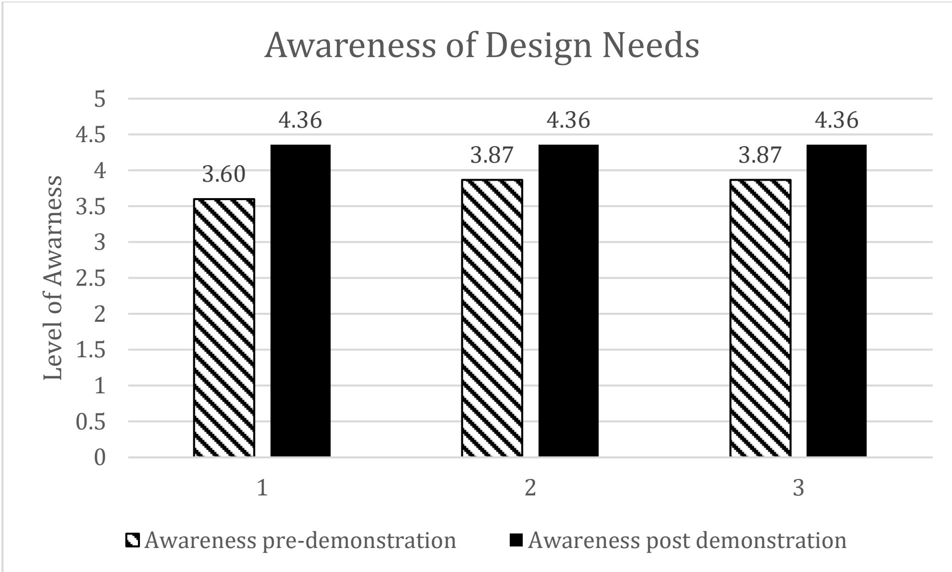

Figure 2. The three categories are the polled class's self-recorded awareness for the need to consider a topic. Categories 1's topic was 'colorblindness when designing software'. Categories 2's topic was 'Differently-abled in General'. Categories 3's topic was 'Differently-abled when building software applications'.

Table 1. Average Scores – Immersion and Recollection

Question	Average Score
Did the immersive experience in the VisCube visualization system increase your knowledge of the need to build software with this issue in mind?	3.79
Do you think you'll remember this experience long term?	4.00

In Figure 2 the students were polled before and after experiencing the colorblindness demonstration. After the demonstration the students were asked to rate on a scale of one to five the following questions: Their awareness of the need to consider colorblindness when designing software and similar systems. Their awareness of the need to consider the differently-abled in general. Their awareness of the need to consider the differently-abled when writing code and developing applications. After the demonstration they were also asked two additional questions regarding the experience, touching on the on their knowledge and awareness. A query on longer term impact ("do you think you'll remember") was also posed (see Table 1).

For the first question, which asked them about their awareness of the need to consider colorblindness when designing software and similar systems, there was a 21% increase in awareness post demonstration. The second question, which asked them about their awareness of the need to consider the differently-abled in general, had a 13% increase in awareness post demonstration. The third question asked them about their awareness of the need to consider the differently-abled when creating applications, also had a 13% increase, which may also reflect the similarity of the queries. The last two questions both had most of the participants reported that the VisCube colorblindness demonstration did increase their knowledge of the needs to build software systems with colorblindness needs in mind.

CONCLUSIONS AND FUTURE WORK

The initial survey results indicate an overall improvement with awareness. This initial trial data indicates that a compelling environment was created. A longer term follow up, if only to test the duration of impact, is planned as part of the ongoing use of this classroom exercise as a part of the departmental long term assessment program. Further deployment of the exercise to other courses is also planned, including both the capstone project course and the initial sophomore course with a design focus. The classroom-friendly length of the demonstration makes this particularly easy to implement this, but will generate a need for additional scenarios and environments. It is expected that this eventual ensemble of tools will broaden and deepen the impression the experience makes on students.

From a graphics and technical standpoint there are improvements that can be made, including increases to the overall the visual fidelity. The implementation of other forms of colorblindness, particularly tritanopia, is also planned for the near term. Context and supporting materials, including video from those with colorblindness and other ability issues, are also being investigated for use outside the classroom and to enable more reflection on this topic.

The Valparaiso Department of Psychology has also expressed in both the initial demonstration and in crafting similar tools to support their courses. Further interdisciplinary efforts are under consideration in partnership with the programs in the University's College of Nursing and Health Professions. It is expected that these efforts will also include trials with HMD display systems for greater portability and to test implementations with lower overhead costs and facilities requirements.

REFERENCES

[1] US Government. 1990. Americans with Disabilities Act. US. Retrieved from https://www.ada.gov/pubs/adastatute08.htm

[2] US Government. Section 508 Homepage. Retrieved from https://www.section508.gov/

[3] W3C. Japan - Web Accessibility Initiative. Retrieved from https://www.w3.org/WAI/Policy/policy/japan/

[4] W3C. Web Accessibility Laws & Policies. Retrieved from w3.org/WAI/Policy/

[5] ACM Computing Curricula Task Force (Ed.). 2013. Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science. ACM. DOI:https://doi.org/10.1145/2534860

[6] Paying for Mistakes: The Cost to Fix a Software Defect and How to Avoid It. Retrieved September 1, 2018 from https://praecipio.com/pc/display/ae/2014/10/09/Paying+for+Mistakes%3A+The+Cost+to+Fix+a+Software+Defect+and+How+to+Avoid+It

[7] Peter Freeman. 1987. Essential Elements of Software Engineering Education Revisited. Retrieved September 1, 2018 from https://www.computer.org/csdl/trans/ts/1987/11/01702160.pdf

[8] Stanford University Press Office. 2018. Virtual reality can help make people more compassionate compared to other media. *Eureka Alert*. Retrieved from https://www.eurekalert.org/pub_releases/2018-10/su-vrc101518.php
[9] Fernanda Herrera, Jeremy Bailenson, Erika Weisz, Elise Ogle, and Jamil Zaki. 2018. Building long-term empathy: A large-scale comparison of traditional and virtual reality perspective-taking. PLoS One 13, 10 (October 2018), e0204494. DOI:https://doi.org/10.1371/journal.pone.0204494
[10] Austin van Loon, Jeremy Bailenson, Jamil Zaki, Joshua Bostick, and Robb Willer. 2018. Virtual reality perspective-taking increases cognitive empathy for specific others. PLoS One 13, 8 (August 2018), e0202442. DOI:https://doi.org/10.1371/journal.pone.0202442
[11] Brian Wentz, Paul T Jaeger, and Jonathan Lazar. 2011. Retrofitting accessibility: The legal inequality of after-the-fact online access for persons with disabilities in the United States. First Monday 16, 11 (November 2011). DOI:https://doi.org/10.5210/fm.v16i11.3666
[12] Kristen Shinohara, Saba Kawas, Andrew J Ko, and Richard E Ladner. 2018. Who Teaches Accessibility? In Proceedings of the 49th ACM Technical Symposium on Computer Science Education - SIGCSE ’18, 197–202. DOI:https://doi.org/10.1145/3159450.3159484
[13] National Eye Institute/National Institutes of Health. Facts about Colorblindness. Retrieved from https://nei.nih.gov/health/color_blindness/facts_about
[14] Craig Stephenson. The Physics of Color Vision and Color Blindness. Retrieved from http://ffden-2.phys.uaf.edu/212_spring2005.web.dir/Craig_Stephenson/colorblindness.html
[15] US Census. Age and Sex Distribution in 2005. Retrieved from https://www.census.gov/population/pop-profile/dynamic/AgeSex.pdf
[16] Colour Blind Awareness Project. Types of Color Blindness. Retrieved from http://www.colourblindawareness.org/colour-blindness/types-of-colour-blindness/
[17] Visbox Inc. VisCube Product Description. Retrieved from http://www.visbox.com/products/
[18] Unity3D. 2018. Unity Documentation 2018.2 - Post-processing stack. Retrieved from https://docs.unity3d.com/Manual/PostProcessing-Stack.html
[19] Unity3D. 2018. Unity Documentation 2018.2 - LUTs. Retrieved from https://docs.unity3d.com/Manual/PostProcessing-UserLut.html