15. Designing in 360 Degrees

Cueing the Player for Immersive Learning

LARYSA NADOLNY, KRISTIE TANK, AND QUINNE FOKES

Abstract: Previous research on cueing has focused on multimedia environments where the information is within the player's field of vision. Virtual reality environments have the unique challenge in that information is located in all directions around the player. The purpose of this study was to examine the impact of cueing on patterns of engagement within a 360° image. Exploratory data analysis was used to examine 3,337 user interactions. Although there was an overall decrease in clicks from front to back in all groups, the text- and audio-cueing groups more frequently selected items behind the field of view. These findings support the use of cueing as a way to direct the player's attention to the back of the virtual environment.

Introduction

In complex digital environments, the location and combination of media impact the cognitive ability of the player to understand and process information. The work by Mayer and other researchers on multimedia learning have demonstrated principles for reducing extraneous processes in these visually rich learning environments, including the importance of cueing the player on important information (Mayer & Moreno, 2003). This foundational research is focused on computer-based learning experiences in which the field of vision is in front of you. Rapid advances in technology have complicated the application of these principles, particularly in learning environments that are not only in front of your field of vision, but also all around you (Dodd & Antonenko, 2012). Examples are the increasing popularity of educational uses for virtual reality (e.g., Google Cardboard) and augmented reality in which information is presented in front, above, below, beside, and behind the player. Therefore, research is needed to examine how players navigate these 360° learning environments. This research study specifically examines user engagement with content overlaid on a 360° image. In this study, cueing is used to signal the player to engage with information located in all directions.

Theoretical Framework

Cueing has been shown to increase academic achievement and retention of information in multimedia environments (Jamet, 2014; Mautone & Mayer, 2001; Tabbers, Martens, & Van Merriënboer, 2004). For example, a simulation may include audio cues, text cues, color changes, or highlighting as a way to focus attention. This method of decreasing cognitive load is categorized as the signaling effect of multimedia learning (Mayer & Moreno, 2003). Signaling can be defined as "the placement of non-content visual and or verbal elements that serve to guide the learner's attention and aid in the cognitive processes of selecting and organizing instructional materials" (Dodd & Antonenko, 2012, p. 1103). The mechanism for this process is that the cued information assists the player in more quickly and efficiently finding and processing important information (Ozcelik, Arslan-Ari, & Cagiltay, 2010).

In 360° environments, a majority of the presented information is outside of the player's visual field at any given time. Few studies have examined the signaling effect in virtual reality, particularly when used to guide the player's attention and progress (Dodd & Antonenko, 2012). Preliminary research includes how the use of arrows in a virtual learning environment resulted in a significant increase in learning as compared with the noncued environment (Chen & Ismail, 2008). In this study, we examined user interactions with both audio and visual cueing in a 360° environment to answer the following research question: How do players engage with 360° content in cued and noncued learning environments?

Method

Exploratory data analysis (EDA) is a data-driven approach to exploring quantitative information through visualization with the goal of generating areas of study for hypothesis testing (Tukey, 1977; Weiner, Schinka, & Velicer, 2012). This methodology was selected in response to the lack of prior research studies on cueing in educational simulations within virtual environments. The study was designed with three versions of the simulation for data collection and analysis: (a) no cueing, (b) text cueing with four additional text cue buttons, and (c) audio cueing with an audio cue every four minutes.

Simulation Design

The study used the ThingLink educational technology platform that can immerse viewers in a 360° image or video. The simulation can be navigated and viewed using a computer mouse on a computer, swiping finger movements on a cell phone, or physically moving around on a cell phone or VR viewer. The activity the research team created in this environment, *Ocean Exploration*, allowed viewers to experience a 360° interactive virtual tour of an underwater coral reef that presented a variety of links in front, above, below, to both the sides, and behind the player (Figure 1).

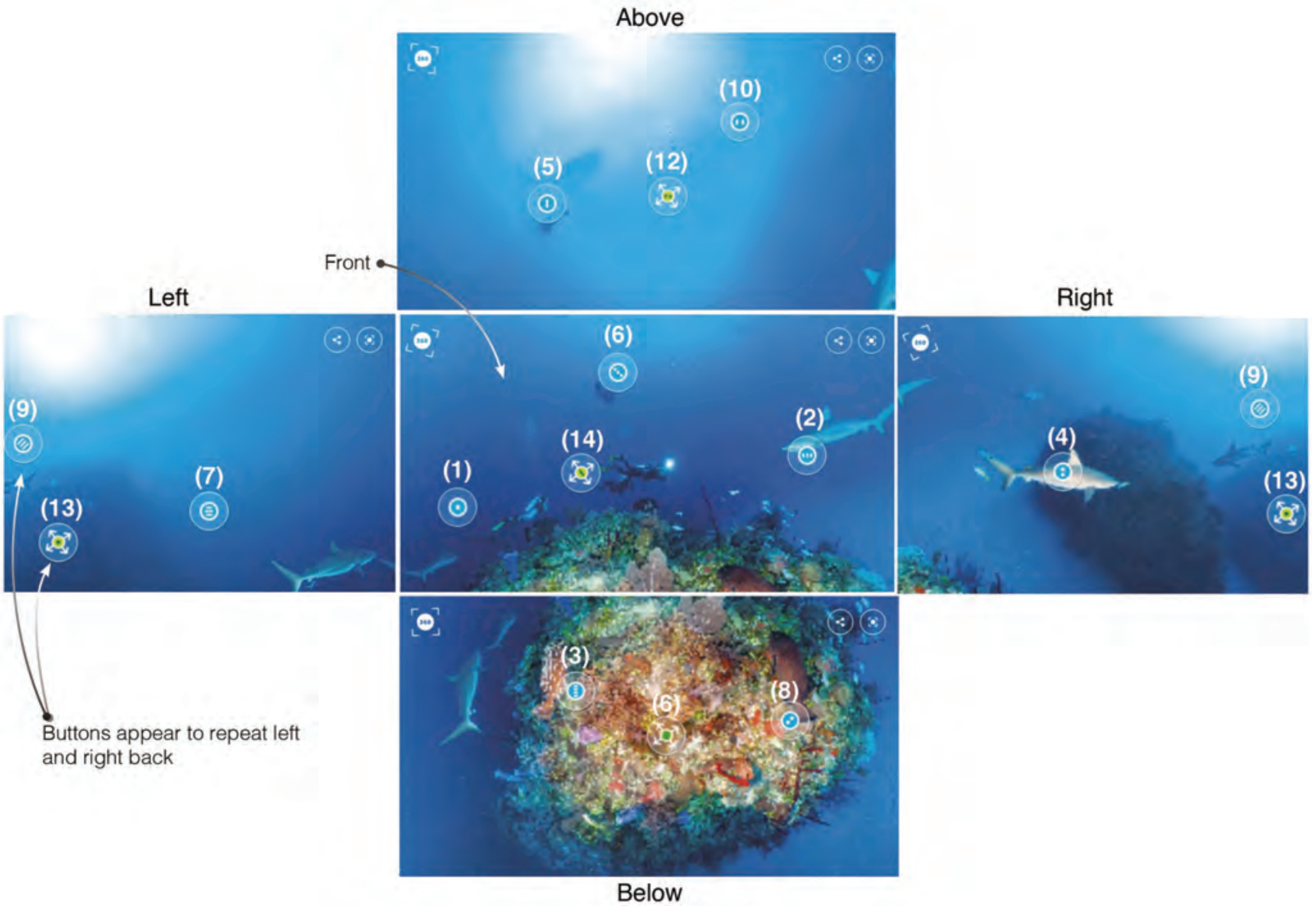

Figure 1. Flat 2D representation of the 360° simulation.

The buttons or tags in the environment can be selected to reveal additional content such as videos, interactives, and maps. The 360° underwater image, the placement of buttons, and content buttons were identical in all three groups with the exception of the additional text cue buttons in Group 2 (Table 1).

Button #	Button location	Button Educational Content
1	Front	Prezi on coral reef bleaching
2	Front	Prezi on coral reef food chain
3	Below	360 image of bleached coral reef
4	Right	360 image of sharks
5	Above	Video on 3D printed reefs
6	Front	Video on history of scuba diving
7	Left	360 image of coral reef nursery
8	Below	360 image of dead coral reef
9	Back	Video on coral reef basics
10	Above	Video on restoring coral reefs

Table 1. Button location and educational content.

The environments for both audio cueing and no cueing contained a total of 10 buttons, while the version with text cueing included an additional four buttons. The buttons were spread out through the environments roughly equally (see Figure 1), and the types of educational content were also distributed equally. Button #6 is directly in front of a player's field of vision while #9 is directly behind the player.

The buttons were marked with small glyphs in order to differentiate the buttons for the player and provide a visual marker for the location in the environment. To minimize the level of visual distraction, while still affording searchability, the buttons were designed using a primarily white color for a higher level of luminance contrast against a predominantly blue (lower luminance) background (Xu, Higgins, Xiao, & Pomplun, 2007), and they were also designed with a moderate level of complexity and distinctiveness (Huang, 2008; Näsänen & Ojanpää, 2003). Numbers were not used on the buttons in order to avoid semantic bias (Telling, Kumar, Meyer, & Humphreys, 2010).

Design of the text cue. In order to visually separate the cue buttons from the content buttons within the text cue treatment group, the cue buttons were marked with a glyph surrounded by four small arrows. When selected, a text box appeared with the statement "Be sure to look all around! This is a 360° image, so there's more to see all around you!"

Design of the audio cue. The researchers recorded and inserted an audio file into the simulation for the audio cue treatment group. The audio group presented the same cueing instruction as the text group, lasting seven seconds and repeating every four minutes.

Participants

To encourage a wide distribution of the simulation in authentic contexts, the *Ocean Exploration* link was promoted and shared through media outlets of the target audience for formal and informal educators. This included direct communication to science teachers, professional society mass communication, social media, and as a feature on the ThingLink education blog.

Data Collection

Before accessing the virtual reality experience, participants were directed to a survey link that randomly assigned the participant to one of three conditions. Although most viewers accessed the simulation through the survey and randomization, it could also be viewed by participants sharing a direct link. The data set that was used for this study was a collection of click data retrieved from the ThingLink site for the period from March 31, 2017 to July 6, 2017.

Data Analysis

Quantitative data were analyzed using descriptive statistics to compare the total number of clicks per button for each group. To assist in direct comparison of the three groups, the clicks per button were scaled to represent equal maximum click counts for each group. Those results were then graphed in three dimensions in order to more easily uncover and analyze.

Results

The 360° environment with no cueing received 239 total clicks, text cueing 833 total clicks, and audio cueing 2,265 total clicks, for a total of 3,337 clicks (Table 2). At one point during the study, the ThingLink platform featured the audio cue version on its education blog, which accounts for the high number of clicks in that group.

Button #	No Cueing	Text Cueing	Audio Cueing
1	32	96	303
2	32	78	311
3	21	58	163
4	28	71	244
5	25	54	159
6	26	68	289
7	25	66	186
8	23	61	177
9	14	61	272
10	13	43	161

Table 2. Button click counts for each comparison group.

When scaled for a direct comparison of the three groups, there was a general decrease in the number of clicks between the front to back (Figure 2). Players most frequently selected the front left (#1) and front right (#2) buttons. The buttons below (#3) and above (#10) were the most infrequently selected across all three groups. Overall, the buttons above the player were infrequently selected, with the exception of button #5 for the no cueing group.

In comparing the three groups, the button directly behind the participant (#9) was selected least often in the no cueing group. There was an increase in the selection of the back button for the text cueing group and an even greater selection by the audio cueing group.

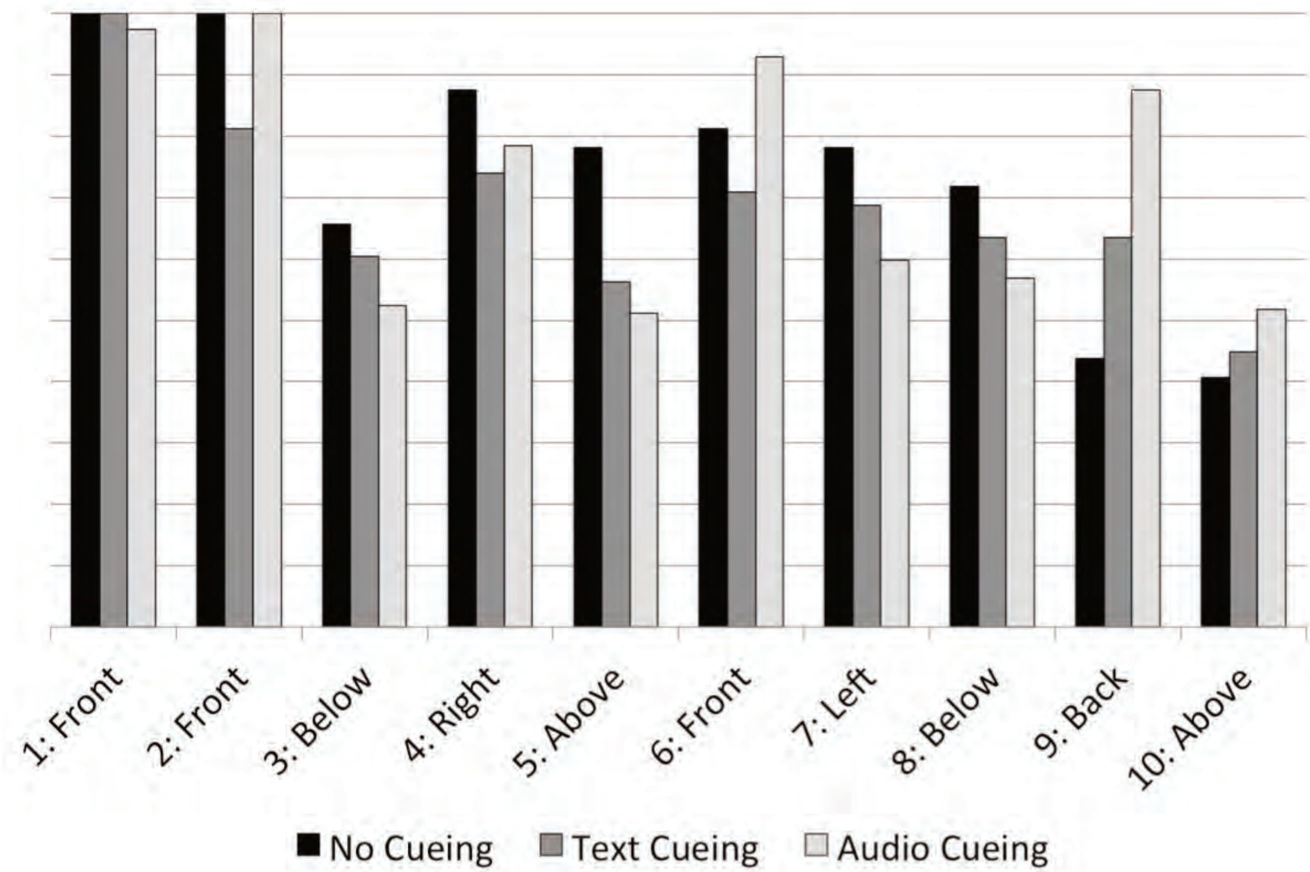

Figure 2. Scaled click counts per button for each comparison group.

The difference in the clicks on the back button is evident when viewing a three-dimensional representation of the simulation (Figure 3). The number of clicks is greater in the cueing groups and largest in the audio cueing group.

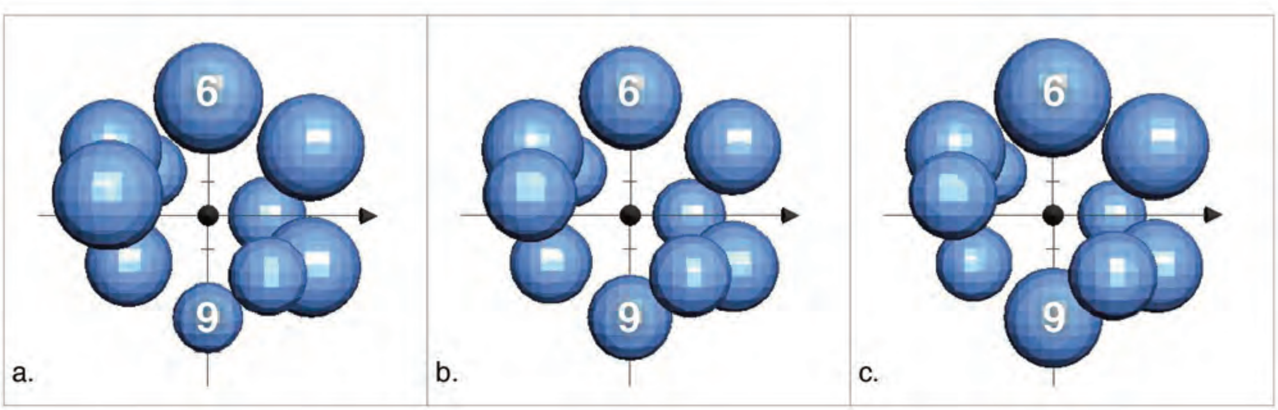

Figure 3. Graphic representation of data as viewed from above: no cueing (left, a.), text cueing (center, b.), and audio cueing (right, c.).

Discussion and Limitations

The more frequent selection of the button behind participants in the two cueing environments confirms studies indicating that text and audio cueing in 360˚ environments can lead to increased engagement for viewers, provided the cues are not so distracting as to cause cognitive overload (Dodd & Antonenko, 2012; Huang, 2008).

All three groups had lower click rates for the buttons above their field of vision, particularly the above back button (#10). This result may be explained through research in the fields of human computer interaction, psychology, and human factors engineering. A human's line of sight is usually measured to be 10 to 15 degrees below the horizontal plane (Wickens, Lee, Liu, & Gordon-Becker, 2013), and participants' apparent pattern of turning their heads from side to side and looking down may reflect an ergonomic preference. The increased selection of the top button closest to field of vision in the no cueing group (#5) may indicate a normal pattern that was interrupted by the visual or verbal cueing (Hancock, Mercado, Merlo, & Van Erp, 2013) and can be further explored through eye-tracking studies.

Few studies have examined the signaling effect in virtual reality environments, and this study is significant in that it confirms the positive impact of cueing on attention getting but also presents questions for future study. For example, although the audio cue in this study occurred every four minutes, researchers may want to compare different time intervals and the impact on engagement. In addition, one of the affordances of virtual reality is perceptual immersion in the environment, which may be affected by the static view of desktop or the movable view of cell phones. Technology used to access the simulation may affect immersion and presence, and therefore cognitive gains.

The study is limited by the exploratory research design, with data collection occurring in uncontrolled real-world settings. Future studies should include a replication of this study using randomization, controlling for access through similar devices, and setting time limits in the simulation.

Conclusion

This study is a first step toward the bigger question of looking at how and why players navigate these 360° learning environments, by providing insight into how users engaged with content in a 360° image. The results suggest that both text and audio cueing were effective in signaling the player to engage with information in all directions within this virtual reality experience. Therefore, when thinking about the design of 360° environments, it is important to recognize that players do not navigate equally in all directions. If the intent is to have players look around and interact with buttons left, right, above, and below them and take full advantage of what a 360° virtual reality experience can provide, then a cueing component can help facilitate these interactions. However, it may not be enough to just add a general cueing component to "look all around," as this work found that users did not tend to look upward regardless of cueing. Future work is needed to extend the learning from this study to look more closely at where and how users engaged in these 360° environments.

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