Using Lighting to Enhance Wayfinding

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Abstract

Gaming is very popular in today's society and, at times, developers of such virtual environments attempt to mimic the real world. Because lighting is important in video games as well as in the real world, this paper attempts to determine if there is a significant difference between the decisions in which people will travel based on different wayfinding techniques. This was presented to participants through a study in which they made a decision after viewing each screenshot of a virtual environment. We found that there was a significant difference between the number of people choosing to go toward the light. And we concluded that signage does play an important role in the decision-making process; however, more people will choose to traverse a lit hallway rather than an unlit one.

1 Introduction

Virtual Reality (VR) is being used more and more to simulate real world experiences, as well as for training and gaming purposes. Recently, a gamer posted a blog regarding the presence and absence of lighting and its impact as navigational cues to other gamers [Lundeen 2009]. It is a general belief that increased levels of illumination result in performance improvement. The purpose of this study is to verify this belief by comparing which wayfinding technique is more significant, lighting or signage. Wayfinding is the art of using landmarks, signage, pathways, and environmental cues to help first-time visitors navigate and experience a site without confusion [Biesek Design 2010]. It is important to study this, not only to improve video games, but also for the improved design of buildings and city streets at night.

2 Background

Many applications of virtual environments (VE's) require people to have some kind of spatial knowledge and use visual cues to perform well in the VE [Vembar et al. 2003]. Recently there has been some discussion on the internet blogs about how lighting is used to help guide people to where they are supposed to go next in the virtual environments [Lundeen 2009]. Visual cues have been considered as one of the most effective ways of improving human performance [Vembar et al 2003].

According to Smith and Worch [2010], a game design technique that developers are pushing for now is environmental storytelling. The developer does not directly tell the player what is happening in the world but uses clues and visual cues in the environment to allow the player to guess what is happening and make up his own conclusions. This is a push towards a constructivist method of explaining the virtual world inspired by Jean Piaget's writings. The idea is that by allowing the player to determine what is happening through exploring the environment, it will build investment in the game and draw them further into the story. This does not limit itself to the plot of the game but also traversing the environment. The goal is to invite players to interpret situations based on their views and experience. Developers want to use this idea to help players navigate the environment. They want the player to survey the environment and, using environmental cues, determine the best way to travel. Not everything should be given to the player, only hints that allow them to determine the best path.

In the case of environmental cues, the Law of Closure says that as humans we have an innate need to categorize and fit visual elements into a larger framework. We draw conclusions based on what we can see and fill in what we hope to be the rest. If a player sees light coming from a door, the developer hopes that the player will come to the conclusion that there is a light source or way to the outside on the other side of the door.

Wayfinding techniques have been used to help guide people through unfamiliar environments for decades. Darken and Sibert's research [1996a] suggests that virtual world navigators may wander aimlessly when attempting to find a place for the first time. This is due to problems associated with wayfinding being used incorrectly or not at all within the virtual environments. Therefore, using directional cues will minimize disorientation [Darken and Sibert 1996b]. Wayfinding can also be described as the process of using visual information to find your way through a complex environment [Biesek Design 2010].

One of the most classic light cues experiments that have been done was by Taylor and Socov [1974]. The study was designed to show how many people would navigate around a barrier using light cues. When both sides of the barrier had the same amount of illumination it was found that 69% of people went to the right side of the barrier. When the left side of the path had a higher level of illumination 75% of the people went to the left, towards the light. The study concluded that people were attracted by higher illumination, and therefore chose to follow the brightest path.

Yorks and Ginthner studied the effects that wall lighting has on desk selection [1987]. They had participants walk into a room that had three desks inside, one near the door, one in the middle of the room, and one at the far side of the room. When the illumination of the room was equal, subjects chose to sit at the desk closest to the door. However when the back wall had a higher illumination level than the rest, the participants chose to cross the room and sit at the desk next to the illuminated wall. Again this study shows that people are attracted to higher illumination and will walk farther distances to get to the brightest area of the room.

Lack of further research and more consistent findings has been one of the reasons that our understanding of the relations between behavioral, subjective, and visual reactions, and, which aspects of the physical environment cue them, still remains primitive [Antonakaki 2006]. Most of the research that has already been done dealing with using lighting cues has not been in virtual environments. There is also a limited amount of research done on usability and adaptability of virtual environment interfaces. By integrating use of an eye tracker, this experiment will be able to present data on participants' fixations and compare it to their unique decisions.

3 Hypothesis

People will choose a lighted path when navigating a virtual environment.

4 Method

a. Participants

There were twenty participants who completed this study. There were seven females and thirteen males.

b. Stimuli

Stimuli in this study consist of sixteen screenshots from a virtual environment. These screenshots are from the same location, an evenly divided hallway, split by a barrier. Screenshots differ as a result of various lighting techniques and other visual cues, such as exit signs and arrows and allow participants to view the environment from a first-person perspective. Areas of interest were created around the visual cues that were added to the environment and lighting sources when applicable.

c. Materials and Apparatus

The eye tracker used for this experiment was a non-invasive Tobii ET-1750 attached to a TFT 17" monitor with a 1280x1024 resolution. Data on eye position is gathered

Figure 1: *Control image of a hallway (both sides lit, no sign)*

Figure 2: *Hallway environment with lighting on the left hall*

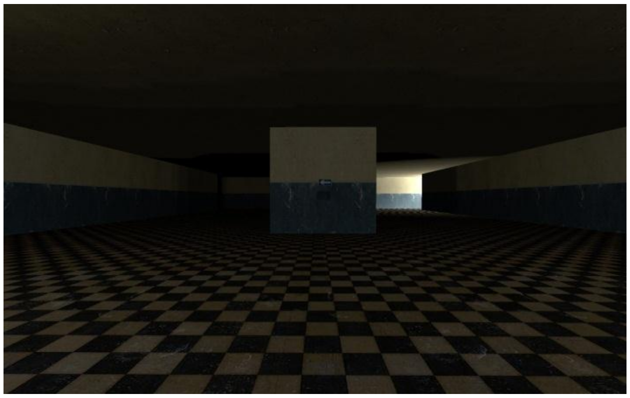

Figure 3: *Hallway environment with right side lit and arrow left*

at 50 Hz with a position accuracy of ~0.5˚. We used Tobii Studio software to run the eye tracking experiment and gather the data.

To develop the virtual environment, we used Valve Software's Source SDK Hammer Editor. In order to traverse the environment and gather screenshots, we used Valve Software's Garry's Mod. The environment code is compiled by the Source Engine and run within the Garry's Mod environment, allowing for editing to take place within the environment itself. Figures 1-3 show example screenshots being used in the experiment.

d. Experimental Design

To help understand how light, whether sunlight or artificial, impacts the direction humans tend to go, in an unfamiliar environment, we designed a study in which participants' eye fixations can be tracked to help determine whether participants focus on light when making a decision about which direction to travel.

This was a within group study since all participants experienced multiple conditions. The data collected from the study was the participants' eye tracking data. Our focus was to measure the speed in which the participants made a decision and what direction the participant decided to travel, toward the light versus in the direction of the other visual cues. We also used heat mapping to help us understand what the participants focus on the most. Another interesting statistic included gathering information based on the participant's gender to determine if there was a significant difference in the time it took to make a decision and the decision made between genders.

Screenshots were developed based on a 3 x 5 model, as shown in Table 1. There are four versions of the test, with each of the 15 screenshots randomized. Each participant experienced only one of the four randomly assigned tests.

Table 1: *3 x 5 Model of screenshots used in study*

Both Sides Lit, No Sign	Left Side Lit, No Sign	Right Side Lit, No Sign
Both Sides Lit, Arrow Left	Left Side Lit, Arrow Left	Right Side Lit, Arrow Left
Both Sides Lit, Arrow Right	Left Side Lit, Arrow Right	Right Side Lit, Arrow Right
Both Sides Lit, Exit Left	Left Side Lit, Exit Left	Right Side Lit, Exit Left
Both Sides Lit, Exit Right	Left Side Lit, Exit Right	Right Side Lit, Exit Right

The participants' chosen direction and the eye tracking data were analyzed using Minitab 16, a statistical software package. The paired t-test was used to analyze the direction the participants traveled and the differences in gender data. The one-way ANOVA was used to analyze the time it took to make a decision. A scatterplot was used to determine if there was a correlation between the direction the participants chose to travel and the time spent looking at each AOI.

e. Procedure

During the study, participants were greeted and briefed on the nature of the study using a script. Then they read an informational document approved by the Clemson University Institutional Review Board. Subsequently, participants were be asked to take part in the calibration of the eye tracker. The ultimate task was for each participant to look at images of an environment and to click which direction they would like to travel at his or her own pace. Upon completion, participants were thanked and dismissed.

5 Results

The eye tracking information was gathered from participants and analyzed in Minitab. To determine if there was a significant difference in the direction (toward the light versus away from the light) the participants chose to travel, the paired t-test was used. As Table 2 shows, the p-value is 0.000 which means that there is a significant difference between the number of people choosing to go toward the light versus the number of people choosing to go away from the light.

Table 2: *Paired T-Test and CI: toward light, away from light*

	N	Mean	StDev	SE Mean
toward light	14	15.214	2.751	0.735
away from light	14	4.143	2.316	0.619
Difference	14	11.07	5.03	1.34

95% CI for mean difference: (8.17, 13.98)
T-Test of mean difference = 0 (vs not = 0): T-Value = 8.24
P-Value = 0.000

To determine if there was a difference in the time it took to make a decision based on whether the exit sign, arrows, or no sign was present, we used the One-Way ANOVA test. As shown in Tables 3a and 3b, the p-value is 0.343 which shows that the information given does not present a significant difference in total time taken to make a decision.

Table 3a: *One-way ANOVA: Arrow, Exit, No Signage*

Source	DF	SS	MS	F	P
Factor	2	3.53	1.76	1.16	0.343
Error	13	19.71	1.52		
Total	15	23.24			

S = 1.231 R-Sq = 15.18% R-Sq(adj) = 2.13%

Table 3b: *Individual Confidence Intervals*

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Individual 95% CIs For Mean Based on
Pooled StDev
Level         N   Mean  StDev  ---+---------+---------+---------+------
Arrow         6  3.428  0.671         (----------*----------)
Exit          6  2.762  0.969  (----------*---------)
No Signage    4  3.951  2.063            (-------------*------------)
---+---------+---------+---------+------
2.0       3.0       4.0       5.0

Pooled StDev = 1.231
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In order to see if there was a correlation between the number of people traveling toward the light and the amount of time the areas of interest (AOIs) were viewed, we used a scatterplot. For each image, we considered three AOIs—the area located in the direction of the light, the area located away from the light, and the barriers which included any kind of signage. Figure 4 shows there is a relationship between the time it took for participants looking toward the light and the barrier and the number of participants choosing to travel toward the light. There is a strong negative correlation between the amount of time people looked away from the light who chose to go toward the light.

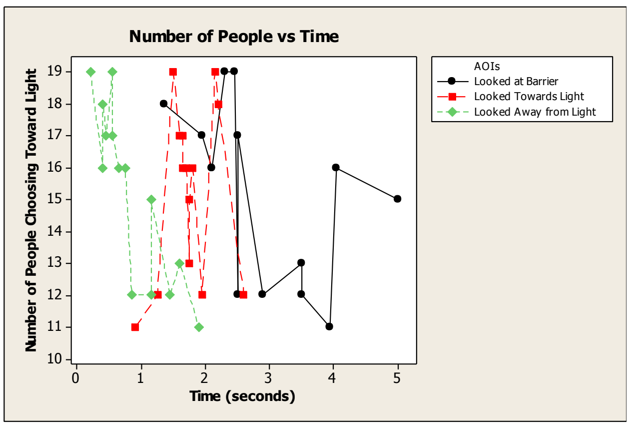

Figure 4: *Traveling toward the light vs. time spent viewing AOI*

We were interested in seeing if there was a difference in the percentage of males choosing to go toward the light and the percentage of females choosing to go toward the light. As Table 4 shows, the p-value is 0.000; therefore, there is a significant difference between the males and females choosing to travel toward the light.

We were also interested in determining if there was a significant difference in the amount of time it took for males and females to make a decision. The paired t-test resulted in a p-value of 0.006, which shows that there is a significant difference between the genders with regard to the amount of time taken to make a decision (Table 5).

Table 4: *Paired T-Test and CI: Males: Toward Light, Females: Towards Light*

	N	Mean	StDev	SE Mean
Males: Toward Light	14	9.571	1.697	0.453
Females: Toward Light	14	5.643	1.499	0.401
Difference	14	3.929	1.639	0.438

95% CI for mean difference: (2.982, 4.875)
T-Test of mean difference = 0 (vs not = 0): T-Value = 8.97
P-Value = 0.000

Table 5: *Paired T-Test and CI: Males, Females*

	N	Mean	StDev	SE Mean
Males	16	2.866	0.983	0.246
Females	16	4.169	2.087	0.522
Difference	16	-1.303	1.622	0.406

95% CI for mean difference:(-2.168, -0.439)
T-Test of mean difference = 0 (vs not = 0): T-Value = -3.21
P-Value = 0.006

6 Discussion

The purpose of this study was to determine whether people would go toward the light. We used exit signs and arrows to determine if they would have an effect on participants' decisions. We found our hypothesis to be true—more people tend to go toward the direction of the light; however, when any kind of signage is involved, people started to question which direction to go. This accounts for the decline in people going toward the light even though the majority still went toward the light.

It has been determined that it did not matter what type of signage was present in the image; it still took the same amount of time for participants to make a decision. We found this interesting because we thought that people would focus more and take longer on the images that had signage. We believed that they would question whether to use the signage or to follow the lights, causing them to spend more time making a decision. However, now we believe that participants went with their first instinct;

therefore, they did not take the time to question the signage or light. Instead, they chose the first direction that felt comfortable to them.

As shown in Figure 4, the two images that had nineteen participants choosing to travel toward the light (images: light left, exit left and light right, exit right) looked toward the light and the barrier more than the non-lit side of the barrier. This leads us to believe that they used both the lit hallway and the exit sign to make their decision rather than the non-lit hallway.

The image that had fifteen participants choosing to travel toward the light (image: both sides lit, arrow right) shows that people tend to focus more on the barrier since both hallways are lit. Here we would have chosen the right side (where the arrow points) as the “towards the light” side since that is the way we would have predicted participants would travel (based on the direction of the sign).

The image for which eleven participants chose to travel toward the light (image: light left, exit right) is the only image that participants focused more on the non-lit hallway than the lit hallway. They also focused on the barrier a lot longer than either side of the hallway. This leads us to believe that the participants had a hard time making a decision about which direction to travel since the light and signage were indicating different directions.

We determined that there were a higher percentage of females who chose to go toward the light than there were for the male participants. Figure 5 shows that there is a difference in the amount of time it took females and males to make a decision. Although the female data is highly variable, females took longer, on average, to make decisions than males did during this experiment.

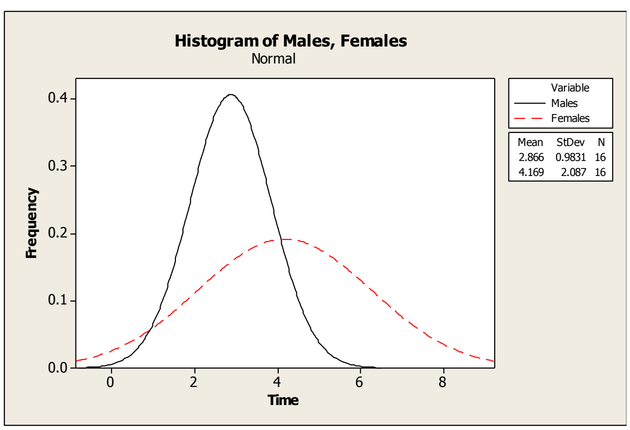

Figure 5: *Time it takes to make a decision (by gender)*

We also used heat maps to visually determine what participants viewed. The following series of heat maps (Figures 6-9) verifies that participants looked toward the signage/barrier most of the time and the lit hallway a little less often, rarely looking toward the unlit hallway. Even though the sign draws more attention, participants still chose the lit path.

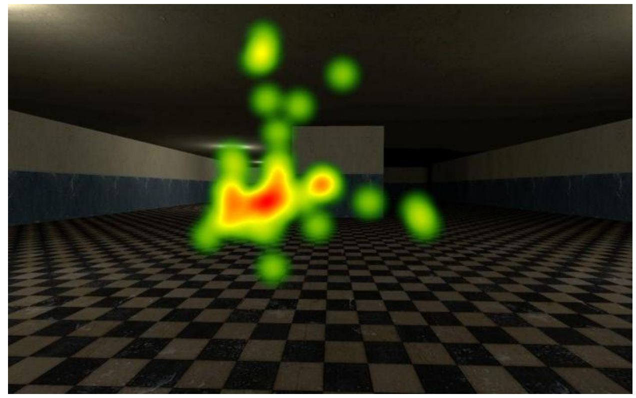

Figure 6: *Light Left*

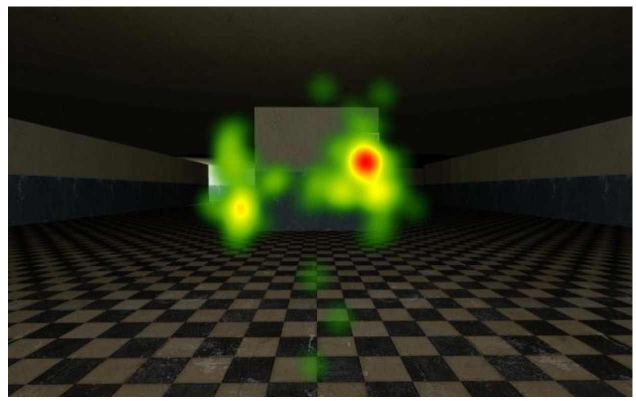

Figure 7: *Light Left, Exit Right*

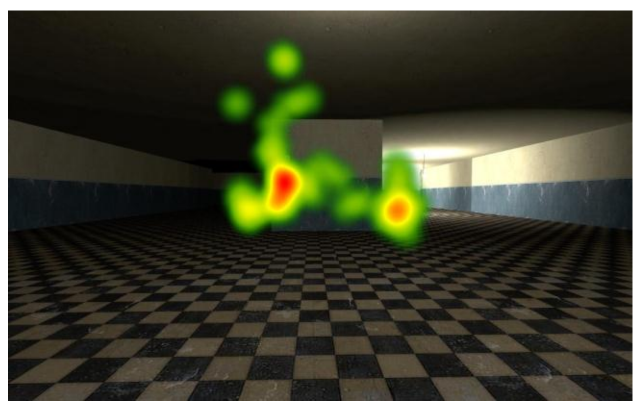

Figure 8: *Light Right, Exit Left*

7 Limitations

We were unable to use an actual virtual environment. Tobii Studio required us to strictly use screenshots instead of a continuous video stream in order to reduce the number of variables among participants. Using a virtual environment, in which participants could actually move around would have been more realistic; therefore, participants' emotions may have played a greater factor into the decision-making process.

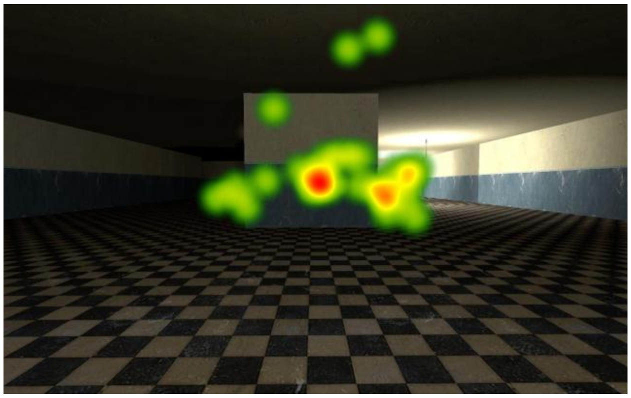

Figure 9: *Light Right, Arrow Left*

8 Future Work

Future research would involve video-taping participants in action and having them retrospectively "think aloud." This would ensure that accurate time data can still be collected. "Think aloud" could have assisted us with determining why participants made a specific decision instead of speculating. A few times, we observed participants who we believe purposely chose to "rebel" and go toward the unlit side.

Since we did find a difference between genders, we think it would be interesting for more research to be conducted to see if this is a common trend.

And since we were limited to screenshots instead of an actual virtual environment, future work should be done to develop a program that supports a gaming environment. It would be interesting to see how participants react to various obstructions in the environment and what impact this would have on time to make a decision and which way the participant would choose to travel.

9 Conclusion

We determined that our hypothesis, that more people will choose the lighted path, is accepted based on our experimental results. We found that even though signage played a factor in the decision making process the majority of the participants still went towards the lit hallway. Therefore, lighting is a more significant wayfinding technique than signage.

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