Using Eye-Tracking Technology to Determine the Effect of Vegetation on the Effectiveness of Stop Signs

Hunter Burkett
Clemson University
Clemson, SC 29634
hburket@g.clemson.edu

Nathaniel Holbrooks
Clemson University
Clemson, SC 29634
holbro2@clemson.edu

Dr. Andrew Duchowski
Clemson University
Clemson, SC 29634
andrewd@cs.clemson.edu

ABSTRACT

Across the United States, drivers avoid accidents by stopping at intersections before proceeding into oncoming traffic. If individuals do not see these intersections, they can be fined by law enforcement officers or they can be involved in potentially fatal automobile accidents. Previous studies have attempted to research various kinds of distractions and obstructions to viewing various road signs. Researchers in the past have also conducted studies to see if stop sign performance could be improved if the color of the sign was different or if the shape was to be changed. The researchers of this study seek to concentrate solely upon the effects that surrounding vegetation plays on the amount of time that it takes a person to fixate on a stop sign in a real world setting. In this experiment, fifteen study participants were asked to view ten different intersection scenes that all have stop signs in them. The amount of vegetation in each intersection scenario is varied intentionally to see if the amount of time to first fixation is increased as a result of the presence of surrounding vegetation. For this study, there exists sufficient evidence to conclude that it takes more time to fixate on a stop sign if it is surrounded by vegetation.

Author Keywords

Time, first fixation, stop sign, conspicuity

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Easily visible street signage is essential to maintaining safety on public roads. Unfortunately, especially in rural areas, clearing overgrowth can sometimes be neglected for periods of time, which can lead to difficulties in seeing signs along the roadsides. This can increase the amount of time a driver takes to react, or even cause a driver to miss a sign completely.

According to the Federal Highway Administration, which is part of the U.S. Department of Transportation, in 2005 approximately 2.5 million accidents occurred at intersections. Of those accidents, 8,655 proved to be fatal [1]. We are hoping that through this study, we can show that any steps that can be taken to increase safety on public roads will be a benefit to drivers in more rural areas where overgrowth is more common. We are not concerned with highways, interstates, and other similar roads, because these roads are usually cleared of overgrowth.

The goal of this study is to determine how vegetation surrounding street signage, specifically stop signs, alters their effectiveness. We are concentrating on stop signs, since these signs mandate an action, as opposed to others, such as speed limit signs, that exist for more informative reasons. Our experiment shows participants random scenes where stop signs have been obscured due to surrounding vegetation, as well as scenes where a stop sign is free of surrounding vegetation. We are trying to determine the difference in the time it takes to fixate on the stop sign in the two different situations. We are also trying to determine if unsigned intersections (those not utilizing traffic signals) could be made safer by ensuring that vegetation surrounding stop signs is removed. In order to analyze our data, we will be using fixations, to determine where a user is looking, and how long it has taken said user to find the stop sign in the scene.

BACKGROUND

The Stop Sign

The history of the stop sign dates back to 1915 when the first model was installed in Detroit, Michigan [8]. The first model looked nothing like what we know today. Instead of the red octagon with white lettering, the first model was a 2-by-2 square of sheet metal with black letters on a white background [6]. It wasn't until 1935 that traffic engineers developed the first set of road signage standards, called the Manual on Uniform Traffic Control Devices. A yellow background with black letters was initially proposed, and the red background rejected because of its low visibility at night. However, once reflective materials became a viable option for use on stop signs, the current white-on-red color scheme was adopted, as red signifies danger [8].

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Previous Studies

It is widely accepted that shortcomings in visual attention are to blame for a large percentage of roadway accidents [3]. At the most basic level, drivers tend to focus on a visual point located directly in front of the driver's point of view, where objects in the peripheral view appear not to move. Along with this, drivers tend to look occasionally at road markers and objects that lie alongside the road [4]. Hazardous events are often the cause of breaking one's fixation. If road signs are not clearly visible, but are obscured by surrounding vegetation, then it could be difficult to grab a driver's attention in enough time to react appropriately.

One of the studies that corresponds to ours is by Ho et al. [6]. In their experiment, they look at the effects of clutter and how it can affect driving performance. According to Edquist, in her dissertation, a visually cluttered environment can be defined as one where visual characteristics have the ability to impair the performance of driving [5]. As part of this study, users were asked to judge whether or not a presented scene consisted of high visual clutter or low visual clutter. Following this, the users were asked to detect a traffic sign located somewhere in the scene. In a high clutter environment, the sign would be among the visual clutter, and in a low clutter environment, it would be easily discerned. The study also examined how luminance and age affected the ability to discern traffic signs in high clutter environments. Unsurprisingly, the study showed that older adults were less accurate and slower to discern the signs in both the high and low visual clutter scenes. In addition, scenes that were captured at night were more likely to produce results where accuracy was not as good as those captured during the day [7].

Another study examined deals with the conspicuity of road signs. Conspicuity is the state of being obvious, which is the most important aspect of road signs. Burns and Pavelka [2] conducted an experiment where they compared the conspicuity of fluorescent colored road signs against their standard-colored counter parts. Participants were asked to try and detect the signs from as far away as 120 meters. The researchers concluded that subjects were able to spot signs with fluorescent material from a much further distance than those without fluorescent materials. It was also determined that the visibility and conspicuity of fluorescent-colored materials are anywhere from two to three times that of materials that are not fluorescent colored.

A follow up test conducted by Burns and Pavelka a few years later discovered that subjects were able to detect fluorescent-colored signs more than 90% of the time at the greatest testing distance, while less than half of the subjects were able to detect road signs not utilizing fluorescent materials [9].

The connection between our study and the conspicuity of road signs should be obvious, as signs that are less conspicuous due to surrounding vegetation can affect a driver's ability to react to a given situation. Stop signs that are more visible, either through the use of fluorescent materials or other ways, will help make the roads safer for drivers. Fluorescent materials have higher luminance and contrast than their standard sign counter parts [9], so there is a greater chance they could be spotted more easily, even when partly obscured by vegetation.

HYPOTHESIS

Our hypothesis for this experiment is that stop signs that are surrounded by overgrown vegetation will be less conspicuous, and will take users longer to discover than stop signs that are not covered by vegetation overgrowth.

METHOD

Participants

Test participants were openly invited to take part in the study. The researchers recruited participants from a pool of students at Clemson University between the ages of 18 and 40. Ideally, we wished to have at least 20 subjects participate in the study. The participants were not allowed in the study if they did not have 20/20 vision or were corrected to be 20/20 vision by the use of glasses or contact lenses. The data for all participants was not separated by age or any other factor. Financial compensation and/or prizes were not offered for participation in the research study. The participants were allowed to pause the test or refuse the test all together if they did not wish to continue. They were also given instruction as to what was expected of them before the test began. The data for fifteen participants, six males and nine females, were used in the final data analysis.

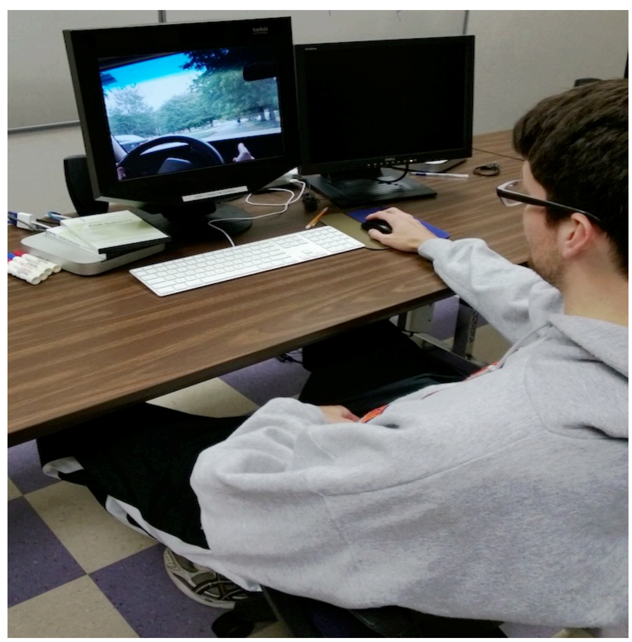

Figure 1: Participant using Tobii eye-tracker

Apparatus

Photos were taken in a 2007 Lincoln Town Car. While one researcher operated the car, another took pictures with a Canon SD1000 7.1 Megapixel camera. Images were presented on a Tobii Eye Tracking Unit, (Model: ET-1750) TFT 17 in (diagonal), with a sampling rate of 50 Hz. Resolution was set to 1280x1024. Accuracy: ~0.5° (bias error) [9].

Figure 2: Stimulus -- Intersection with vegetation (top panel) and without vegetation (bottom panel) surrounding stop sign

Stimulus

Ten pictures were selected for use in the research for their qualities and differing levels of vegetation. The pictures were taken while driving around the campus of Clemson University. The pictures were also taken at the time that was deemed appropriate to apply the brakes to the particular vehicle that was used. We displayed an instructional screen to all of the test participants which let them know the type of images that they would be presented with and it instructed them to visually search for the stop sign in the image and fixate upon it as quickly as possible. The test participants were presented with intersection scenes that varied by the amount of vegetation present in the scene surrounding the stop signage. The next images were presented to the test subjects in random order and were separated by a blank gray screen so that the user would not get used to looking in the same relative spot and to give better test data reliability.

Experimental Design

The study was a 2x5 within subject research study that presented intersection scenes with and without vegetation overgrowth surrounding stop signs within each image. Each study included five images with a stop sign obscured by vegetation and five images featuring a stop sign not obscured by vegetation. Each image had varying amounts of vegetation present, although for the scenes containing non-obscured signs, this was unintentional. In addition, each image was taken sometime between 12:00 pm – 1:00 pm. This was done to try and provide the same amount of light in order to ensure uniformity among images. Each image was taken from approximately the same distance from the user's perspective to the stop sign.

Procedure

Prior to beginning the experiment, the Tobii eye tracker was calibrated for each user using a five-point calibration method run in Tobii Studio. Participants were also asked to remain 50 centimeters from the screen if possible. If a participant required glasses to see, we asked them to remove them if at all possible. The Tobii eye tracker is most accurate when there is nothing in front of the eyes, which could affect the accuracy of the eye tracker.

Users were presented with an image and then were asked to locate the stop sign in the image as soon as possible. The image would remain on the screen until the user clicked the left mouse button, indicating that he or she had located the stop sign. Following the display of each scene, a blank screen would then appear for three seconds, prompting the user to refocus to the center of the computer monitor. This ensured that the subject would start fresh for each scene presented. In total, each subject would be shown ten images in a randomized order.

After each session, a questionnaire was given to the subject with several questions about the study. It utilized the Likert Scale, allowing the subject to choose from five scores ranging from Strongly Agree to Strongly Disagree. The questionnaire was completed anonymously, with no recorded names or other identification. This questionnaire was administered in order to determine the subject's satisfaction with the study. The questions included within the questionnaire were:

1. I believe that surrounding vegetation can greatly affect the effectiveness of road signs.
2. Overall, the images I viewed in this study were accurate of real-life roadway intersections.
3. I think it is important for vegetation to be cleared away from road signs.

4. This study will cause me to notice vegetation surrounding road signs more frequently.

5. This study had a good variety of possible real life scenarios where surrounding vegetation could impact the effectiveness of stop signs.

6. I am comfortable with how I performed during this study.

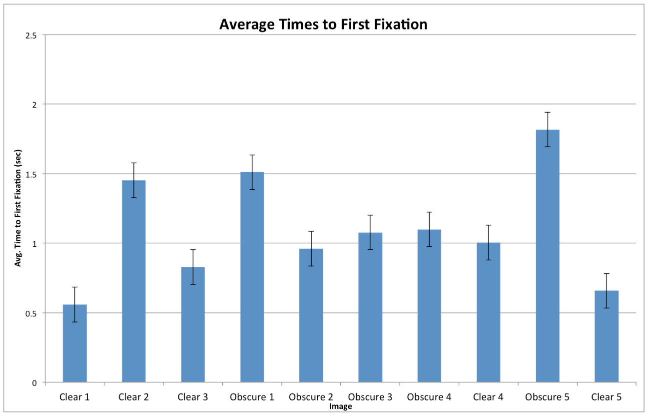

Figure 3: Average of the average times to first fixation for each image (includes standard error bars)

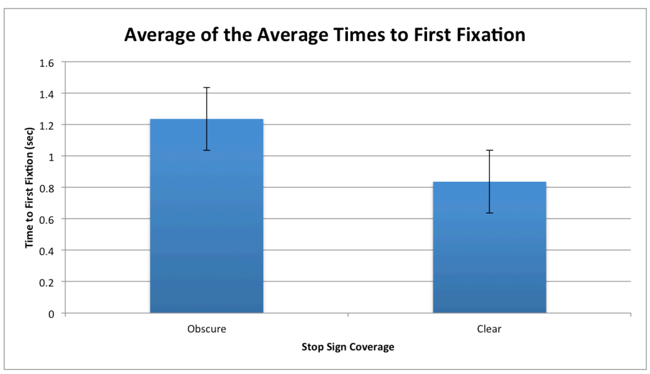

Figure 4: Average of the average times to first fixation for scenes with stop sign not obscured by vegetation and scenes with stop sign obscured by vegetation (includes standard error bars)

RESULTS

The data of fifteen participants were used to analyze the results of this study. Eighteen subjects initially participated in the study, however, due to data anomalies, the data corresponding to three of them had to be removed once data analysis began. The eye-tracker could not be properly calibrated to one participant's eyes, and as a result, the eye-tracker did not properly capture the subject's eye movements. In addition, the data for two other participants had to be stricken, due to the fact that the recorded data was unusable.

Fixation points were gathered for each test participant and then exported to an Excel file. The Excel file was then exported to a .csv file so it could be imported into Minitab.

Figure 5: Aggregate fixations, with vegetation condition (top panel), and without vegetation condition (bottom panel).

Minitab was then used to process the data gained from the participants who took part in the study. A one-way ANOVA test was used to see if the p value was significant or not which would lead to rejecting or accepting our hypothesis.

In analyzing the results of the study, we primarily looked at the average time to first fixation for each image viewed by the participants. Each image had a pre-determined AOI that included either an obscured stop sign or a sign not obscured. The time to first fixation on the pre-determined AOI had the means to tell whether or not vegetation had a factor on road signage.

As we can see in Figure 3, the average time to first fixation on the AOI (stop sign) in the scenes containing obscured stop signs are higher. In some cases, particularly in three of the scenes, the time to first fixation on the pre-determined AOI was much higher. It is no surprise that these three images contained the stop signs that were most obscured by vegetation. With a confidence interval of 95% for all tests, and F(1,69) = 4.46 and $p < 0.05$, the results indicate the faster times to first fixation for the scenes with non-obscured stop signs are significant.

Time measurements, which indicate the amount of time in seconds needed for the subject to fixate upon the stop sign object in the intersection scene, were recorded by the Tobii Studio software. Regarding the intersection scenes with vegetation, we calculated that the mean time to the first fixation was 1.235 seconds (SD = 0.8655 seconds) while those scenes without surrounding vegetation had a mean of 0.8362 seconds with a standard deviation of 0.7294 seconds. This is 67.66% higher than the fixation time with vegetation included in the scene.

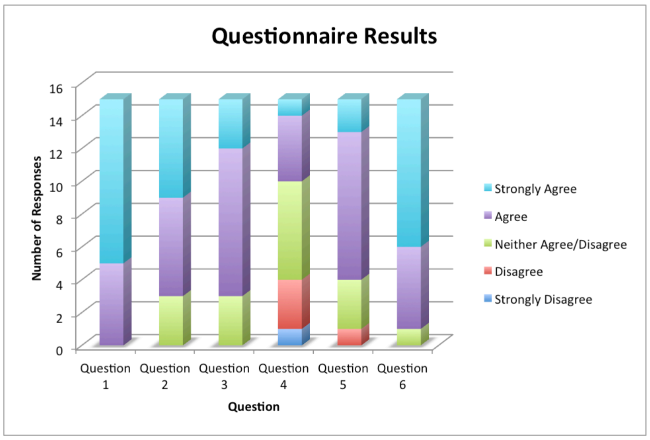

Figure 6: Post-experiment questionnaire results

Following the experiment, each participant was asked to fill out a questionnaire to gauge the effectiveness of the study. The results to the questionnaire are included in Figure 6. The questions correspond to those previously mentioned.

Of the fifteen participants that completed the questionnaire, all of them agree or strongly agree that surrounding vegetation can greatly affect the effectiveness of road signs. In response to a question regarding the similarity of our intersection scenes compared to real world scenarios, 80% of respondents either agreed or strongly agreed that our scenarios were very much like scenarios that would be encountered in the real world. Finally, twelve out of the fifteen study participants agreed or strongly agreed that vegetation should be completely cleared from road signs.

DISCUSSION

Based on the results of our study, we are able to determine that there is significant evidence indicating that vegetation surrounding stop signs does have an impact on their effectiveness. Our results indicate that the average time to first fixation for a stop sign obscured by vegetation was 1.235 seconds, while the time to first fixation for a non-obscured stop sign was 0.8362 seconds. In each image, we tried to capture a scenario that was as true to a real-life scenario as possible.

These results indicate that vegetation surrounding stop signs at intersections with lots of overgrowth is something that should be taken seriously. With what we have learned, it is possible and suggested that further studies be undertaken. Our experiment only considered scenarios during daylight when visibility is at its best. However, other scenarios should be investigated such as during times with lowlight or during bad weather. These can both affect visibility, so it would be interesting to see how much of a difference these factors would make.

While we feel that our experiment was more than sufficient in mirroring real-life scenarios, we believe that a three-dimensional simulation might provide more accurate results. We were only able to provide static images, whereas a 3D simulation could provide a more realistic environment with more detail. This might include a simulated approach to an intersection, which could more accurately capture eye movements and the time it takes to actually locate the stop sign. We expect that the results would lead to the same conclusion.

Finally, we believe that a greater range in the age of participants would also make a difference in a future study. All of our participants were undergraduates at Clemson University and between the ages of 18 – 22. More than likely, senior citizens would have a more difficult time during the study since vision deficiencies become more common as a person ages.

CONCLUSION

Based on the results of our study, we are able to conclude that there is significant evidence indicating that vegetation overgrowth does impact the effectiveness of stop signs. We predicted that vegetation surrounding stop signs in rural areas where overgrowth is more prevalent would alter their effectiveness. Our results indicated this to be true, with there being an almost 68% lower time to first fixation for stop signs not obscured by vegetation as opposed to stop signs that are obscured. While we feel our experiment was successful, there are certainly improvements and modifications that could be made to further enhance the reliability and complexity of the study. We hope that other researchers in the future will build on what we have accomplished in hopes of making driving safer and making road signs more visible.

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