Designing Traffic Signs: A Case Study on Driver Reading Patterns and Behavior

Jacob Chan
Department of Information Systems and Computer Science
Ateneo de Manila University
Loyola Heights, Quezon City 1108
(63) 426-6001
jtchan@ateneo.edu

Paolo Gonzalez
Department of Information Systems and Computer Science
Ateneo de Manila University
Loyola Heights, Quezon City 1108
(63) 426-6001
pggonzalez@ateneo.edu

Ella Mara Melanie Perez
Department of Filipino
Ateneo de Manila High School
Loyola Heights, Quezon City 1108
(63) 426-6001
mdperez@ateneo.edu

ABSTRACT
Eye tracking has been studied in many fields, including advertising and newspaper design. It is an effective tool to study reading and viewing patterns of different kinds of audiences. In this study, we analyze the behavior of motorists in reading traffic signs. Using eye-tracking data, we determine at which parts of traffic signs drivers focus their attention, and if there are differences in viewing patterns when test subjects are shown multiple signs that convey similar meanings. Our results suggest that behavioral patterns, which are common in newspaper design and advertising can also be applied in the analysis of reading traffic signs. We also determined that participants read traffic signs in a standard fashion, and they tend to ignore these signs' other characteristics, such as shape and color. Finally, given our test results, we are able to provide empirical evidence on motorists' sign reading patterns — or if they even read these signs at all — which can further aid in standardizing traffic sign designs.

Categories and Subject Descriptors
H.5.0 [**Information Interfaces and Presentation**]: General, H.5.2 [**User Interfaces**]: *Standardization, User-Centered Design*, J.4 [**Computer Applications**]: Social Sciences – *Psychology*

General Terms
Experimentation, Human Factors, Measurement, Design

Keywords
Traffic sign, design, eye tracking, recognition

1.INTRODUCTION
Reading instructions is one of the most basic skills taught in primary school. However, as people age, this ability tends to be taken for granted. Not paying attention and failing to understand instructions can prove to be detrimental and even dangerous, which is the often case with traffic signs [9,20]. Road signs can be used to control vehicular or pedestrian traffic. These can also minimize risk in areas such as construction sites, schools and hospitals. These can even guide people to their destinations.

Since there is only a limited time to understand the message that each traffic sign is supposed to convey, motorists have to be able to quickly identify and decode these instructions, so much so that most traffic signs should be second nature to them. For a skilled reader, the average fixation takes 250 milliseconds [22,23]. However, crude visual clues can influence saccades as well as fixations, producing negative results.

Although many motorists may be able to recognize road signs, it is not necessarily true that they will fully understand the meaning or purpose of the traffic signs they see. In 2011, the top traffic violations of motorists in the Philippines included violations of no loading/unloading, no U-turn, and speed limit signs [18]. The primary reason for these violations is the lack of discipline of motorists. As a result, this study has been conducted to determine how quickly motorists actually read and understand traffic signs. Furthermore, as a secondary goal, the study also aims to find elements in traffic signs, which can help improve visibility, eye movement patterns, identification and recognition [2,23].

Our goal is to determine how useful traffic signs are in helping drivers to follow basic traffic rules. We want to determine if there are differences in eye movement when users are shown several traffic signs. We also want to find out if changing the appearance of a traffic sign will be able to aid users to better determine traffic rules. Furthermore, we want to know by means of eye tracking how to improve the visibility of traffic signs, especially to be able to inform motorists of traffic rules currently being implemented. Another aspect we looked on in this experiment is the familiarity of driver participants in reading traffic signs. In other words, we want to determine whether there is a difference if the user sees a familiar traffic sign or if the user sees a different version of the same sign. We also want to know if similar methods used for eye tracking in different fields like advertising and newspaper design analysis can also be applied in traffic sign eye tracking.

2.RELATED LITERATURE
2.1. Eye Tracking
Eye tracking is an emerging field in Human-Computer Interaction that focuses on the eye movement patterns of a participant given a particular image. Significant indicators of eye-tracking research include fixations, saccades, scan paths, blink rates, pupil size, and

pupil dilation [23]. Each eye-tracking experiment has stimuli, which participants are asked to view. Each stimulus has certain significant parts known as regions of interest. Fixations are stable gazes (or pauses) [26] that tend to last for 200-300 milliseconds [22,23]. Saccades are eye movements between fixations [26], while scan paths are sequences or collections of saccades and fixations in one eye-tracking experiment. The fixations can also be counted for each eye tracking experiment, and this is known as the number of fixations. Furthermore, each fixation that occurs per region of interest is measured and totaled, and this is known as the total contact time.

2.1. Eye Tracking Applications

Different studies have been conducted in determining eye-tracking patterns. These implementations have been used in various fields, including design and reading behavior analysis. For example, the study of Rayner *et.al* [24] focused on recording eye movements of viewers when shown with print advertisements. Interestingly, the viewers focused more on the text in the ads than the pictures. Saccades were higher when the participants were viewing the images in the ads, but more fixations were found in the ads' text. The larger parts of the print were also more thoroughly read than the smaller parts. The researchers concluded that customers tend to focus more on the text part of ads instead of the ads' images.

Holmqvist and Wartenberg [11] conducted a similar study, but this time in analysis of newspaper design. The study discussed some design principles behind newspaper articles, from the arrangement to the content of each article. Eye tracking methodology was used, which measured 50 times per second where readers were looking. One of the interesting results from the study showed that readers would only spend 128 seconds reading tabloids, and would spend more time reading broadsheet newspapers. Readers also spent more time reading than merely scanning through tabloids. Content analysis may have been the primary reason why users tend to gaze longer at some parts of newspapers. In the future the researchers intend to run the study with two versions of the same newspaper instead of one in order to test the hypothesis further.

Some studies have also been focused on the treatment of different misbehaviors in reading, specifically in reading comprehension remediation and recall [16,27]. An interesting study was conducted by Horstmann *et.al* [13] that utilized eye tracking to determine decision-making patterns. To determine the decision-making skills of users, specifically for distinguishing intuition and deliberation, the participants were asked to perform simple and complex city-sized tasks like determining which city was likely to have more population. The finding was that instruction-induced deliberation had longer fixations, resulting to more complete information search and more repeated investigations.

2.2. Visual Behaviors of Drivers

Studying visual behavior has been linked to attention studies. Some of these studies have been applied in many eye-tracking studies, which include web browsing, image quality assessment, and attention disorders [3,8,17]. However, in the context of driving, there are two major reasons why attention in driving is important. These reasons are distractions [19] and fatigue [12,28], which does not only affect traffic sign reading, but also the overall safety of the driver.

Distrations are one of the key reasons why drivers tend to divide attention based on the tasks given at a certain time. Overloading information can deter driver performance, thus increasing the risk of accident occurring, as well as decreasing road awareness. Most distractions are auditory in nature, especially caused by mobile phone calls [5,19]. When phone calls are finished, drivers tend to be less focused on the road because they are still preoccupied by the previous phone call made [25]. Furthermore, the effects of auditory distractions have been determined to be comparable to driving while intoxicated.

Another possible reason why driver performance can deteriorate is fatigue. When drivers are fatigued, some of the effects include slower eyelid movement, yawning, and gazing [6,29]. A study by Ji and Yang [15] suggest a more robust system for determining driver vigilance. The researchers were able to devise a more real-time eye-tracking system to determine the alertness level of drivers, thus enhancing their awareness of different recognition of objects along the path they are driving at.

2.4. Traffic Sign Recognition, Design, and Analysis

In the field of traffic sign design, there have already been different studies conducted. In the study of Gao *et.al* [7], color and shape were the most dominant visual features to be seen in traffic signs. In the experiment conducted, visual models were used to extract color and shape features. Overall, their proposed FOSTS (Foveal System for Traffic Signs) model was able to identify different traffic signs at a moderate distance. However, the experiment did not focus much on eye tracking patterns, since the experiment was limited to feature extraction.

Ho *et.al* [9] conducted another study on traffic signs, specifically on eye movements. The study focused on the different effects of clutter, aging, and luminance on the visual search for traffic signs. The study found interesting results, including the increased response times and fixations as well as increased traffic sign luminance during nighttime. Errors were mostly found among the elderly participants. With increased clutter and aging came decreased search efficiency.

Al-Madani and Al-Janahi [1] conducted a different study on traffic signs that studied the comprehension of traffic signs by different types of drivers. On average, the drivers recognized 56% of the 28 different traffic signs based on several factors, including education, monthly income, accident rates, and nationality. Most Western drivers had a more comprehensive knowledge of the traffic signs, which raises serious questions on the worldwide applicability of traffic signs.

Jacobs *et.al* [14] conducted another study involving the legibility of traffic signs in comparison with participants that have normal or reduced visual acuity. The study showed that given 16 familiar road signs, symbols were more legible by 50% at a certain distance threshold than alphabetized signs. They concluded that using more symbols and increasing the size of signs with text were required, which can aid drivers in detecting them.

Most of these studies on traffic sign design and analysis do not focus much on eye-tracking behavior itself. However, some studies have shown that most of these systems can be adapted to detect and possibly determine human eye tracking recognition patterns of these signs using the same factors as an artificially intelligent system, including color, shape, and motion [4,21].

3.METHOD

3.1.Participants

Six (6) motorists with at least two years of driving experience participated in the experiment. Each participant was at least 18 years old, and has held at least a non-professional driver's license. We had to reject a seventh participant, because she could not reach the minimum score to start the experiment. The participants were compensated with food as a reward for completing the task.

3.2.Apparatus

Eye movement data for the experiment were collected using the EyeNTNU developed by the Department of Electrical Engineering in the National Taiwan Normal University. It is a table-mounted eye-tracking device with a sampling rate of 120 Hz and an angle error of less than 0.3^{o}. The eye-tracking device has two infrared LED lights and can be connected to a desktop or laptop computer with USB 2.0. The eye tracker is supported on Windows XP or higher. The eye tracker hardware has a holder to keep it in place. While detecting their eye movements, participants are kept from moving by having them place their head on a chin rest. When the participants blink, the eye-tracking device does not record the eye movements. Figure 1 shows the set-up of the eye-tracking device:

Figure 1. EyeNTNU Eye-Tracking Device

The EyeNTNU eye tracker has a software package included. The software has two main features. First, the researchers are able to define regions of interest given certain images at which participants are asked to look. Figure 2 shows an example of the regions of interest defined in an experiment for studying eye movement patterns for handbag selection in e-commerce [10]:

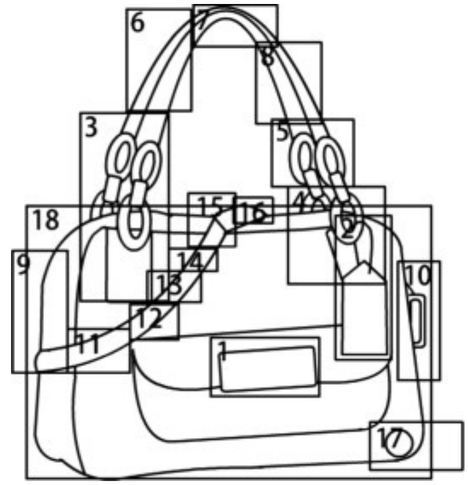

Figure 2. Regions of Interest Example

Another feature of the software tool for the EyeNTNU is that it has a built-in fixation calculator, which computes different parameters for the regions of interest, namely the total contact time (TCT), number of fixations (NOF), latency of first fixation (LFF), and duration of first fixation (DFF). The software uses descriptive statistics for analysis of the eye movement data collected, while considering also the regions of interest as possible factors.

3.3.Materials

There were 16 traffic sign rules that were gathered from across the Internet using Pixabay, a library of Public Domain images. These images were initially large, and were later edited to fit the 1366x768 size required by the EyeNTNU Eye Tracking software. The participants, given that they had prior driving experience for two years, are expected to already be familiar with some of the traffic signs gathered. Each sign can have another version with words instead of symbols, as shown in Figure 3. Some of the signs were modified in terms of their color and shape. Each of the images were shot at different angles and with different background scenarios.

Figure 3. Example of Different Versions of No U-Turn sign with a) sign only, b) word only

3.4.Procedure

3.4.1. Experimentation

First, the EyeNTNU Eye Tracker was set up. During the experiment setup, the destination for the results was set, and each of the traffic sign photos were loaded in the software.

The participants were then asked to put their chin on the chin rest and gaze at the monitor of the laptop. The EyeNTNU Eye Tracker was placed approximately 45 degrees under the eye at approximately 5 centimeters away from the bottom of the eye. Sometimes, a manual calibration was necessary, in which the test subject is asked to look at different locations on the monitor, in order to ensure that the camera could properly detect the pupil. Then, the eye tracker was calibrated for the software to accurately follow the eye gaze. A mini-game known as the nine-point dot test was set up to calibrate the eye-tracker, and the goal of the participants is to follow the nine-point dot test as accurately as they can. A passing mark of at least four (4) stars for the test was necessary before each participant was allowed to proceed with the experiment. Otherwise, the test is repeated until the participant gets at least one 4-star mark.

Once calibration was complete, the eye tracking software is then connected to the gaze tracker to record the gaze of the participant. Each participant was asked to stare at a particular image of a traffic sign as long as they needed to be able to see and decode it. Once they were able to interpret it, they could move on to another traffic sign image. The gaze tracker is used to measure how quickly the participant can identify important parts of the sign. It was also used to determine which among pictorial or written road signs were able to more quickly and easily deliver traffic rules information.

3.4.3. Analysis

After collecting the data from the EyeNTNU Eye Tracker, analysis was performed. The hot zones were then determined given the data previously collected. If the hot zones were off the traffic sign, corrections had to applied to properly overlap it on the image. Figure 4 shows an example on how the hot zones were collated:

Figure 4. Hot Zone Example

Once accomplished, the regions of interest were then gathered. Using the ROI Splitter software from the EyeNTNU software package, rectangles were drawn on each image to determine the regions of interest per image. Once accomplished, the analysis is performed using the built-in fixation calculator from the EyeNTNU Eye Tracking software package, resulting in the following parameters: total contact time (TCT), number of fixations (NOF), latency of first fixation (LFF), and duration of first fixation (DFF).

4.RESULTS AND ANALYSIS

We analyzed our data based on the total contact time and the number of fixations for each of the 16 traffic sign images gathered. We found out interesting results based on the empirical data we gathered from the experiment. First, we report the data initially gathered. Then, we analyze our data based on our proposed hypothesis that state the reading patterns of different drivers on average. Finally, we discuss the general implications of the different kinds of traffic sign design based on the data gathered.

4.1. Total Contact Time Results

Table 1 shows the empirical results of the average total contact time (in milliseconds) of each image, while describing each image based on the shape, message, and the region of interest with the highest total contact time. Furthermore, some significant images that were gathered were also analyzed in relation to reading patterns.

Table 1. Summary of Eye-Tracking Results with Maximum Total Contact Time

Picture	Name	Shape	Type	Highest ROI	Time
1	Stop	Hexagon	Word	STOP	152.67
2	Rail	Circle	Symbol	Head and Body	95.33
3	Stop	Hexagon	Word	STOP	122.67
4	School Zone	Pentagon	Symbol	2 People	161.33
5	Ped Xing	Triangle	Symbol	Person	78.67
6	Ped Xing	Square	Symbol	Person	95.83
7	Bike Lane	Circle	Symbol	Bike	111.33
8	Do Not Enter	Circle	Word	Bar	51
9	Give Way	Triangle	Word	GIVE	69.33
10	Speed Limit	Square	Word	35	48.5
11	Do Not Enter	Circle	Symbol	Bar	107
12	Right Side	Circle	Symbol	Arrow Tail	48.5
13	Slippery When Wet	Triangle	Symbol	Car	35.5
14	One Way	Rectangle	Symbol	Way	30
15	Left Side	Diamond	Symbol	Backgrou nd	33.17
16	Bus Stop Arrow Here	Circle	Symbol	Arrow Tail	47.33

Each image is classified into either a word or a symbol. Signs that have words and symbols in them are considered words as well, as shown by the “Do Not Enter” sign in Figure 5. For symbols, each image has three regions of interest, namely the symbol itself, the background, and the foreground. Figure 6 shows an example of this.

Figure 5. Do Not Enter Sign With Words

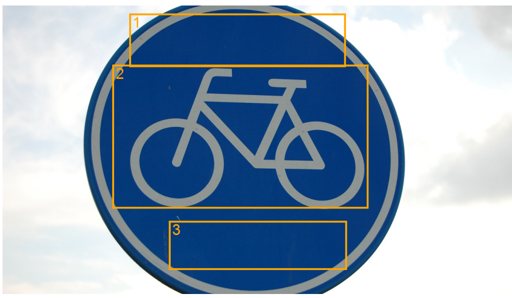

Figure 6. Bicycle Lane Sign With Regions of Interest

On the other hand, for word-type traffic signs, each word is a region of interest, with the background representing another region of interest. However, for images 12, 14, 15, and 16, the arrowhead and tail are considered regions of interest as well. Figure 7 shows an example of a one-way sign that has three different regions of interest: the arrowhead, the "one" and the "way."

Figure 7. One Way Sign With Regions of Interest

In terms of the type of symbol, as shown in Table 2, worded traffic signs had a higher total contact time compared to those only with symbols. Perhaps this is a result of users reading and deciphering the message the moment they were shown word images. Furthermore, the participants tend to be adept in reading symbols, implying that motorists were able to decipher symbols much faster given their driving experience. Moreover, drivers did not read the color background of both words and symbols, which proves that the content of each statement, whether in words or in pictures (as represented by symbols in the traffic sign design) is more important [11].

Table 2. Comparison of Word and Symbol Traffic Signs Based on Average Fixation Time

Traffic Sign Type	Average Fixation Time
Symbol	76.73
Word	88.83

Many of the reading patterns of each of the symbols in the study focused on a top-down, left-right approach. However, this was not always the case. The main focus of circular signs was the middle part, such as the Do Not Enter sign shown in Figure 8. In non-circular signs, the scan path distribution showed that the focus was more evenly distributed. In other words, the focus is on the center of the signs, regardless of the background shown [11], regardless if the traffic sign is a word or a symbol.

Figure 8. Do Not Enter Sign With Scan Path

For triangles and other sided polygons, participants mostly looked at the top part first. In the case of arrows, however, the participants stared at the direction of the arrow first, as shown in Figure 9. Most of the hot zones were found in the direction of the arrow, which was pointing to the background. Perhaps this is an issue of the perspective of the driver. The same was also true in the One-Way sign shown in Figure 7.

Figure 9. Give Way Sign Showing Gaze Distribution

Another interesting feature in the experiment is that participants will tend to focus on words printed in larger typeface. Regardless of the color, participants focused more on the bigger part of word traffic signs. A possible reason for this is because the participants are very familiar with the traffic signs such that even with words, they tend to glimpse at it even without looking at the image. Figure 10 shows a speed limit sign, signifying that the participants focused more on the number 35. Perhaps this is because of numbers being easier to interpret and recall [7].

Figure 10. Speed Limit Sign Signifying Focus on the Number Part of the Sign

4.2. Number of Fixations Results

Table 3 shows the results gathered of each image in relation to the total number of fixations per region of interest. We added each number of fixations of each participant and computed the average for each sign. This is done in order to show how detailed each fixation was on average. Our goal is to show that lesser fixations may imply that there is lesser gazing from the participant.

Table 3. Summary of Eye-Tracking Results for Total Number of Fixations

Picture	Name	Shape	Type	Total Average Fixations
1	Stop	Hexagon	Word	4.33
2	Rail	Circle	Symbol	2.17
3	Stop	Hexagon	Word	2.83
4	School Zone	Pentagon	Symbol	5
5	Ped Xing	Triangle	Symbol	2.67
6	Ped Xing	Square	Symbol	2.5
7	Bike Lane	Circle	Symbol	2.33
8	Do Not Enter	Circle	Word	1.83
9	Give Way	Triangle	Word	2
10	Speed Limit	Square	Word	1.83
11	Do Not Enter	Circle	Symbol	3.5
12	Right Side	Circle	Symbol	3
13	Slippery When Wet	Triangle	Symbol	1.5
14	One Way	Rectangle	Symbol	1.33
15	Left Side	Diamond	Symbol	2.33
16	Bus Stop Arrow Here	Circle	Symbol	2

Each image was classified as either symbols or words. Given the total average number of fixations, the sign that received the least total average number of fixations was the One-Way symbol shown in Figure 7. It only had an average fixation of 1.33, meaning that this sign was the least gazed upon by the participants on average. However, the traffic sign with the highest total average fixations is the School Zone sign found Figure 11. Perhaps this is because it had a unique shape. Furthermore, the empirical results imply that the participants were not very familiar with the sign. Perhaps the cause of this again was its shape, although this is not necessarily true in comparison with the two Stop signs shown.

Figure 11. School Zone Sign

The School Zone sign is similar to the Pedestrian Crossing sign shown in Figure 4, but what made the sign different is the lack of familiarity of the participants. Most Pedestrian Crossing signs also show a symbol of a pedestrian lane, as shown in Figure 4. However, Figure 11 does not show a pedestrian lane, which may have caused either confusion or further gazing from the participants. In Table 1, the School Zone sign also scored the highest average fixation time, thus implying that the sign was the most gazed upon by participants.

Another statistic that can be considered is the average fixations for words and symbols, as shown in Table 4. The average fixations of word and symbol traffic signs are almost identical to one another, with words having more fixations than symbols. This implies that participants read the words on average, and they looked at the words more than they did the symbols. Furthermore, this also shows that the fixations and the total fixation times are directly proportional to one another.

Table 4. Comparison of Word and Symbol Traffic Signs Based on Average Number of Fixations

Traffic Sign Type	Average Fixations
Symbol	2.46
Word	2.75

5.CONCLUSION

Our study suggests that drivers tend to read traffic signs in a top-down, left-right approach. Furthermore, one consistent pattern seen in reading the different traffic signs is that they primarily focus on the center part of the sign, while at the same time having a well-distributed scan path. Furthermore, different traffic sign design is not affected by color or even variation of signs. This implies that regardless of shape or color, traffic signs tend to be consistent in conveying the message, showing that most participants do not take note of the traffic sign details [11]. Perhaps this is a result of the familiarity of the participants in the traffic signs and rules, regardless of traffic sign shape. Also, a lesser contact time for the signs implies that the participants memorized the sign already, resulting into not going much into details of the signs, further implying familiarity. This is especially important so that traffic sign design will be much simpler in conveying current traffic rules, which are necessary for all times, especially times of emergency or even road readjustments.

Studying traffic sign design can possibly lead to standardization of traffic signs based on empirical data. A possible future study for this topic is the implementation of more standardized traffic signs, depending on the shape. As shown by Holmqvist and Wartenberg [11], most users tend to give more importance to the content of what they read rather than the details, which is also true for our study. What is needed is a more direct way of conveying traffic sign rules, thus increasing public safety measures and reducing traffic crime rates. Modified versions of the same traffic sign do not affect users simply because they want to get the message without going into details, which is similar to the advertising design study conducted by Rayner *et.al* [5]. However, when users are shown the same sign with different shapes, participants tend to gaze longer and fixations increase, implying that the participant is trying to grasp the message of the sign by gazing at it longer. Based on the data gathered and analysis, our study suggests that a similar approach can indeed be implemented in future studies for traffic sign design.

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