ABSTRACT

MACHADO, PATRICIA VEIGA SILVA. The Impact of Nine-Panel Logo Signs, Logo Familiarity, Logo Format, and Drivers’ Age on Food and Attraction Target Accuracy. (Under the direction of Dr. William Rasdorf.)

Logo signs are large blue signs located in advance of strategic interchanges that allow businesses that provide food, gas, and lodging to promote marketing by placing their logos on these signs. Some of the benefits of participating in the Logo Signing Program include improvement in the businesses’ chances of increasing sales and revenue, the having their logos placed on a large and visible sign along Interstates.

The MUTCD states that the maximum number of business logos per sign is six. The NCDOT desires to increase the maximum number of logos per sign from six to nine. However, once the number of logos per sign increases, the additional information might overload drivers’ capacity to identify businesses placed on logo signs, which reduces the effectiveness of the logos. This could result in an unexpected outcome; businesses might lose interest in participating in the program because drivers are not able to identify their logo from among the nine presented.

The objective of this study was to verify how drivers from different age groups (young, middle age, and elder) were able to accurately identify a logo target on a logo sign under different logo sign presentation formats (number of logos per sign, logo familiarity, and logo format). It also sought to determine if correct identification of logo targets has some relation to either driver performance and/or visual behavior.
A total of 60 participants used a driving simulator to identify both food and attraction logo targets. The scenario simulated a normal Interstate driving environment and both lane and speed deviation data were collected in real time. In addition, eye-tracking equipment was used to collect the participants’ eye movement data including maximum off-road glance duration and fixation frequency to the area of interest (AOI).

Three different analyses were performed to assess target identification accuracy (how accurately drivers can identify a target on a logo sign); ANOVA, contingency tables, and logistic regression. With respect to number of logos per sign, the results showed that drivers’ accuracy was not significantly different between six and nine-panel signs when drivers were looking for familiar logo targets. However, when the logo targets were unfamiliar, drivers had lower accuracy for nine-panel than they did for six-panel sign. Logo familiarity was also found to have a significant effect on accuracy with unfamiliar logos (small and local business) resulting in lower accuracy than familiar logos (chain businesses). With respect to logo format, the results showed that drivers had lower accuracy for symbol-logos than for text-based logos. While the difference was significant, both formats resulted in accuracy of 89% and greater. Another major finding was that elder drivers performed worse than young and middle age drivers; overall, elder drivers had only a 54% accuracy rate, while the other two age groups’ accuracy was above 80%.

It was also found that a driver’s target identification accuracy was primarily dependent on the maximum off-road glance duration. Logistic regression models revealed that an increase of 1 second on maximum off-road glance duration increases the chance of correctly identifying the target by 21%.
These findings are of interest to NCDOT with regard to their intent to increase the number of panels from six to nine per logo sign. Also, when deciding on a specific logo sign design, driver age should be considered, with special attention to elder drivers, having the worst accuracy among the groups. Other parties that might benefit from these findings are the businesses that participate in the Logo Signing Program.
The Impact of Nine-Panel Logo Signs, Logo Familiarity, Logo Format, and Drivers’ Age on Food and Attraction Target Accuracy

by
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DEDICATION

Dedicated to my family for their unconditional love and for always believing in me. Who I am is just a small reflection of who they are. Even the great distance between the U.S. and Brazil was not enough to separate us.
BIOGRAPHY

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1.0 INTRODUCTION

Logo Signing Programs were approved by the Federal Highway Administration (FHWA) through the Highway Beautification Act of 1965 to support the placement of signs in advance of strategic interchanges that allow businesses to promote marketing by placing their logos on these signs. These large blue signs are now located along freeways, interstates, and exit ramps and are referred to as logo signs.

According to the Manual of Uniform Traffic Control Devices (MUTCD) (FHWA, 2009), logo signs (designed by “specific service sign” on the manual) are defined as “guide signs that provide road users with business identification and directional information for services and for eligible attractions” (FHWA, 2009). They are large blue signs that contain logos of business which “shall be limited to gas, food, lodging, camping, attractions, and 24-hour pharmacies” (FHWA, 2009).

According to Park et al. (2013), symbol logos have a significant and positive effect on consumer commitment to business; as a consequence of this commitment, businesses perform better. Based on this study, it can be inferred that businesses participate in the Logo Signing Program to improve their chances of increasing sales and revenue. Also, small businesses enable their logos to become better known by displaying them on logo sign. In doing so, drivers from other areas become aware of the local business options. A survey conducted by the Oregon Travel Information Council (OTIC) in 2010 interviewed 200 Oregon drivers and found that 86% of the participants said they were aware of logo signs and from that group, 94% said logo signs were helpful while they were traveling (OTIC, 2010).
Additional benefits of participating in the Logo Signing Program include the fact that drivers rely more on those businesses. This may be because the logo signs are state-sponsored and are clearly visible, consisting of 15 feet by 10 feet signs (NCDOT, 2006). Another benefit is that the logo signs located on exit ramps provide drivers with important and timely information about the business location (direction and distance).

However, the MUTCD states that the maximum number of business logos per sign is six and there is a maximum of four logo signs allowed at each interchange. In other words, the maximum number of businesses that can participate in the Logo Signing Program per interchange is limited to 24 (six businesses times four logo signs). This limitation spans all six logo categories: gas, food, lodging, camping, attractions, and 24-hour pharmacies. These limitations are neither explained nor justified in the manual.

The six-panel limitations set by the MUTCD might raise some issues involving businesses as well as the North Carolina Department of Transportation (NCDOT) due to the fact that at some interchanges there is higher advertising demand by businesses (especially near large commercial centers) and consequently more than 24 businesses want their logos displayed at the interchange.

To mitigate the effects of this limitation, NCDOT is interested in increasing the maximum number of logos per sign from six to nine. To do so, NCDOT obtained permission from the Federal Highway Administration to conduct studies whose goal is to show the feasibility of increasing the maximum number of logos per sign from six to nine. As part of one of those studies, fifteen nine-panel logo signs were distributed at twelve interchanges in North Carolina to enable the comparison of crash data before and after their installation (Simpson, 2007).
After analyzing the crash data, the author found that the crash rate decreased after installation of nine-panel logo signs, and therefore, concluded that there is no reason to not use nine-panel logo signs.

From a business’s’ perspective, it is important that drivers can see and identify their logos on the signs, as there is an average annual investment of $1,200.00 per business per interchange to have their logo on a sign in North Carolina (see Appendix A). This dollar amount may not concern large businesses, but it may represent a significant cost for small and local businesses. Therefore, if the NCDOT wants to increase the number of logos per sign from six to nine, it is important to conduct research to verify how accurately drivers are able to identify a business’s logo on a logo sign. If the case accuracy rate is significantly lower for nine-panel signs than for six-panel signs, NCDOT might reconsider this option.

Despite the fact that the MUTCD has a standard nomenclature for different types of signs, this study (as well as past studies) has adopted different names to identify a specific type of sign or to describe a sign. Therefore, the section 3 of this document presents definitions and explanations of the terms related to logo signs that are necessary to better understand this subject matter.

1.1 Problem Statement

The NCDOT desires to increase the maximum number of logos per logo sign from six to nine. However, it is a question as to whether or not the additional information might overload drivers’ capacity of identifying businesses placed on the logo sign, thereby reducing the
effectiveness of the logos. It is then possible that businesses might lose interest in participating in the program because drivers are not able to identify a specific logo among the nine presented.

A survey conducted by OTIC, also in 2010, interviewed the 200 businesses that participated in the Oregon Logo Signage Program and found that although 38% of those businesses believed that logo signs were extremely effective, more than half (53%) of those interviewed said that logo signs were “somewhat” effective. Thus, more than half of the businesses were not completely satisfied with the benefits of the program. If the results of that survey are representative of businesses’ satisfaction among different states, precaution should be taken with new logo sign presentation formats in order to ensure that businesses are fully satisfied and do not withdraw from the program due to a lack of sales as might be the case if drivers are unable to identify their logo on the logo signs.

Also, additional logos may require drivers to have a longer off-road glance duration to find the logo target that they are looking for. However, when the maximum off-road glance duration exceeds 2 seconds unsafe conditions for drivers may arise (NHTSA, 2012). Because of this, it is necessary to ensure that a configuration of nine logos per sign does not represent a safety issue to the driver.

1.2 Study Objectives

The objective of this study was to assess drivers’ accuracy (ability to identify logos on a sign) under different configurations of signs and logos and, moreover, to determine if correct identification of logo targets has some relation to either driver performance (speed and lane
deviation) and/or visual behavior (fixation frequency to AOI and maximum off-road glance duration). The following four independent variables were explored.

- **Age:** this study assessed the impact of drivers’ age on logo identification accuracy.

- **Number of panels:** one of the goals was to assess how the number of panels on a logo sign might affect drivers’ logo identification accuracy. As explained before, a nine-panel logo sign presents more information than a six-panel sign, and as a result, drivers might have a lower rate of identification accuracy.

- **Logo familiarity:** this study also explored how the familiarity of the logos may impact the drivers’ accuracy. Some businesses are more familiar to the drivers than others, which poses the premise that drivers may take shorter glances away from the road while viewing a familiar logo. In this research, familiar business were defined as well-known businesses, usually chains, and unfamiliar are typically local businesses with a low name recognition rate by drivers.

- **Logo format:** another goal of this report was to compare text-based versus symbol-based logos. Park et al. (2013) found that symbol-based logos are significantly more effective than text-based logos in terms of representing businesses. However, the Park et al (2013) study had a general approach and was not focused on logo signs. Therefore, this study analyzed how both symbol-based and text-based logos might affect drivers and whether or not symbol-based or text-based logos have a better impact on the participants (as occurred in Park et al (2013) study).
Given these independent variables, additional analyses were conducted to evaluate the simple effects of miles driven in the past year on target identification accuracy under the different logo sign presentation format and the dependence of target accuracy on fundamental driving performance and visual behavior.

1.3 Research Tasks

This study was comprised of eight main research tasks as listed below. It is important to note that tasks 1 to 6 were performed by the research team rather than by one person.

1. Study the logo signs standards defined in the MUTCD (FHWA, 2009).
2. Conduct field surveys with two goals: (1) to determine the logo sign dimensions and the distances between them and (2) to estimate the percentage of familiar and unfamiliar logos for three different categories: lodging, food, and gas.
3. Develop a logo database to be used in the experiment.
4. Determine all signs necessary to create a realistic driving environment to be used in the driving simulator.
5. Design scenarios to be used in the driving simulator which manipulate variables, including, but not limited to, number of interchanges, spacing between the signs, distribution of six and nine-panel signs, of familiar and unfamiliar logos, and of text and symbol-based logos.
6. Data collection, which included 60 experiment participants at an average of 3hours/participant.
7. Analyze results obtained from the experiment and draw conclusions.
8. Produce a set of recommendations based on the findings.
2.0 LITERATURE REVIEW

The following sections summarize the literature relevant to logo signs. The literature review is organized into four sections: number of panels on logo signs, logo familiarity and format, drivers’ age, and driving simulators.

2.1 Number of Panels on Logo Signs

Research about how number of panels on a logo sign might affect driving performance, accuracy, and safety have been ongoing for a number of years, offering a significant body of knowledge on the subject. This section covers six studies that contain a considerable amount of information. To facilitate, the available information was organized into two subcategories: “accuracy” and “driving performance and visual behavior.”

2.1.1 Accuracy

Studies were conducted to compare how an increase from six to nine in the number of panels per logo sign might impact drivers’ ability of identifying a given logo target (accuracy analysis). Hummer and Maripalli (2008) and Dagnall et al. (2013) found that drivers’ accuracy was significantly higher for six-panel than for nine-panel logo sign. In contrast, Zhang et al. (2013) and Kaber et al. (2015) found that the number of panels was not a significant factor influencing drivers’ accuracy.

According to Hummer and Maripalli (2008), accuracy was significantly higher for six-panel than for nine-panel logo signs. In this slide-based experiment, the participants were asked to find a specific target on six-panel logo signs, on nine-panel logo signs, and on two services logo signs (one sign that contains two different categories). The authors suggested that drivers
might have more difficulty identifying a target on a nine-panel logo sign than on a six-panel sign during short exposure time, which this research established as 1 second. In this case, accuracy was only 60% for nine-panel configuration. However, when the exposure time increases from 1 to 2.5 seconds, accuracy for nine-panel signs increased from 60% to 89%. Another finding was that the position of the logo on the sign influences the time it takes a participant to identify a target. One limitation of this study was the fact that it was a slide-based experiment, which means that it does not simulate realistic driving conditions nor does it simulate a true driving environment.

Dagnall et al. (2013) conducted a study to evaluate and compare the impact of four-panel, six-panel, and nine-panel logo signs on driver performance. They found that participants had higher rates of accuracy for six-panel configurations than for nine-panel. When the number of panels increased from six to nine on a logo sign, participants required longer reaction times to identify the target. In addition, researchers found that the response accuracy was also a function of the position of the logo on the sign. One limitation of this study was that even though they used an LCD screen to simulate a highway and their data were electronically collected, there was no simulation of real driver conditions and driving tasks.

There were two additional studies funded by the NCDOT to investigate the impacts of nine-panel logo signs and overflow combination signs on drivers’ safety and accuracy. In the first study, Zhang et al. (2013) used a driving simulator where participants were asked to find a specific food target while driving. The authors found that although participants had slightly lower accuracy for nine-panel than for six-panel logo sign, it was not a significant difference.
The second study, by NCDOT (Kaber et al., 2015), also analyzed the effects of nine-panel logo signs on driver performance when compared with six-panel logo signs. This study used a driving simulator to create realistic driving conditions. The findings showed that drivers’ accuracy was not statistically different for both six and nine-panel logo signs. One limitation of this second study is that it used a familiar food target (Hardee’s) for all trials. It is postulated that doing so may have made the identification of the target easier for the different configurations of logo signs.

2.1.2 Driving Performance and Visual Behavior

Some studies were conducted in order to analyze how an increase in the number of panels per logo sign might impact drivers’ performance and behavior as well as their safety. Dagnall et al. (2013) concluded that a nine-panel logo sign (compared to a six-panel sign) increases unsafe conditions to drivers because participants required more than 2 seconds (accepted standard of eye glances away from the forward roadway. NHTSA, 2012) to identify a target on the logo sign. On the other hand, studies conducted by Carte and Wang (2007), Simpson (2007), Hummer and Maripalli (2008), Zhang et al. (2013), and Kaber et al. (2015) indicated that there was not significant impact on drivers’ performance when the number of panels per logo signs increases from six to nine.

Dagnall et al. (2013) found that young and old participants spent 2.2 seconds and 2.9 seconds respectively to find a target on a nine-panel logo sign, which is more than the accepted standard of eye glances away from the forward roadway (2 seconds according to NHTSA, 2012). The conclusion of this study was that an increase in the number of panels per logo sign was unsafe for drivers. One limitation of this study is the fact that the research team used the 2 second
standard as being the total search time (time participant took to determine whether or not the target was on the sign). While indeed the 2 second standard is intended to represent the maximum off-road glance duration at any one glance.

In contrast, Carter’s and Wang’s (2007) findings showed that nine-panel logo signs did not significantly affect driver performance when compared to the standard six-panel logo sign. The study was conducted by analyzing field observed unusual driving behaviors (e.g., breaking and drifting) in the field at specific interchanges where NCDOT installed nine-panel and overflow combination logo signs. The authors concluded that nine-panel logo sign did not increase driver distraction. However, one limitation of this study is that the data were collected using video cameras in the field and then analyzed at the office. Therefore, it was not always possible to determine the reason for a specific driver behavior.

Using the same procedure as Carter and Wang (2007), Simpson (2007) analyzed the crash data of specific interchanges within North Carolina before and after the installation of nine-panel and overflow combination logos signs. After almost 2 years of data collection, the author concluded that there was no significant evidence that these new configurations of logo signs (nine-panel and overflow combination) have a negative impact on the crash rate, and as a result, there is no reason to forbid their use.

Hummer and Maripalli (2008) also found that nine-panel logo signs do not have a significant impact on driver performance. The researchers found that subjects took slightly longer to find targets on nine-panel logo signs and two service logo signs when compared with the responses obtained from the six-panel logo sign. However, that time difference was not statistically significant in such a way that it could affect drivers’ performance.
Zhang et al. (2013) found that there was no significant effect of nine-panel configuration on either speed deviation or lane deviation. Greater visual attention was required to find targets on nine-panel logo signs and overflow combination signs and off-road fixation frequency was statistically higher for nine-panel than six-panel logo signs. However, the authors said that this result in fact means that drivers were more conservative in the presence of nine-panel signs and they would look back to the road with higher frequency rather than just looking at the sign. In relation to the maximum off-road glance duration, the difference was statistically insignificant and smaller than the 2.0 seconds standard established by NHTSA (2012). Based on these results, the researchers concluded that increasing from six to nine the number of panels on a logo sign does not have a significant effect on driver distraction or safety.

Similar, Kaber et al. (2015) found that there was no significant difference on driver performance (lane deviation and speed deviation) and visual behavior (maximum off-road glance duration and off-road fixation frequency) between six and nine-panel logo signs. The research team concluded that the proposed logo sign configuration (nine-panel) did not significantly affect driver safety.

2.1.3 Summary
The reviewed literature shows that even though drivers take slightly longer glances while looking for a logo target on a nine-panel logo sign when compared with the standard six-panel, there was not a significant impact on drivers’ performance that could represent higher risk to their safety. As a result, most of the studies, except for Dagnall et al. (2013), concluded that
there are no safety reasons to forbid the use of nine-panel logo signs in areas where there are a large number of businesses.

One measure of effectiveness of a nine-panel logo sign is how accurately drivers can identify a target on a logo sign. Dagnall et al. (2013) and Hummer and Maripalli (2008) found that nine-panel logo signs had lower accuracy, but when the viewing time increases to 2.5 seconds, the accuracy drastically increases. Two other studies (Zhang et al., 2013 and Kaber et al., 2015) found that there was no significant difference with respect to accuracy for six and nine-panel logo signs.

Table 2.1 shows a summary of the most relevant papers discussed here. The “References” column lists the reference cited. “Logo Sign Configurations” refers to the number of logos per sign and to overflow combination logo signs. The “Research Methods” column indicates which method was used in that specific study.

## Table 2.1 Summary of Papers by Logo Sign Configurations and Research Methods

<table>
<thead>
<tr>
<th>References</th>
<th>Logo Sign Configurations</th>
<th>Research Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Four-Panel</td>
<td>Six-Panel</td>
</tr>
<tr>
<td>Carter &amp; Wang (2007)</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Dagnall et al. (2013)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Hummer &amp; Maripalli (2008)</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Kaber et al. (2015)</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Simpson (2007)</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Zhang et al. (2012)</td>
<td>-</td>
<td>X</td>
</tr>
</tbody>
</table>
Table 2.2 shows a summary the papers related to logo signs and their findings. The first column shows the references, the second column shows the methods used by the research team, and the third column summarizes the findings.

### Table 2.2 Summary of Logo Signs Papers by Research Methods and Findings

<table>
<thead>
<tr>
<th>Reference</th>
<th>Method</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carter and Wang (2007)</td>
<td>Field observations</td>
<td>Nine-panel logo signs did not affect driver performance when compared to six-panel logo signs.</td>
</tr>
<tr>
<td>Dagnall et al. (2013)</td>
<td>Software and one 60-inch LCD monitor</td>
<td>Higher accuracy with six-panel compared to nine-panel logo signs. Nine-panel logo sign (compared to a six-panel sign) increases unsafe conditions to drivers because participants required off road glance duration longer than 2 seconds to identify the target.</td>
</tr>
<tr>
<td>Hummer and Maripalli (2008)</td>
<td>Slide-based</td>
<td>Higher accuracy with six-panel compared to nine-panel logo signs. Did not find difference on drivers’ performance when the number of panels increases from six to nine.</td>
</tr>
<tr>
<td>Kaber et al. (2015)</td>
<td>Driving simulator</td>
<td>Did not find difference in accuracy between six and nine-panel logo signs. Did not find difference on drivers’ performance when the number of panels increases from six to nine.</td>
</tr>
<tr>
<td>Simpson (2007)</td>
<td>Crash data analysis</td>
<td>Nine-panel logo signs did not have significant impact on crash rate when compared to six-panel signs.</td>
</tr>
<tr>
<td>Zhang et al. (2013)</td>
<td>Driving simulator</td>
<td>Did not find difference in accuracy between six and nine-panel logo signs. Did not find difference on drivers’ performance when the number of panels increases from six to nine. Nine-panel logo signs required higher off-road fixation frequency.</td>
</tr>
</tbody>
</table>

### 2.2 Logo Format and Familiarity

It has been postulated that different logo formats, including text-based and symbol-based logos might have different impacts on drivers’ accuracy. Hawkins and Rose (2005) performed a study to evaluate the impact of dual-logo panel (unique panel that contains two different logos)
on the response time and recognition of businesses by drivers. The methodology used in this research was to show pictures of logo signs to participants and ask them to indicate whether or not a logo target was present on the sign. In addition to dual-logo panels, the researchers also analyzed how the familiarity of a business influenced the response accuracy. The results showed that there are different response times for familiar versus unfamiliar logos and that dual-logos had a lower recognition rate than single logos at shorter response times. On the other hand, the response accuracy of dual-logos increased with logo familiarity and exposure time. The authors concluded that there was no reason to prohibit the use of dual-logos. However, they recommended that there should be a monitoring of driver performance in the field when exposed to this kind of logo.

Hummer and Maripalli (2008) compared the participants’ accuracy when they were searching for an unfamiliar food logo versus a familiar logo. Unexpectedly, participants had a better performance when looking for unfamiliar logos than for familiar. The authors suggested that these results are due the fact that if there is only one unfamiliar logo among a set of familiar logos, it is an easy target since participants can quickly recognize it through a process of elimination.

In Dagnall et al. (2013), the effect of different logo formats (text-based and symbol-based) on driving performance was analyzed when increasing the number of logos per sign (from four to six to nine). When analyzing logo format, isolated from other factors such as number of panels, it was found that elder drivers took longer to identify symbol-based than text-based logos, which does not happen with younger drivers. When the researchers analyzed the interaction of number of panels and logo format, they found that independent of the logo format, the
average response time of all participants increased with the number of panels per sign. These findings indicate that changing the logo format was not helpful in mitigating the effects that nine-panel logo signs have on driver identification performance. The authors also performed a search task which consisted of showing a logo target to the participants and then asking them whether the target was on a logo sign that was displayed on the screen. Based on this task, Dagnall et al. found that participants had higher accuracy (percentage or correct responses when the target was present) for text-based logos than they did for symbol-based logos for both four, six, and nine-panel logo signs; however, it is not clear in the text if these differences were significant.

In the study conducted by Kaber et al. (2015), it was found that distance guide signs (text-based) require lower off-road fixation frequency and maximum off-road glance duration than logo signs (symbol-based), which was the opposite of their hypothesis. One possible explanation is that for a text-based sign, drivers tend to follow a reading pattern (reading from left to right); however, drivers do not have a specific pattern for reading logo signs, which may result in inefficiency. Also, according to the authors, logo signs are significantly larger than distance guide signs, and furthermore, they may require more visual attention. With respect to accuracy, the authors did not find significant difference between distance guide signs and logo signs.

2.2.1 Summary

The reviewed literature shows that there is significant difference on driver performance when looking for symbol-based and text-based logos. It is interesting that both Dagnall et al. (2013) and Kaber et al. (2015) found that symbol logos drew more visual attention than text-based
logo and guide signs. In addition, logo familiarity seems to have significant impact on participants’ target identification performance; nevertheless, it is not clear how this variable affects drivers. While Hawkins and Rose (2005) found that driver performance improves with logo (business) familiarity, Hummer and Maripalli (2008) found that participants had higher identification accuracy rate for unfamiliar logos than for familiar logos. The differences may be explained by the different method used in both research studies. Based on these findings, it is clear that further studies are necessary to assess how logo familiarity impacts driver performance.

Table 2.3 shows a summary of the papers discussed above. The column “References” lists the reference cited. “Types of Logo” is divided into three categories: dual-logo, text-based, symbol-based logos, and logo familiarity. The “Research Method” column indicates which method was used in that specific study.

<table>
<thead>
<tr>
<th>References</th>
<th>Types of Logos</th>
<th>Research Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dual-Logo</td>
<td>Text-Based Logo or Guide Sign</td>
</tr>
<tr>
<td>Dagnall et al. (2013)</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Hawkins &amp; Rose (2005)</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Hummer &amp; Maripalli (2008)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kaber et al. (2015)</td>
<td>-</td>
<td>X</td>
</tr>
</tbody>
</table>
Table 2.4 shows a summary the papers related to logo format and logo familiarity as well as their findings. The first column shows the references, the second column shows the methods used by the research team, and the third column summarizes the findings.

Table 2.4 Summary of Logo Format and Logo Familiarity Papers by Research Methods and Findings

<table>
<thead>
<tr>
<th>Reference</th>
<th>Method</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dagnall et al. (2013)</td>
<td>Software and one 60-inch LCD monitor</td>
<td>Elder drivers took longer to identify symbol-based than text-based logos. Participants had higher accuracy for text-based logos than they did for symbol-based logos (it is not clear if it is a significant difference)</td>
</tr>
<tr>
<td>Hawkins &amp; Rose (2005)</td>
<td>LCD display</td>
<td>The response accuracy increased with the familiarity of the logo.</td>
</tr>
<tr>
<td>Hummer and Maripalli (2008)</td>
<td>Slide-based</td>
<td>Unfamiliar logos had significantly higher accuracy than familiar logos.</td>
</tr>
<tr>
<td>Kaber et al. (2015)</td>
<td>Driving simulator</td>
<td>Guide signs (text-based) required lower off-road fixation frequency and maximum off-road glance duration than logo signs (pictorial-based).</td>
</tr>
</tbody>
</table>

### 2.3 Drivers’ Age

Previous studies have concluded that drivers’ age has a significant impact on crashes or level of distraction caused by in-vehicle device use or by out of vehicle advertising and signs. Using questionnaires, Chen et al. (2007) found that drivers whose age ranges between 25 and 60 years old had a lower crash rate than those who are younger than 25 or older than 60.

Dingus et al. (1989) used an instrumented vehicle to analyze the impact of navigation devices on driver performance and found that drivers over 50 had their driving performance significantly degraded by the use of the instrument. Results showed that these drivers spent
more time looking at the device’s screen, took longer to complete required tasks, and also committed more task errors than drivers younger than 50 years old.

The study conducted by Hummer and Maripalli (2008) compared the percentage of correct answers between three age groups to verify if age had a significant effect on the participants’ performance. The young group consisted of drivers between 18 and 25 years old and represented novice drivers; the middle age group consisted of participants between 26 and 55 years old and represented experienced drivers; the elder group consisted of drivers between 65 and 75 years-old that were considered to be experienced, however with degrading physical and cognitive abilities compared to the middle age group. The results showed that the middle age group had significantly better accuracy performance than both young and elder groups.

To assess the impact of outdoor advertising, Edquist et al. (2011) conducted a study focused on drivers’ distraction caused by the presence of billboards on the road for different age groups. The researchers found that drivers younger than 25 years old (less than one year of experience) and drivers older than 65 years old were more affected by the presence of billboards than those who are between 25 and 55. Both younger and elder drivers are more likely to be slower in a lane changing task and took longer looking at billboards than they did looking at the road ahead, which can have a negative impact on their safety.

Kaber et al. (2012) conducted a study and used a driving simulator to verify how different roadway hazards affect the performance of younger (18 to 25 years old) and elder drivers (more than 65 years old) considering different driving environments (rural and city). The authors found that elder drivers are more affected by the increased complexity of a city environment than they are in a rural scenario. In addition, the results showed that elder drivers are more
cautious when exposed to hazards, e.g. they drove slower in the presence of hazards, which according to the research team might be a form of counterbalance to offset their reduction in perceptual and cognitive abilities.

Dagnall et al (2013) suggested that drivers over the age of 50 might be more affected by the increasing of number of panels on logos signs than younger drivers (less than 50 years old). In addition, they found that elder drivers took significantly longer to identify symbol-based logos than they did to identify text-based logos. This did not occur with younger participants. According to the authors, one possible explanation is that elder participants are not as familiar with the symbol logos as younger drivers are.

2.3.1 Summary
The literature shows that age is an important factor to be considered when studying driver’s performance. Different kinds of distractions and hazards have an impact on younger and elder drivers’ performance and safety when compared with drivers between 25 and 50 years old. Overall, studies suggested that this age influence might be explained by the fact that younger drivers are still inexperienced while elder drivers might have some decline in perceptual and cognitive abilities.

Table 2.5 shows a summary of the papers discussed above. The column “References” lists the reference cited. “Driver Characteristics” is divided into two categories: age and experience. The “Research Method” column indicates which method was used in that specific study.
### Table 2.5 Summary of Papers by Driver Characteristics Studied and Research Methods

<table>
<thead>
<tr>
<th>References</th>
<th>Driver Characteristics</th>
<th>Research Methods</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age</td>
<td>Driving Experience</td>
<td>Questionnaires</td>
</tr>
<tr>
<td>Chen et al. (2007)</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Dagnall et al (2013)</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dingus et al. (1989)</td>
<td>X</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Edquist et al. (2011)</td>
<td>X</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Hummer and Maripalli (2008)</td>
<td>X</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>Kaber et al. (2012)</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2.6 shows a summary the papers related to driver’s age and their findings. The first column shows the references, the second column shows the methods used by the research team, and the third column summarizes the findings.

### Table 2.6 Summary of Driver’s Age Papers by Research Methods and Findings

<table>
<thead>
<tr>
<th>Reference</th>
<th>Method</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen et al. (2007)</td>
<td>Questionnaires</td>
<td>Middle age drivers had a lower crash rate than both young and elder drivers.</td>
</tr>
<tr>
<td>Dagnall et al (2013)</td>
<td>Software and one 60-inch LCD monitor</td>
<td>Drivers over the age of 50 might be more affected by the increasing of number of panels on logos signs than younger drivers.</td>
</tr>
<tr>
<td>Dingus et al. (1989)</td>
<td>Instrumented vehicle</td>
<td>Drivers over 50 had worse driving performance than younger drivers.</td>
</tr>
<tr>
<td>Edquist et al. (2011)</td>
<td>Driving simulator</td>
<td>Both younger and older drivers are more likely to be slower in a lane changing task and took longer looking at signs than middle age drivers.</td>
</tr>
<tr>
<td>Hummer and Maripalli (2008)</td>
<td>Slide-based</td>
<td>Middle age group had significantly better accuracy than both young and elder drivers.</td>
</tr>
<tr>
<td>Kaber et al. (2012)</td>
<td>Driving simulator</td>
<td>elder drivers are more affected by the increased complexity of a city environment than they are in a rural scenario</td>
</tr>
</tbody>
</table>
2.4 Driving Simulator

Driving simulators are equipment that reproduce road and traffic conditions using simulation. They have been used in many studies with different purposes, including determining the effects that devices (e.g., navigators) and sign types might have on driver’s safety and performance (speed control, lane deviation, and acceleration).

2.4.1 Diving Simulator Data Validation

Some studies were conducted in the past with the goal of validating fixed-based driving simulators. In 1982, Blaauw performed a study to verify fixed-based driving simulator data by comparing it to field data obtained with the use of an instrumented car. Participants drove the simulator and the instrumented car while lane and speed deviation data were collected. By the end of the study, the author verified relative validity for lane deviation meaning that data collected in both simulator and instrumented car had the same “interactions effects of driving experience and task demands” (Blaauw, 1982), however, the driving simulator presented significantly higher values of lane deviation than those obtained in the instrumented car. Blaauw also verified absolute validity for speed deviation; that means there were no significant differences in absolute value of interaction of the speed data collected in the instrumented car and the simulator.

Like Blaauw (1982), Santos et al. (2005) conducted a study to validate a medium-fidelity driving simulator. Their research team analyzed in-vehicle information systems (IVIS) data obtained from three different apparatus: a low-cost laboratory simulator, a medium-fidelity simulator, and an instrumented car. According to this study, a medium-fidelity simulator
provides detailed analysis (including the nature and significance of an IVIS) and its data is validated by comparison with data collected by an instrumented vehicle in the field.

A similar study was also performed by Wang et al. (2010) to compare the data from a fixed-based driving simulator with field data. Participants were required to perform destination entry tasks using different IVIS devices while driving (at separate times) both an instrumented vehicle in the field and later the driving simulator. The results showed that measures of off-road glance frequency and total off-road glance duration were almost the same for both field and simulator conditions. Also, the standard deviation of speed for both apparatus was absolutely validated, meaning that there was an absence of significant impacts on driver performance due to differences between the field and simulator driving experience. Therefore, the research team recommended the use of a fixed-based driving simulator for data collection of both driver visual behavior and driving performance.

2.4.2 Driving Simulators on Signs Studies

Since driving simulators were validated as described above, researchers have been using them to conduct different studies with a variety of focuses such as drivers’ safety, impact of hazards on driver performance, and more. Some of those studies focused on the effect of logo sign presentation format on driver performance and logo identification accuracy rate.

Zhang et al. (2013) used an STISIM Drive M400 fixed-based driving simulator to assess the impacts of logo sign design on driver performance. This simulator consisted of a driver’s seat, a full size panel control with steering wheel, brake and gas pedals, and three 38-inch monitors that enable 135-degree of view for the participants. This study collected objective data such
as average speed, lane deviation, and speeding percentage data. Similarly, Kaber et al. (2015) also used the same STISIM Drive M400 to observe driver behavior under the distraction of guide and logo signs. Lane deviation and speed deviation data were collected and analyzed. In both studies, eye movement data was collected during the simulation with the use of eye tracking equipment.

2.4.3 Summary

The literature regarding driving simulators shows that they are a valuable tool for studying driver performance, as well as for investigating the impacts of independent variables such as signage and in-vehicle information systems (e.g. navigational aids). It may be the case that data obtained from instrumented cars might better represent driver performance under real driving conditions. However, this approach has two disadvantages. First, it is difficult to control aspects of traffic during the experiment, which can impact the results in different ways. Second, special attention must be given to participants’ safety when they drive an instrumented car under real conditions because they are subject to risks (e.g. crashing the car). As an alternative, the literature suggested that medium-fidelity driving simulators are capable of collecting valid data that is comparable with field data. In addition, driving simulators represent a safe method of studying and analyzing drivers’ performance under real driving conditions. Finally, according to Wang et al. (2010), a low-cost laboratory simulator can detect effects that IVIS might have on driver performance.

Other studies used driving simulators to analyze driver performance subject to the distraction of signs on the road. Data collected in those studies included, but was not limited to: speed deviation, average speed, lane deviation, and time of lane change. In addition, eye movements
(such as maximum off-road glance duration and off-road fixation frequency) were collected by using eye tracking equipment in conjunction with the driving simulator.

The “References” column in Table 2.7 lists the reference of papers discussed in this section. “Response Measures” presents the type of measure that was collected in each specific research study.

**Table 2.7 Summary of Papers by Kind of Response Measures Collected in Simulators**

<table>
<thead>
<tr>
<th>References</th>
<th>Response Measures</th>
<th>Research Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lane Deviation or Lane Change</td>
<td>Instrumented Car</td>
</tr>
<tr>
<td>Blaauw (1982)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Kaber et al. (2015)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Santos et al. (2005)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Wang et al. (2010)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Zhang et al. (2013)</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 2.8 shows a summary the papers related to driving simulators and their findings. The first column shows the references, the second column shows the methods used by the research team, and the third column summarizes the findings.
# Table 2.8 Summary of Driving Simulator Papers by Research Methods and Findings

<table>
<thead>
<tr>
<th>Reference</th>
<th>Method</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edquist et al (2011)</td>
<td>High-fidelity driving simulator</td>
<td>Sign study – data collected:</td>
</tr>
<tr>
<td>Kaber et al (2015)</td>
<td>Medium-fidelity driving simulator</td>
<td>Logo sign study – data collected: Speed deviation, lane deviation, off-road fixation frequency, maximum off-road glance duration (these last two responses were collected with an eye-tracking system).</td>
</tr>
<tr>
<td>Santos et al (2005)</td>
<td>Instrumented car, low-cost laboratory simulator, and medium-fidelity driving simulator</td>
<td>Driving simulator data was validated by comparison with data collected by an instrumented vehicle in the field.</td>
</tr>
<tr>
<td>Wang et al (2010)</td>
<td>Instrumented car and medium-fidelity driving simulator</td>
<td>Driving simulator data validation: Maximum off-road glance duration, off-road fixation frequency, and speed deviation data were validated.</td>
</tr>
</tbody>
</table>
3.0 SIGNS

This section describes the different signs used in the experiments described herein. All signs are specified according to the MUTCD (FHWA, 2009).

3.1 Logo Signs

Logo Signs are large blue signs that contain business information that is important to drivers. They are divided into lodging, food, gas, attractions, and camping categories. The MUTCD (FHWA, 2009) refers to this type of sign as “Specific Service Signs.” However, because most researches on this subject use the term “Logo Sign” the current document also uses this term.

Logo signs located on Interstates and freeways contain the following information: service category (lodging, food, gas, attraction, camping, or 24-hour pharmacy), the number of the next exit, and the logos of the businesses that are located near that exit.

Figure 3.1 shows some typical logo signs configurations. The left sign indicates only one exit (44) and one service category (gas). The center sign also indicates one exit (211), however, different from the left sign, there is a combination of two categories (gas and lodging). Finally, the right sign contains only one category (gas), but two different exits (211 A and 211 B).

![Figure 3.1 Examples of Six-Panel Logo Sign Located on an Interstate](image)
The MUTCD (FHWA, 2009) does not specify logo sign dimensions. Instead, the manual establishes (through section 2J.04) the maximum dimensions of the logos to be placed on the signs which is 60 x 36 inches (width x height). The dimensions of the logo signs used by the NCDOT can be found in the NCDOT Logo Signing Manual (NCDOT, 2006). This study adopted the dimensions specified in this manual and that are listed below.

- Six-panel logo sign (one service): 15 x 10 feet (width x height).
- Six-panel logo sign (two service): 15 x 11.5 feet (width x height).
- Nine-panel logo sign (one service): 15 x 13.5 feet (width x height).
- Nine-panel logo sign (two service): 15 x 15 feet (width x height).

3.1.1 Definitions

Despite the fact that the MUTCD (FHWA, 2009) has a standard nomenclature for different types of signs, past studies have adopted different names to identify a specific type of logo or to describe a particularity sign. As a result, this section has the goal of clarifying terms and avoiding misunderstanding by defining and explaining the terms that are used in this report.

**Panels** are the positions of the logos (text or symbol) on a logo sign as Figure 3.2 shows. Thus, a panel is a space or location. It may be the case that not all the panels of a logo sign are filled with logos.

A **logo** is a symbol or a name that represents a business, which may be a restaurant, hotel, gas station, attraction, campground, or pharmacy. As show in Figure 3.3, logos may be either text-based or symbol-based.
A **text-based logo** is a blue panel that contains the name of a business in white letters as shown in the bottom of the logo sign in Figure 3.3 (the textual logos of three different attraction businesses are shown). According to section 2J.03 of the MUTCD (FHWA, 2009), the minimum letter size for text-based logos on Interstates is 8 inches.

A **symbol-based logo** is a trademark, a graphic representation, or a symbol that represents a business as shown in the top row of the logo sign in Figure 3.3 (the symbol-based logo of three different gas stations are shown).

A **dual-logo panel** is a unique panel that contains two different logos (businesses) as shown in the top left portion of Figure 3.3. In such a case, these two businesses are co-located. However, according to the MUTCD (FHWA, 2009), dual-logo panels are not permitted since each panel shall contain only one logo.

An **overflow sign** is a second (extra) logo sign of one of the original categories. The MUTCD (FHWA, 2009) allows it when there are a high number of businesses in a specific interchange and their logos cannot all fit on one sign. But the total number of logo signs, including the overflow one, shall not be more than 4 signs.

An **overflow combination sign** is an overflow sign (an extra sign) that combines two different categories of service. Figure 3.3 is such a sign.
3.2 Guide Signs

Guide Signs are green signs located along Interstates, expressways, and streets. According to the MUTCD (FHWA, 2009) these signs have the objective of providing drivers with the followings valuable information.

- “Directions to destinations, or to streets or highway routes, at intersections or interchanges."
• Advance notice of the approach to intersections or interchanges.

• Direct road users into appropriate lanes in advance of diverging or merging movements.

• Identify routes and directions on those routes.

• Show distances to destinations.

• Indicate access to general motorist services, rest, scenic, and recreational areas.

• Provide other information of value to the road user.”

3.2.1 Advance Guide Sign

The advance guide signs are specified in Section 2E.33 of the MUTCD (FHWA, 2009). These are large green signs that contain information such as the exit number, the intersecting route number, the distance to the upcoming exit, and the cities that are at the next exit. Usually there are two of these signs before an interchange; the first one is located 1 mile away from the exit ramp and the second sign is 0.5 mile from the ramp as shown in Figure 3.4. The MUTCD (FHWA, 2009) does not specify the size of an advance guide sign.

![Advance Guide Signs](image)

**Figure 3.4 Advance Guide Signs**
3.2.2 Exit Direction Guide Sign

The exit direction guide signs are specified in Section 2E.36 of the MUTCD (FHWA, 2009). They are large green signs located just before an exit on the right shoulder of the Interstate (see Figure 3.5). Their objective is to indicate the exit ramp direction with an arrow and also the cities that are at that interchange. The MUTCD (FHWA, 2009) does not specify the size of an exit direction guide sign.

![Exit Direction Guide Sign](image)

Figure 3.5 Exit Direction Guide Sign

3.2.3 Exit Gore Sign

The exit gore sign is specified in Section 2E.37 of the MUTCD (FHWA, 2009) and it is identified as E5-1a in the manual. It is a rectangular green sign that indicates the number of the exit and its direction with an arrow, as Figure 3.6 shows. As the name suggests, it is located at the gore between the Interstate and the exit ramp. The sign size is 78” x 60” for an exit number with 2 digits and 96” x 60” for a three digit exit number as shown in Figures 3.6.
3.2.4 Distance Guide Sign

The distance guide sign is a green post-interchange sign described in Section 2E.39 of the MUTCD (FHWA, 2009). This type of sign provides two or three significant destinations (cities and route numbers or names of highways) followed by the distance in miles to those destinations. Figure 3.7 illustrates an example of a distance guide sign with three destinations: Burlington, Greensboro, and Winston-Salem in order of distance from the present location. According to the manual, distance signs that contain three destinations are identified as D2-3 and their size may vary depending on the length of the destination name. However, the height has a fixed dimension of 72.”
3.3 Other Signs

To better represent normal Interstate conditions, five other signs were used in the scenario of the simulation:

- Merge Sign
- Speed Limit Sign
- Interstate Route Sign

3.3.1 Merge Sign

The merge sign is a yellow diamond-shaped sign identified as W4-1 by the MUTCD and described in Section 2C.40 (FHWA, 2009). It indicates that a lane is joining the major roadway. This sign is located on the right shoulder of the major roadway and before the junction of the two lanes. The manual specifies that the sign size shall be 48” x 48” for Interstates as Figure 3.8 shows.

![Figure 3.8 Merge Sign W4-1](image)

3.3.2 Speed Limit Sign

The speed limit sign (see Figure 3.9), as the name suggest, indicates the speed limit on the Interstate and it is described in Section 2B.13 of the MUTCD (FHWA, 2009). These signs are placed at specific locations along the Interstate that are determined by engineering studies. A
speed limit sign is required to be located after interchanges where a secondary roadway joins the major one. In this case, the speed limit sign is located 1,500 feet after the end of the acceleration lane. The manual specifies that the sign size shall be 48” x 60” for Interstates.

![Figure 3.9 Speed Limit Sign R2-1](image)

3.3.3 Interstate Route Sign

The Interstate route sign shown in Figure 3.10 is a blue and red sign that identifies an Interstate highway. It is described in Section 2D.10 of the MUTCD (FHWA, 2009). All Interstates must have this sign in order to identify the route. Similar to the speed limit sign, an Interstate route sign is required after all interchanges and is located 500 feet after the end of the acceleration lane. The manual specifies the sign size as being 24” x 24” for Interstate route numbers with either one or two digits.

![Figure 3.10 Interstate Route Sign M1-1](image)
4.0 EXPERIMENTAL APPARATUS

This study combined driving simulator and eye tracking systems to collect automobile drive performance data (lane maintenance and speed control), visual behavior data (fixation frequency to area of interest and maximum off-road glance duration), and logo target identification accuracy.

4.1 Driving Simulator

A STISIM Drive Model 400 driving simulator from System Technology, Inc. (System Technology, Inc., 2013) was used in the study. It is a medium-fidelity, fixed-based simulator located in the NCSU Ergonomic Laboratory in Daniels Hall. The driving simulator represents a realistic automobile cabin that has a driver’s seat and a set of full-size driving controls, including accelerator and brake pedals, steering wheel, and turn signals. Through three 37” HDTV monitors, the simulator provides the driver with a 135-degree driving view. In addition, the simulator also contains audio speakers for roadway sounds and driver warnings. Drivers are provided with real-time feedback about speed control and lane maintenance through the use of high-resolution digital sensors and a vehicle dynamics model (Ford Taurus). The computer renders 3D dynamic images based on the scenarios designed by the experimenters and the drivers’ inputs. The simulator software allows participants to speed, brake, change lanes, and pass other cars. Also, the rear and side rear view mirrors offer drivers with realistic dynamic images representing the driving environment.

Figure 4.1 shows the driving simulator and its features as described above. In this picture, the driving scenario shown on the monitors consists of a rural Interstate environment where the driver would be approaching an interchange. Note that there is a rear view mirror that is shown
on the top portion of the central screen. Side rear view mirrors also can be seen on the bottom portion of the right and left screens. Figure 4.1 also shows the driver’s seat and the steering wheel.

Figure 4.1 Simulation Configuration

Figure 4.2 shows details of the steering wheel, turn signals, and speedometer. It is also possible to see in this picture the eye tracking device (cameras and red-pod) that is located behind and above the steering wheel.
Driving simulators similar to the STISIM Drive Model 400 have been validated in past studies by comparing them to real world driving. Santos et al. (2005) conducted a study where they compared in-vehicle information system (IVIS) data obtained from three different apparatus: a low-cost laboratory simulator, a medium-fidelity simulator, and an instrumented vehicle. According to this study, while a low-cost laboratory simulator covers only basic information about the impact that an IVIS has on drivers’ performance, a medium-fidelity simulator provides more detailed analysis (including the nature and significance of an IVIS). The study’s data were validated by comparison with data collected by an instrumented vehicle in the field.

A similar study was performed by Wang et al. (2010) to compare the data from a fixed-based driving simulator with field data. Participants were required to perform destination entry tasks using different IVIS devices while driving (at separate times) both an instrumented vehicle in the field and later the driving simulator. The results showed that measures of off-road fixation frequency and total glance duration were almost the same for both field and simulator.
performance. Also, the standard deviation of speed for both apparatus was absolutely validated, meaning that there was an absence of significant impacts due to differences between the field and simulator driving experience on driver performance. Therefore, the research team recommended the use of a fixed-based driving simulator for data collection for both driver visual behavior and driving performance.

4.1.1 Adjustment for Screen Resolution

Driving simulators are valuable tools for analyzing driving conditions and collecting data; however, care must be taken in order to avoid deterioration of participant performance due to differences between real world and simulator visual conditions. This means that participants must be able to detect features on a sign during a simulation at the same distance they would detect them under real world driving conditions.

Wickens et al. (2004) explained that drivers with normal vision can detect features at a distance of 20 feet with a visual angle of 1/60 of 1 degree. The finest feature of a logo sign is the exit number text (e.g., EXIT 11) whose characters are 6 by 10 inches (0.5 by 0.83 feet). The identification distance for this text was calculated using Equation 1 below. “Feature dimension” is 0.5 feet, which is the smallest dimension of the text character.

\[
Identification \ Distance = \frac{feature \ dimension/2}{\tan\left(\frac{1/60^\circ}{2}\right)} \quad \text{Equation (1)}
\]

\[
Identification \ Distance = \frac{0.5/2}{\tan\left(\frac{1/60^\circ}{2}\right)} = 1,718 \text{ feet}
\]
To represent real world conditions as much as possible in the driving simulator, the finest feature of the logo sign must be represented by 1 pixel of the screen when a driver is at a distance of 1,718 feet from the sign. To ensure those conditions, Hummer et al. (2011) used a factor of 1.8 to enlarge the logo signs used in the driving simulator. The same procedure was adopted by our research group. Therefore, an average six-panel logo sign in the field, which measures 10 by 15 feet, resulted in a logo sign 18 by 27 feet in the simulator. Similarly, a nine-panel logo sign which is 13.5 by 15 feet in the field was represented in the simulator by a 24.3 by 27 feet sign. To be consistent and avoid major visual differences between logo signs and other signs (e.g., guide signs, speed limit, and merge signs) in the driving simulator, all signs were enlarged by the same factor of 1.8.

4.2 Eye Tracking Equipment

A FaceLAB 5.1 eye tracking system was used in the study to collect real-time data on gaze directions as well as on eye closure and blink rates (Seeing Machines, 2011). As Figure 4.3 shows, the system hardware has two cameras (A and B) and an infrared pod that are integrated into the driving simulator cab. During an experiment, both cameras were calibrated for each participant using an eye tracking head monitor that can be configured to capture each person’s iris or pupil.
The eye tracking system works through an infrared light that is emitted by the pod, reflected off the eyes, and captured by the cameras. The system records eye movement at 60 HZ with an accuracy of 0.5° to 1° of rotational error. Figure 4.4 shows the minimum and maximum distance between the participants’ eye positions and the screen (which are respectively 43.31 inches and 53.94 inches) to enable the tracker to know what they are looking at.

Given the distance ranges shown (43.31 to 53.94 inches) and the rotational error, the range of height for physical dimension of the tracking error at the display is calculated by the equation below. The range of height for the minimum distance ($D_{\text{min}}$) is represented by $H_{0.5, \text{min}}$ and $H_{1.0, \text{min}}$ as Figure 4.4 shows. The range of height for the maximum distance ($D_{\text{max}}$) is represented by $H_{0.5, \text{max}}$ and $H_{1.0, \text{max}}$ as Figure 4.4 shows.

$$VA(\text{minutes}) = \frac{3438 \times H}{D}$$
Where:

\[ VA = \text{Visual Acuity (minutes)} \]

\[ H = \text{height (inches)} \]

\[ D = \text{distance between participant’s eyes and the screen (inches)} \]

By replacing the minimum and maximum values of VA and D in the equation above, it was possible to calculate \( H_{0.5,\text{min}} \), \( H_{0.5,\text{max}} \), \( H_{1.0,\text{min}} \), and \( H_{1.0,\text{max}} \). The procedure to calculate the height for physical dimension of the tracking error at the screen at a distance of 43.31 inches and 0.5º of rotational error is shown below. The same equation is used to calculate the other heights shown in Figure 4.4.

\[
VA_{\text{min}} = \frac{3438 \times H_{0.5,\text{min}}}{D_{\text{min}}}
\]

\[
0.5 \times 60 = \frac{3438 \times H_{0.5,\text{min}}}{43.31}
\]

\[ H_{0.5,\text{min}} = 0.38 \text{ in} \]

In summary, the height for physical dimension of the tracking error at the screen ranges from 0.38 to 0.94 inches.
Figure 4.4 Height for Physical Dimension of the Tracking Error at the Screen

Eye Works Record software (Eye Tracking, Inc, 2011) was also used in the experiment. This software receives eye movement data from the FaceLAB system and overlays gaze onto the simulation that is shown on STISIM television. In this study, only the right and center television screens had their simulation recorded because the road signs (which were an experimental manipulation) were located on the right shoulder of the simulated Interstate. Thus, they only appeared on the center and right monitors, making it unnecessary to record the left screen simulation as it was not used in the experiments.
5.0 FIELD SURVEY

Two field surveys were conducted in order to collect actual NC logo sign data, such as the dimensions of the logos signs on the Interstate and the distance between the signs. Another two field surveys were conducted to determine the proportion of familiar and unfamiliar logos for three service categories (lodging, food, and gas) within NC.

5.1 Sign Dimensions and Distances

Initially, two field surveys were conducted on the I-40 (west) at Exits 284 and 287. Their main purpose was to collected more information related to logos signs. Both interchanges were documented through photographs, their dimensions were measured, and the distance between them was measured, all using a surveyor wheel odometer and a 100-feet tape.

5.1.1 Interchange at Interstate 40 and SR 3015 at Exit 284

On November 1st, 2014, a field survey was conducted at the intersection of I-40 and SR 3015 (Airport Boulevard) at Exit 284. The objective was to measure distances between the logo signs (lodging, food, and gas) as well as the sign sizes. Figure 5.1 shows the overall layout of this interchange and the results of the field survey measurements. As it can be observed, there are four logo signs in sequence, which is the maximum number of signs per interchange according to the MUTCD (FHWA, 2009). The first two logo signs are lodging signs; the third is a food logo sign, and finally, the last one in the sequence is an overflow combination of food and gas. All the signs contain six logos each. The logo signs on the Interstate that have a horizontal rectangle shape (lodging and food logo signs) are 15.0 x 10.0 feet (width x height).
The fourth logo sign on the Interstate is an overflow combination, and its shape is a vertical rectangle with dimensions 12.0 x 14.5 feet (width x height).

Figure 5.1 Sign Sizes and Distances Between the Signs on I-40 and SR 3015 at Exit 284
All logo signs located at this specific interchange were documented through pictures. Figure 5.2 shows the location and direction from where these photos were taken.

**Figure 5.2** Interchange of I-40 and SR 3015 at Exit 284: Locations from Where the Pictures Were Taken
Figure 5.3 shows the first lodging logo sign located at this interchange (shown at the bottom of Figures 5.1 and 5.2). There are six logos, which is the maximum number per sign. Also, all lodging business presented on this sign are familiar (chain) to most drivers.

![Lodging Logo Sign 1 on I-40 at Exit 284](image)

**Figure 5.3 Lodging Logo Sign 1 on I-40 at Exit 284**

Figure 5.4 shows the second lodging logo sign. There are six lodging logos showing 100% familiar businesses.

![Lodging Logo Sign 2 on I-40 at Exit 284](image)

**Figure 5.4 Lodging Logo Sign 2 on I-40 at Exit 284**
Figure 5.5 shows the third sign which is a food logo, also with six logos of which five are familiar (chain) and only one is unfamiliar (Carmen’s Cuban Café).

![Food Logo Sign on I-40 at Exit 284]

**Figure 5.5 Food Logo Sign on I-40 at Exit 284**

Figure 5.6 shows the fourth sign which is an overflow combination of food and gas. This sign contains six logos, of which four belong to the gas service category and the other two belong to the food category. All of the logos are familiar (chain) logos. Note that unlike the others signs, this fourth sign is a vertical rectangle instead of a horizontal one with a distribution of four gas logos and two food logos.
On October 25th, 2014, a field survey was conducted at the intersection of I-40 and SR 1652 (Harrison Avenue) at Exit 287. The objective was to measure distances between the logo signs (lodging, food and gas) as well as the sign sizes. Figure 5.7 shows the results of this field survey measurements.

Figure 5.7 shows three logo signs, which are lodging, food, and gas. The two first signs on the Interstate are lodging and food signs, and each one of them has six logos and their dimensions are 15.0 x 10.0 feet (width x height). The third sign on the Interstate is a gas sign and, unlike the other two, it has only three logos, which makes it smaller: 15.0 x 8.5 feet (width x height).
Figure 5.7 Sign Sizes and Distances Between Signs on I-40 and SR 1652 at Exit 287

All logo signs located at this specific interchange were documented through pictures. Figure 5.8 shows the location and direction from where these photos were taken.
Figure 5.8 Interchange of I-40 and SR 1652 at Exit 287: Locations from Where the Pictures Were Taken

Figure 5.9 shows a lodging logo sign at this interchange (shown at the bottom of Figures 5.7 and 5.8). There are six panels (logos positions), of which only four have logos on them. From the four lodging logos, only one is unfamiliar, which is the Umstead Hotel & Spa.
Figure 5.9  Lodging Logo Sign on I-40 at Exit 287

Figure 5.10 shows the second sign which is a food logo sign. There are six food logos, and all of them are familiar (chain). Note that both the Mc Donald’s and Chick-fil-a logos have a message at the bottom that conveys additional information related to these specific businesses (“24 Hour Drive-Thru” and “Closed Sunday,” respectively). This kind of text on a logo is classified as a supplemental message according to section 2J.03 of the MUTCD (FHWA, 2009).

Figure 5.10  Food Logo Sign on I-40 at Exit 287
As Figure 5.11 shows, unlike the other logo signs at this interchange, the gas logo sign has only three panels of which only one is filled with a logo. The other two panels are “blank.” Also note that this logo is split into two businesses (dual-logo panel), Kangoroo Express and BP. According to the MUTCD (FHWA, 2009), each panel shall be filled with only one business logo. However, a possible explanation for the existence of a logo split into two businesses in the field is that this sign probably was made before the MUTCD established that requirement. This logo also contains a supplemental message of “24 hours.”

![Figure 5.11 Gas Logo Sign on I-40 at Exit 287](image)

**Figure 5.11 Gas Logo Sign on I-40 at Exit 287**

### 5.2 Logo Familiarity

On November 29th and 30th of 2014 two field surveys were performed with the goal of collecting data logo sign data (food, gas, and lodging) on Interstates I-40 (West and East) and I-85 (North and South), to inventory them through photographs, and to classify their individual logos as familiar or unfamiliar.

On the I-40, all interchanges between Exits 287 and 224 (total 29 interchanges) were inventoried. On I-85, data was collected between Exits 179 and 229, total 17 interchanges. On both Interstates, logo signs were inventoried in both directions.
The specific activities undertaken regarding the surveying signs were:

- Take pictures of the signs (food, gas, and lodging).
- Classify their logos as familiar or unfamiliar.
- Determine the frequency of appearance of each logo.
- Compare the frequency familiar versus unfamiliar logos.

It is important to highlight some observations about the collected data. These include the following.

- Most of the signs were six-panel logo signs.
- There were only two nine-panel logo signs. They were overflow combination signs (food and gas) on I-85 at Exit 213.
- There were a few signs that did not have any logo in any of their panels (blank content). Examples include the lodging logo sign at Exit 280 on I-40 (West) and the gas logo sign at Exit 223 on I-85 (North).
- The signs and logos in both directions (round trip) were basically the same since the interchanges were the same, however, there were rare exceptions. For example, a restaurant called “Red Bowl Asian Bistro” was present in the food logo sign on I-40 (East) at Exit 140, but not in the corresponding sign at the same exit in the westerly direction. Such cases were not taken in consideration in the data analysis.

Finally, a set of analyzes were made using the data collected during the field survey. To avoid duplication, only the logo signs in one direction on each Interstate were considered.
5.2.1 Lodging

There were a total of 25 lodging logo signs on I-40 (West) and I-85 (North) divided into three-panel, six-panel, and overflow combination logo signs. For lodging there were a total of 43 different lodging businesses of which 36 were familiar and seven were unfamiliar as shown in Table 5.1.

An analysis is provided related to the percentage of familiar and unfamiliar lodging logos (Table 5.1). As expected, 84% of the lodging businesses were familiar. Table 5.2 shows the “Top 10 Lodging Logos”, which consisted of familiar businesses only. Table 5.3 provides a sample of general information concerning the logos, showing only the first twenty lodging businesses, which are organized in alphabetical order.

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>Number of Businesses</th>
<th>Percentage Compared Between Them</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar</td>
<td>36</td>
<td>84%</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>7</td>
<td>16%</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Table 5.2 Top 10 Lodging Logos**

<table>
<thead>
<tr>
<th>Top 10</th>
<th>ID Lodging</th>
<th>Lodging</th>
<th>Familiarity</th>
<th>Number of Appearances of This Logo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>Holiday Inn</td>
<td>Familiar</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>Hampton Inn</td>
<td>Familiar</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>Comfort Suites</td>
<td>Familiar</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>Courtyard Marriott</td>
<td>Familiar</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>Hilton Garden Inn</td>
<td>Familiar</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
<td>Microtel Inn &amp; Suites</td>
<td>Familiar</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>28</td>
<td>Quality Inn</td>
<td>Familiar</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>Best Western Plus</td>
<td>Familiar</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>Country Inn &amp; Suites</td>
<td>Familiar</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>Days Inn</td>
<td>Familiar</td>
<td>2</td>
</tr>
</tbody>
</table>
### Table 5.3 Lodging Logo Data

<table>
<thead>
<tr>
<th>ID Lodging</th>
<th>Lodging</th>
<th>Familiarity</th>
<th>Number of Appearances of this Logo</th>
<th>Percentage Compared to Other Logos (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aloft</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>2</td>
<td>Baymont Inn &amp; Suites</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>3</td>
<td>Best Western Plus</td>
<td>Familiar</td>
<td>2</td>
<td>3%</td>
</tr>
<tr>
<td>4</td>
<td>Cambria Suites</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>5</td>
<td>Chapel Hill University Inn</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>6</td>
<td>Chex Motel</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>7</td>
<td>Comfort Suites</td>
<td>Familiar</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>8</td>
<td>Corporate Suites</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>9</td>
<td>Country Inn &amp; Suites</td>
<td>Familiar</td>
<td>2</td>
<td>3%</td>
</tr>
<tr>
<td>10</td>
<td>Courtyard Marriott</td>
<td>Familiar</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>11</td>
<td>Crown Motel</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>12</td>
<td>Days Inn</td>
<td>Familiar</td>
<td>2</td>
<td>3%</td>
</tr>
<tr>
<td>13</td>
<td>Double Tree</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>14</td>
<td>EconoLodge</td>
<td>Familiar</td>
<td>2</td>
<td>3%</td>
</tr>
<tr>
<td>15</td>
<td>Embassy Suites</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>16</td>
<td>Fairfield Inn &amp; Suites</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>17</td>
<td>Four Points</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>18</td>
<td>Hampton Inn</td>
<td>Familiar</td>
<td>4</td>
<td>6%</td>
</tr>
<tr>
<td>19</td>
<td>Hilton Garden Inn</td>
<td>Familiar</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>20</td>
<td>Holiday Inn</td>
<td>Familiar</td>
<td>6</td>
<td>9%</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>43</td>
<td>Town Place Suites</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
</tbody>
</table>

#### 5.2.2 Food

There were a total of 50 food logo signs on I-40 (West) and I-85 (North) divided into three-panel, six-panel, nine-panel, and overflow combination logo signs. There were a total of 29 different food businesses of which 49 were familiar and 20 were unfamiliar as shown in Table 5.4.
An analysis is provided related to the percentage of familiar and unfamiliar food logos (Table 5.4). Note that 71% of the food businesses were familiar. Table 5.5 shows the “Top 10 Food Logos.” It should be noted that in this particular survey all food top 10 food logos were familiar.

Table 5.6 provides a sample of general information concerning the food logos, showing only the first twenty businesses, which are organized in alphabetical order.

### Table 5.4 Comparison Between Familiar and Unfamiliar Food Businesses

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>Number of Businesses</th>
<th>Percentage Compared Between Them</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar</td>
<td>49</td>
<td>71%</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>20</td>
<td>29%</td>
</tr>
<tr>
<td>Total</td>
<td>69</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Table 5.5 Top 10 Food Logos

<table>
<thead>
<tr>
<th>Top 10</th>
<th>ID Restaurant</th>
<th>Restaurant</th>
<th>Familiarity</th>
<th>Number of Appearances of This Logo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44</td>
<td>McDonald's</td>
<td>Familiar</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>62</td>
<td>Subway</td>
<td>Familiar</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
<td>Wendy's</td>
<td>Familiar</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>Bojangles</td>
<td>Familiar</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>63</td>
<td>Taco Bell</td>
<td>Familiar</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>66</td>
<td>Waffle House</td>
<td>Familiar</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>39</td>
<td>KFC</td>
<td>Familiar</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>Burger King</td>
<td>Familiar</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>31</td>
<td>Hardee's</td>
<td>Familiar</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>Chick-fil-a</td>
<td>Familiar</td>
<td>5</td>
</tr>
</tbody>
</table>
### Table 5.6 Food Logo Data

<table>
<thead>
<tr>
<th>ID</th>
<th>Restaurant</th>
<th>Familiarity</th>
<th>Number of Appearances of this Logo</th>
<th>Percentage Compared to Other Logos</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Andy's Burger Shake &amp; Fries</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>2</td>
<td>Applebee's</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>3</td>
<td>Arby's</td>
<td>Familiar</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>4</td>
<td>Biscuitville</td>
<td>Familiar</td>
<td>4</td>
<td>2%</td>
</tr>
<tr>
<td>5</td>
<td>Blue Ribbon Diner</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>6</td>
<td>Bob Evans</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>7</td>
<td>Bocci Pizza &amp; Pasta</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>8</td>
<td>Bojangles</td>
<td>Familiar</td>
<td>11</td>
<td>6%</td>
</tr>
<tr>
<td>9</td>
<td>Brixx Wood Fired Pizza</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>10</td>
<td>Buffalo Wild Wings</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>11</td>
<td>Burger Beer Town Hall</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>12</td>
<td>Burger King</td>
<td>Familiar</td>
<td>7</td>
<td>4%</td>
</tr>
<tr>
<td>13</td>
<td>Caio Pizza</td>
<td>Unfamiliar</td>
<td>2</td>
<td>1%</td>
</tr>
<tr>
<td>14</td>
<td>Captain D's</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>15</td>
<td>Carmen's Cuban Café</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>16</td>
<td>Charc-Grill</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>17</td>
<td>Chex Restaurant</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>18</td>
<td>Chick-fil-a</td>
<td>Familiar</td>
<td>5</td>
<td>3%</td>
</tr>
<tr>
<td>19</td>
<td>Chili's</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>20</td>
<td>China Garden Restaurant</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>69</td>
<td>Zaxby's</td>
<td>Familiar</td>
<td>2</td>
<td>1%</td>
</tr>
</tbody>
</table>

#### 5.2.3 Gas

There were a total of 41 gas logo signs on I-40 (West) and I-85 (North) divided into three-panel, six-panel, nine-panel, and overflow combination logo signs. There were a total of 19 different fuel businesses of which 18 were familiar and only 1 was unfamiliar as shown in Table 5.7.
An analysis is provided related to the percentage of familiar and unfamiliar gas logos (Table 5.7). Note that 18 out of 19 gas businesses were familiar, totalizing 95% of all businesses. Table 5.8 shows the “Top 10 Gas Logos” which consisted of familiar businesses only.

Table 5.9 provides a sample of general information concerning the gas logos, showing only the first twenty businesses, which are organized in alphabetical order.

**Table 5.7 Comparison Between Familiar and Unfamiliar Gas Businesses**

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>Number of Appearances per Type</th>
<th>Percentage Compared Between Them</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar</td>
<td>18</td>
<td>95%</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>1</td>
<td>5%</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Table 5.8 Top 10 Gas Logos**

<table>
<thead>
<tr>
<th>Top 10</th>
<th>ID Gas</th>
<th>Gas Station</th>
<th>Familiarity</th>
<th>Number of Appearances of This Logo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>BP</td>
<td>Familiar</td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>Shell</td>
<td>Familiar</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Exxon</td>
<td>Familiar</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>Hess</td>
<td>Familiar</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>Marathon</td>
<td>Familiar</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>Citgo</td>
<td>Familiar</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>Kangaroo Express</td>
<td>Familiar</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>Mobil</td>
<td>Familiar</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>16</td>
<td>Sheetz</td>
<td>Familiar</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>Valero</td>
<td>Familiar</td>
<td>3</td>
</tr>
</tbody>
</table>
### Table 5.9 Gas Logo Data

<table>
<thead>
<tr>
<th>ID Gas</th>
<th>Gas Station</th>
<th>Familiarity</th>
<th>Number of Appearances of This Logo</th>
<th>Percentage Compared to Other Logos</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BP</td>
<td>Familiar</td>
<td>21</td>
<td>23%</td>
</tr>
<tr>
<td>2</td>
<td>Citgo</td>
<td>Familiar</td>
<td>4</td>
<td>4%</td>
</tr>
<tr>
<td>3</td>
<td>Exxon</td>
<td>Familiar</td>
<td>14</td>
<td>15%</td>
</tr>
<tr>
<td>4</td>
<td>E-Z Stop</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>5</td>
<td>Flying J.</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>6</td>
<td>Hess</td>
<td>Familiar</td>
<td>7</td>
<td>8%</td>
</tr>
<tr>
<td>7</td>
<td>Circle K</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>8</td>
<td>K Mart Express</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>9</td>
<td>Kangaroo Express</td>
<td>Familiar</td>
<td>4</td>
<td>4%</td>
</tr>
<tr>
<td>10</td>
<td>Kroger</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>11</td>
<td>Marathon</td>
<td>Familiar</td>
<td>7</td>
<td>8%</td>
</tr>
<tr>
<td>12</td>
<td>Mobil</td>
<td>Familiar</td>
<td>4</td>
<td>4%</td>
</tr>
<tr>
<td>13</td>
<td>Murphy USA</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>14</td>
<td>Petro Stopping Centers</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>15</td>
<td>Pilot Travel Centers</td>
<td>Familiar</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>16</td>
<td>Sheetz</td>
<td>Familiar</td>
<td>4</td>
<td>4%</td>
</tr>
<tr>
<td>17</td>
<td>Shell</td>
<td>Familiar</td>
<td>15</td>
<td>16%</td>
</tr>
<tr>
<td>18</td>
<td>Valero</td>
<td>Familiar</td>
<td>3</td>
<td>3%</td>
</tr>
<tr>
<td>19</td>
<td>Variety Mart</td>
<td>Unfamiliar</td>
<td>1</td>
<td>1%</td>
</tr>
</tbody>
</table>
6.0 METHODOLOGY

This section covers the methodology used in this study, describing all the steps from the experiment design to the data analysis.

6.1 Participants

The experiment had 60 participants (who completed the experiments) divided into young (18 to 22 years old), middle age (23 to 64 years old), and elder (65 years old and above) age groups. Each age group contained 20 participants, balanced with equal numbers of males (10) and females (10). The three requirements to participate in this study were that the participants must have a valid driver’s license from North Carolina, be a native English speaker, and have 20/20 vision. Participant use of glasses and contact lenses were permitted in the study.

6.1.1 Recruitment

The participants were recruited thought printed flyers distributed around the NC State campus, through online advertisements such as Craigslist, and through contact with senior centers and independent living facilities.

Out of a total of 184 people who contacted the research team, 70 were schedule for participation in the experiment. Among these participants, two were unable to complete the experiment due to a persistence of simulator sickness symptoms, another two had to leave the experiment early for personal reasons, and six were cancelled because of issues in calibrating the eye tracking system.
6.1.2 Demographics

Thirty (30) males and 30 females participated in this study. Their ages ranged between 18 and 79 years and the average age was 43.02 years. Among the 60 participants, twenty minor crashes and seven major crashes were reported while driving in the last three years. None of the drivers reported that they had been convicted of driving under influence of alcohol or drugs or were given tickets for careless or dangerous driving. With regard to prior traffic violations, fifteen drivers reported receiving tickets for speeding and four drivers received tickets for other moving violations such as running a stop sign.

The participants were asked to indicate how many days per week they currently drive, how many miles they have driven in the past year, and the type of roads they frequently use. Figure 6.1 to 6.3 show the data from the answers to these three questions.

Figure 6.1 shows the overall participant distribution according to the number of days driven per week. Over 70% (45/60) of the participants drive seven days per week, 13% of the total of 60 participants reported driving five to six days per week, 10% (6/60) reported driving three to four days per week, and one participant drove only one to two days per week.
Figure 6.1  Reported Number of Days Driven per Week

Figure 6.2 shows the average number of miles driven by the participants in the past year. 60% (36/60) of the participants reported that they drove more than 10,000 miles in the past year. Additionally, most participants are used to driving on all of city streets, freeways, and other main roads as shown in Figure 6.3. Because of this, the research team expected that the Interstate driving scenarios of the experiment would be familiar to most of the participants once they began the Interstate simulation.
Figure 6.2 Reported Number of Miles Driven in the Past Year

Figure 6.3 Reported Frequently Driven Road Types
6.2 Driving Scenarios

The driving environment consisted of 12 feet wide highway lanes comprising a four-lane rural Interstate. There was a 46 foot grassy median separating the two lanes in each direction. The left and right shoulders were 6 feet wide.

There are three typical diamond interchanges (each with a single-exit) that are spaced three miles apart. At each interchange there is a crossing road on an overpass that is perpendicular to the Interstate. Each interchange contained a deceleration lane to exit the Interstate and an acceleration lane to it (both 500 feet long) and all interchanges contained a complete set of signs before and after the interchange (as required by the MUTCD (FHWA, 2009)).

Figure 6.4 shows the general layout of the driving scenario used for all trials. The beginning of a trial considered that the participant had just passed an interchange. Then there are three interchanges spaced three miles apart (identified as Exits 11, 14, and 17 in Figure 6.4). The layout of the seven pre-interchange signs located before Exit 11 are shown in greater detail in Figure 6.5. The four post-interchange signs located after Exit 11 are shown in Figure 6.6.

The sets of signs before and after Exits 14 and 17 are not illustrated because they follow the same configuration as those located at Exit 11. The only difference lies in the content of the logo signs and guide signs rather than in the spacing, sign, and configuration.
Before each interchange, there are two advance guide sign (1 mile and ½ mile prior the interchange), one exit direction sign, and one exit gore sign. In addition, there are three logo signs (lodging, good, and gas/attraction). The layout and distance between these signs are shown in the Figure 6.5.

After each interchange, there are four signs. The first one is a merge sign to indicate that a ramp is merging into the main road ahead. The second is a route sign located 500 feet after the deceleration lane. The third is a speed limit sign and the fourth is a distance guide sign. The las three signs are spaced 1,000 feet apart. Figure 6.6 shows the layout of the signs after the interchange as well as their spacing.
Figure 6.5 Type and Spacing of Signs Before an Interchange

Figure 6.6 Type and Spacing of Signs After an Interchange
6.3 Independent Variables

The experiment was designed to explore the impact of four independent variables on drivers’ accuracy:

- Age
- Number of panels per logo sign (six-panel logo signs versus nine-panel signs)
- Logo familiarity (familiar logos versus unfamiliar logos)
- Logo format (text logos versus symbol logos)

6.3.1 Age

Previous studies have concluded that drivers’ age has a significant impact on crashes. For example, Chen et al. (2007) found that drivers whose ages range between 25 and 60 years old have a lower crash rate than those who are younger than 25 or older than 60. Also, Edquist et al. (2011) reported that drivers outside of the range of 25 to 55 years old (both younger and elder) are more likely to be slower in a lane changing task.

One goal of this study was to investigate the question of how driver’s age might impact their performance while they are driving and simultaneously looking for a specific logo target. To study this question, we used the same approach as Chen et al. (2007) and Edquist et al. (2011), including three different age groups: young, middle, and elderly. However, the present research team chose to independently verify and define these three age group ranges.

To do so we performed a statistical analysis on the crash data in the U.S between 1995 and 2000 (Tefft, 2012) that relates driver age and crash rate per 100 million miles driven. In doing so we found three distinct age groups to consider. Results showed that drivers under 23 years
old or above 64 years old have a significantly higher crash rate than those who are between 23 and 64 years old. Given these results and the age groupings found in the literature, three groups were defined for our study as a young age group (between 18 and 22 years old), a middle age group (between 23 and 64 years old), and an elder age group (65 years old and above).

6.3.2 Number of Panels per Logo Sign

To evaluate the drivers’ accuracy when the maximum number of panels per logo sign increases from six to nine, the experiment included eight trials evenly distributed into nine-panel and six-panel configurations. To be consistent, all logo signs (lodging, food, and gas/attraction) in a specific trial had either a six-panel or a nine-panel configuration.

Figure 6.7 shows examples of six and nine-panel food logo signs used in the study. Both signs have a heading indicating the service category (in this case it is food) and the exit number. The six-panel logo sign has two rows, each one with three logos. The nine-panel logo sign is similar to the six-panel but it has three rows instead of two.

Participants were asked to find one food and one attraction target among the logo signs. The effect that the number of panels contained on a logo sign has on accuracy was assessed by analyzing the participants’ response to identifying a food target on either a six-panel or nine-panel logo sign. Attraction targets were not considered in this analysis because an attraction was always present on the bottom row of a two-service sign. See section 6.3.4 for additional discussion of this topic. Therefore, participants would look for attraction targets only at the bottom portion of the sign rather than throughout the whole logo sign.
6.3.3 Logo Familiarity

The research team had an interest in comparing how business logo familiarity would affect drivers’ accuracy. In this study, food logos were selected to explore the familiarity of logos and its influence on driver performance. Because almost 100% of the gas stations along the Interstates are chain, they are familiar to drivers. Thus, they were dismissed as an option to analyze the familiarity factor.

However, a detail had to be considered to establish a true distribution between familiar and unfamiliar logos. According to a study conducted by Hummer and Maripalli (2008), if there is only one unfamiliar logo among other familiar logos, it is an easy target since the participant would quickly recognize it by elimination. Hence, the configurations of 1 unfamiliar/5 familiar for the six-panel logo signs and 1 unfamiliar/8 familiar for the nine-panel logo sign were discarded.
Therefore, in order to determine the proportion of unfamiliar versus familiar food logos per sign, the research team used the results of the I-40 and I-85 field surveys (see section 5.2). That survey showed there were a total of 50 food logo signs divided into three-panel, six-panel, nine-panel, and overflow combination signs. There were 69 different restaurant businesses of which 49 were familiar (chain) and 20 were unfamiliar (local).

Based on these field findings, a proportion was set as being the standard for all food logo signs in all the trials: 1/3 of the food logos per sign would be unfamiliar and the remaining logos (2/3 of the food logos) would be familiar for both six-panel and nine-panel logo signs. Note that this rule applied only to food logo signs. Figure 6.8 shows an example of the distribution of familiar (F) and unfamiliar (U) food logos on a six-panel logo sign. The locations of familiar and unfamiliar logos were randomized for each logo sign presented across the eight trials.

![Figure 6.8 Distribution of Unfamiliar and Familiar Food Logos on a Six-Panel Food Sign](image)

To avoid a situation in which participants could become familiar with an unfamiliar food logo (due repetitive exposure during different trials), it was determined that an unfamiliar food logo would be unique among all the eight trials, which means that no unfamiliar food logo ever repeated in this study.
Lodging logo signs contained 100% familiar logos since they were never a target in the experiment, and thus, they would not affect driver performance during the observational window. An analysis of the lodging logo signs inventoried during the Interstate field survey showed that it is indeed realistic to have lodging logo signs with all familiar logos. Of the 25 lodging logo signs inventoried there were actually nine signs consisting of 100% familiar businesses (six of them had some panels that were blank, with no logo).

In a like manner, gas logo signs in this experiment also consisted of 100% familiar logos because they too were never a target in the experiment. The field survey data also verified the existence of gas logo signs consisting of 100% familiar businesses. Of the 41 gas logo signs inventoried there was only one six-panel overflow combination with attraction that had an unfamiliar gas logo. All other gas logo signs contained only familiar businesses.

Thus, the research team believed that because participants were given a set of two targets (food and attraction) before each trial, they would rather scan the business category (lodging, food, gas, and attraction) on the top of the logo signs searching for the category targets (food and attraction) than look directly at the logos. Once the participants had identified that a specific sign was not a target category (the case of gas and lodging logo signs) they would not search for a target on that sign.

The left portion of Figure 6.9 shows that all logos on a lodging logo sign would be familiar (F). The second logo sign shown in Figure 6.9 is a combination of gas and attraction logo categories. For these categories, all gas logos (upper row of the sign) are familiar (F) but all
attraction logos (lower row of the sign), which is one of the two logo targets, consisted of 100% unfamiliar (U) logos, as explained in Section 6.4.3.

Figure 6.9 Distribution of Unfamiliar and Familiar Logos on Six-Panel Lodging and Gas/Attraction Signs

Figure 6.10 shows the three selected logo sign categories and their percentage of familiar and unfamiliar logos in a six-panel logo sign configuration. The first sign shown in the figure is a lodging logo sign consisting of 100% familiar logos. The second sign is a food logo sign and it followed the proportion of 2/3 familiar and 1/3 unfamiliar food logos. In this example, the two unfamiliar logos (1/3 of six logos) are Pizza Express and Neato Burrito.

The third sign shown in Figure 6.10 is a combination of gas and attraction logos. As discussed before, gas logos (upper row of the sign) consisted of 100% familiar logos. Attraction logos (one of the targets) that are located at the bottom row of the third sign are 100% unfamiliar (IncredWorld, Stone Mountain, and War Museum). All logos were randomly positioned on their respective signs.
One objective of this study was to assess how the format of a logo (text-based or symbol-based) can impact drivers’ performance in the identification of a target. However, a business that is very well known by drivers, such as McDonald’s, skews the experiment results because participants would identify its symbol logo much faster than the text-based one. Hence, to eliminate potential confusion between log familiarity and logo format, the text versus symbol comparison was conducted on the attraction logos consisting of 100% unfamiliar businesses.

Moreover, the research team was interested in exploring attraction logos because they constitute a business category that is still new to the drivers. One goal was to determine whether drivers could identify an attraction on the logo sign even though they did not know its logo.
Finally, combining the text versus symbol factor with a driver’s capacity to identify an attraction, it was decided that unfamiliar attraction logos (text and symbol-based) would be used as the target to measure this independent variable.

Unlike food and lodging, attraction logos are presented in combination with gas logos. This is explained by the fact that it is not common to see attraction logos signs in North Carolina. Thus, to represent a more realistic local driving environment, it was decided to place attraction logos in the bottom row of a two service logo sign where the other category is gas (top row of the sign).

Figure 6.11 shows examples of text-based and symbol-based attraction logos on a six-panel and nine-panel two-service logo signs (gas and attraction). In this example, the attraction logos on the bottom row of the left sign (six-panel) are text-based. The second sign on the figure is a nine-panel gas/attraction logo sign. Note that it has two rows of gas logos; the third row belongs to attraction category which is symbol-based.

The text-based logo was designed according to specifications of the MUTCD (FHWA, 2009) described in Section 2J.03 which stated that a text-based logo “should have a blue background with white legend and border.” Also, the minimum letter size is 8 inches for text-based logos on logo signs located on Interstates.

The attraction symbol logos were obtained from Google Images. They consisted of attraction businesses located within the U.S. that are not familiar to the general population (local or small businesses). Therefore, attraction businesses that are widely known (Disney World) or that are chains (Madame Tussauds Wax Museum) were avoided.
6.4 Experiment Design

Crossing the two levels of number of panels (six and nine-panel), two levels of logo familiarity (familiar and unfamiliar logo), and two levels of logo format (text and symbol-based logo), there were eight trials per participant. The eight trials were randomly ordered for each participant to avoid learning effects.

Table 6.1 shows the logo sign configurations, logo format, logo familiarity, and the targets per trials. The first column (Trial) identifies the eight trials. The column “Number of Panels” indicates whether the logo signs in that specific trial are six-panel or nine-panel. There are two columns under the major category “Food Target.” The column “Familiarity” indicates whether the food logo target is familiar (e.g. Trial 1) or unfamiliar (e.g. Trial 3). The fourth column identified as “Name” indicates the name of the food target in each trial and displays its logo. The final two columns are listed under the major category “Attraction Target.” The column “Logo Format” indicates the attraction logo configuration, whether it is text-based (e.g. Trial
1) or symbol-based (e.g. Trial 2). Finally, the last column “Name” indicates the name of the attraction target in each trial and also displays its logo.

**Table 6.1 Trials, Independent Variables Crossing Levels, and Targets**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Number of Panels</th>
<th>Food Target</th>
<th>Attraction Target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Logo</td>
<td>Name</td>
</tr>
</tbody>
</table>
| 1     | Six-panel        | Familiar    |                      | Text        | ![Holiday World Logo](image)
| 2     | Six-panel        | Familiar    |                      | Symbol      | ![Life’s Savory Treats Logo](image)
| 3     | Six-panel        | Unfamiliar  |                      | Text        | ![Village Garden Logo](image)
| 4     | Six-panel        | Unfamiliar  |                      | Symbol      | ![Food Court Logo](image)
| 5     | Nine-panel       | Familiar    |                      | Text        | ![World of Fun Logo](image)
| 6     | Nine-panel       | Familiar    |                      | Symbol      | ![Theme Park World Logo](image)
| 7     | Nine-panel       | Unfamiliar  |                      | Text        | ![Everest Logo](image)
| 8     | Nine-panel       | Unfamiliar  |                      | Symbol      | ![Museum of Natural Sciences Logo](image)

**6.5 Dependent Measures**

Through the driving simulator and the eye-tracking software, data reflecting speed deviation, lane deviation, fixation frequency to area of interest (AOI), and maximum off-road glance
duration were collected. In addition, experimenters recorded the participants’ answers whenever they verbally indicated that they saw the food or attraction logo targets on the signs.

6.5.1 Target Identification and Accuracy

Each participant received two business targets per trial (one restaurant and one attraction) and was asked to verbally indicate when the logo targets were present either on the food or attraction logo signs.

In each trial the goal was to determine whether or not a driver was able to correctly identify a logo target (food or attraction) that was present on the logo sign. Therefore, the responses were recorded as “correct” if a participant correctly identified a logo target that was present on the sign and “incorrect” if a participant did not correctly identify a target present on the sign. Thus, accuracy was defined as the percentage of “correct” answers to all responses.

6.5.2 Visual Behavior

An area of interest (AOI) on the screens of the simulator, in which the logo signs appeared during the simulation, was defined. The AOI extended horizontally from the left edge of a sign, when it first became visible in foveal vision, to the right edge of the simulated vehicle windshield. The AOI extended vertically from the lower edge of a sign, when it first became visible, to the lower edge of the simulated vehicle rear view mirror (which obstructed driver views of any roadside signage).

Two eye movement measures were derived from the FaceLAB system output. The first response was off-road driver fixation frequency (number of times the driver looked) to the AOI
during the target identification phase. In this experiment, a fixation was defined as any time the participant’s gaze traveled at a velocity less than 100 degrees per second, for a minimum of 100 msec. (Holmqvist et al., 2011). The second response was the maximum off-road glance duration, where a glance was defined as the total time the focus of attention remained within the OAI, including both fixations and saccades (a rapid movement of the eye between different points of fixation).

6.5.3 Driver Performance

Driver performance was analyzed through speed deviation and lane deviation. The data collection block (observation window) started 650 feet before the target and ended 112 feet before the target (Kaber et al, 2015) where the 1/3 top portion of the logo sign was obstructed by the rear view mirror.

For speed deviation, drivers were asked to maintain the 65 mph posted speed limit at all times. Based on this, the average absolute deviation of actual vehicle speed from the posted speed limit was computed. To measure the lane deviation, drivers were told to remain in the center of the right lane of the Interstate. The average absolute deviation of the center of the vehicle from the center of the right lane was computed during the target identification phase.

6.6 Training Trial

Each participant drove a training trial of approximately five minutes duration at the beginning of the experiment to become familiar with all of the elements of the simulator including the steering wheel and pedals. The training trial presented a normal rural Interstate driving
environment and required the participant to maintain a consistent position of the vehicle in the right lane and to maintain the speed at the posted speed limit of 65 mph.

At the end of the training trial the experimenters ensured that the participant met two criteria. The first criterion, lane maintenance, required the driver to maintain an average lane deviation of less than 1.37 feet (Horrey & Wickens, 2004) from the center of the right lane. To determine the second criterion, speed deviation, a pilot test was conducted with expert simulator users that had to drive the same training trial that would be used in the experiment. Then, the research team determined the average speed deviation, which was 1.0 mph, resulting from the pilot test. This deviation was established as a criterion for training trials. Thus, participants were limited to an average speed deviation of 1.0 mph during the training trial.

If either or both of these criteria were not satisfied, the participant was required to repeat the training trial. If a participant’s training performance remained unacceptable after three consecutive trials, his or her participation in the experiment was terminated.

6.7 Test Trial

The experiment had eight trials that presented the same configuration of a rural Interstate with three diamond interchanges that were spaced three miles apart. Before each interchange, there were three logos signs (lodging, food, and gas/attraction).

The driver was instructed to maintain the posted speed limit at all times and to remain in the center of the right lane. The participant was looking for two targets (one attraction and one restaurant) on the logo signs while driving. Therefore, participants had to verbally indicate when they saw the targets on the logo signs.
Each trial had a different set of targets. Table 6.1 showed the logo targets used in the study and classified them as familiar or unfamiliar (food) and symbol or text-based logos (attraction). Table 6.1 also indicated the logo sign configuration (six-panel or nine-panel logo signs) of each trial. The order of administration of all trials was randomized for each participant.

6.8 Consent and Demographic Forms

Before beginning the experiment, participants were required to read and sign a consent form (see Appendix C) that contained significant information related to the study including its objectives, procedures, risks, and compensations. Once they agreed to participate in the experiment, they were required to complete two questionnaires. The first was a demographic questionnaire (see Appendix D) that consisted of three sections: demographic information, driving background, and video-game experience. The second questionnaire was a simulator sickness questionnaire (SSQ; Kennedy et al., 1993) that was performed at the beginning of the experiment and then every two trials. This questionnaire had the purpose of determining if a participant was developing simulator sickness symptoms that went beyond his or her baseline response. If a participant started to show persistent symptoms, he or she was provided with a 20-minute break. After this interval, if the participant did not recover his or her participation in the study was terminated.

The SSQ presented 16 symptoms and participants were asked to provide a rating from 0 to 4 for each one of the symptoms, where 0 represented no symptoms and 4 represented severe symptoms at that specific moment.
6.9 General Procedure

Participants received instructions to meet in the Ergonomic Laboratory in Daniels Hall, NCSU, at their scheduled experiment time. They first read and signed a consent form. After signing the consent form participants were asked to complete two questionnaires.

Participants were taken to the driving simulator after completing the paperwork. The experimenter provided a brief description of the equipment and demonstrated the driving simulator’s features: driver’s seat and a set of full-size driving controls, including pedals (accelerator and break), steering wheel, and turn signals. The training trial was then started in order to familiarize participants with the different elements of the simulator. At the end of the training trial, the speed deviation and lane deviation measures were checked to verify that the participant met the established criteria. In addition, participants were asked again to complete the SSQ.

Finally, there was a short PowerPoint presentation to show some of the signs that participants would see while driving the next test trials. The presentation addressed speed limit signs, advance guide signs, distance guide signs, and logo signs along the Interstate.

After the presentation, participants were introduced to the FaceLab eye-tracking system and told how it obtains real-time data on their gaze direction as well as their eye closure and blink rates. Then, cameras A and B were positioned to capture the participants’ faces and the eye-tracking system was calibrated for each participant by creating a new eye tracking head model. Also, the gaze was calibrated to the center screen.
After the FaceLab eye tracking system was calibrated, a brief trial description was presented to participants and they were ready to start the nine test trials. Before each trial, two logo targets (one food and one attraction) were shown to the participants and they were asked to look for them while driving. Participants were provided with five-minute breaks between trials and every two trials they completed a new SSQ. Each experiment had an approximate duration of three hours. At the completion of the experiment, participants were paid $20.00/hour, averaging $57.00 per participant.

**6.10 Hypotheses**

The hypotheses were drawn based on the literature review and the experimenter’s expectations. There are a total of eight hypotheses as described below.

- Hypothesis 1 stated that number of panels would not have a significant effect on accuracy. Hypothesis 1 was based on the research of Zhang et al., 2013 and Kaber et al., 2015 for two reasons: they were the most recent studies in the topic and they used a driving simulator that represents better a driving environment when compared to a slide-based experiment, for example.

- Hypothesis 2 stated that age would have a significant impact on accuracy. Hypothesis 2 was based on all the references listed in the literature review (section 2.4), which verified that, indeed, age affects driver performance in different ways.

- Hypothesis 3 stated that the middle age group would have a significantly better accuracy than both young and elder age groups. Hypothesis 3 was based on Chen et al.
(2007), Hummer and Maripalli (2008), and Edquist et al. (2011). Those studies found that in general, middle age group had better performance than the other groups.

- Hypothesis 4 stated that the elder group would have a significantly worse accuracy than both young and middle age groups. Hypothesis 4 was based on Dingus et al. (1989), Kaber et al. (2012), and Dagnall et al. (2013) research. Those studies found that drivers older than 50 or 65 years old had worse performance under varied conditions.

- Hypothesis 5 stated that logo familiarity would have a significant effect on accuracy and that participant will have higher accuracy for familiar logos. Hypothesis 5 was based on the study by Hawkins and Rose (2005), which found that accuracy was higher for familiar logos. Hummer and Maripalli (2008) results were disregarded in Hypothesis 5 because one of the possible explanations for their results (unfamiliar logos way far easier identified) is that drivers could identify easier one unfamiliar logo among familiar logos. However, this observation was taken in consideration in the design of our scenarios and trials: the research team established a proportion of 1/3 (two on a six-panel and three on a nine-panel) of unfamiliar logos on the signs.

- Hypothesis 6 stated that logo format would have a significant impact on accuracy and that text-based logos will present higher accuracy than symbol-based. Hypothesis 6 was based on Dagnall et al. (2013) who found that under different sign and logo configurations, elder drivers took longer to identify symbol-based than text-based logos. The authors also verified that all drivers had higher accuracy for text-based logos than they did for symbol-based logos (although it is not clear this difference was significant).
• Hypothesis 7 stated that drivers who drove more miles in the past year would have significantly higher accuracy than drivers who drove less miles in the same period of time. It was expected that who drove more miles would have more experience and, therefore, higher accuracy.

• Hypothesis 8 stated that there would be dependence of correct target identification upon visual behavior (maximum off-road glance duration and/or fixation frequency to AOI). Hypothesis 8 was based on Hawkins and Rose (2005), Hummer and Maripalli (2008), and Dagnall et al. (2013) studies. Both research found that, under different logo sign presentation format and logo familiarity, accuracy increased with the increase of exposure time of the target because drivers had more time to scan the sign and identify the targets. Therefore, in the present study was expected that when drivers had longer off-road glance duration or higher fixation frequency to AOI, correct identification of the targets would be higher.

6.11 Data Analysis

This report focuses on the analysis of the effect of driver’s age, logo sign presentation formats, miles driven in the past year, visual behavior, and driving performance on target identification accuracy. For each analysis a specific statistical approach was used. Before conducting the analysis, data cleaning was performed with the identification and removal of outliers as well as an assessment of parametric assumptions when necessary.
6.11.1 Data Cleaning

During the data collection phase, experimenters maintained a lab notebook to record any information that might have made an impact on the data that was gathered during the experiment. These notes could be related to technical issues with the equipment or software or they could be related to participant performance. The nature of the comments found in the notebook can be seen in the following examples:

Equipment or Software related:

- Participant wears glasses and right eye is not perfectly captured by the FaceLab (eye tracking software).
- Eye tracker does not work because of reflection on the glasses (experiment was canceled).
- Eye tracker was not working 100%; camera B was not capturing points located on the left side of the center screen.

Participant Performance related:

- Participant developed simulator sickness symptoms after four trials. Gave him a 20-minute break, and then continued the experiment.
- Participant was not following the instructions (driving at 80 mph).
- Participant changed the head position (during the observational window) and the cameras did not capture the eye movements during this instant.

To ensure a valid statistical analysis, outliers were identified and removed from the data set. An outlier is an observation that is significantly distant from other points observed, indicating that it is not representative of the population. An outlier may occur due to equipment
malfunction, measurement error, or a participant who did not properly follow the given instructions.

Data cleaning was performed through the following two steps: analysis of residual plots for each dependent variable and analysis of their distributions.

Step 1: Residual plots were analyzed. The research team cross-referenced suspicious observations to entries in the lab notebook to see if there was a malfunction of the equipment or if the participant was not following the instructions during the observational window (when the data were collected). If a mistrial occurred, the observation was identified as an outlier and, therefore, was removed from the data set. Step 2: Distributions of the residuals of lane deviation, speed deviation, maximum off-road glance duration, fixation frequency to AOI data, and accuracy were analyzed and deviant points were cross-referenced with notebook comments in order to identify outliers.

In an analysis of the lane deviation data, observations with values larger than 12 feet were excluded from the data set because they suggest that the participant was not driving in the right lane (he was either driving in the left lane or on the shoulder of the Interstate) as required by the instructions. As described earlier in section 6.3, a lane is 12-feet wide.

For accuracy, two data sets were removed from analysis due to the persistent simulator sickness symptoms experienced by the participants (likely their performances were affected by simulator sickness). In addition, the data sets corresponding to four other participants were removed because, in spite the fact there were no specific comments in the lab notebook, their
levels of performance represented either a lack of understanding, forgetfulness of the target to be identified, or failure to complete the required task.

6.11.2 Diagnostics

Parametric procedures are widely used in statistics analysis and are usually faster than nonparametric procedures (Murphy, 2012). To use parametric procedures, the data need to meet a set of pre-established criteria or parameters (as the name suggests) whose objective is to ensure more accurate statistical analysis results than those provided by nonparametric procedures.

The accuracy analysis on this project included three different approaches: Analysis of Variance (ANOVA), contingency tables, and logistic regression. While contingency analysis (chi-square) and logistic regression are nonparametric procedures and therefore do not rely on assumptions, parametric ANOVA requires the data to be tested for some assumptions as explained below.

Three assumptions must be met in order to use parametric ANOVA. These assumptions are that the data is made up of independent samples, that there is homogeneity within the data, as well as normality within the data sample.

The first assumption was met due to the fact that the participants in this study were independent of one another. That means that participants within each age group were randomly selected; there is no relationship between them. This assumption ensures a better representation of the general population, which in this study, is defined by North Carolina drivers.
To assess homogeneity, Bartlett's test (Snedecor and Cochran, 1989) was used; a \( p\)-value resulting from this test that is greater than 0.05 indicates that the data were homogeneous. To assess normality, Shapiro-Wilk test (Shapiro and Wilk, 1965) was used; a \( p\)-value resulting from this test that is greater than 0.05 indicates that the data were normally distributed.

Untransformed food target accuracy data violated both normality and homogeneity assumptions. Untransformed attraction target accuracy was homogenous, however, not normally distributed. Square-root and logarithmic transformations were performed in both food and attraction data set, however, they did not solve the parametric assumption violations. Based on this, the data were ranked and nonparametric ANOVA was performed.

According to Montgomery (1991), if the results of the nonparametric ANOVA performed on ranked data are similar to the results obtained with untransformed data in terms of significance of effects, untransformed data should be used in the analysis and the results reported. Otherwise, the nonparametric ANOVA procedure (ranked data) should be used in the analysis and the results reported.

### 6.11.3 Statistical Analysis

Three different analyses were performed on accuracy and target identification. Each one of these three analyses was performed separately for food and attraction targets because although both they explored drivers’ age, the other independent variables for them: food covered number of panels and logo familiarity while attraction covered logo format.

Due the fact that logo sign presentation formats (number of panels, logo format, and familiarity) were controlled variables, an ANOVA procedure was indicated for analysis.
Based on this, mixed between-subject and within-subject ANOVA analyzes were performed to assess the influence of logo sign presentation formats and age group on accuracy. Age group was included in the ANOVA models as a between-subject variable because participants were not selected completely at random, but rather randomly within each age group. When necessary, the post-hoc analysis Tukey’s Honest Significant Difference (HSD) test was performed in ANOVA results to determine the significant groupings. Although Tukey’s HSD is considered more conservative than most post-hoc methods, its use eliminates chances of criticism in relation to the validation of significance groupings.

Contingency tables were used to assess the influence of simple effect of miles driven in the past year on target accuracy under various logo sign presentation formats. The reason is that “miles driven in the past year” is not a controlled variable; it is observed states of the participants, and therefore, contingency analysis is indicated.

To verify the influence of fundamental driver abilities (visual behavior and driving performance) on target identification, logistic regression analysis was performed to assess the probability of succeed on a task, which in this case was defined as the correct identification of a target on a logo sign. The initial model included visual behavior (fixation to AOI and maximum off-road glance duration) and driving performance (lane and speed deviation) predictors. The backward elimination method was used in order to remove from the model predictors that were not significant and, therefore, to obtain a more predictive model. The advantage of this method is the fact that it is more likely to detect predictive utility of a useful set of variables than does the forward selection method.
Table 6.2 shows a summary of the analyses performed on target identification accuracy. The first column identifies the type of analysis while the second column describes the analysis as well as its response measure and predictors. The last column shows which statistical test was used for each type of analysis.

**Table 6.2 Type of Analyzes, Description, and Test Used**

<table>
<thead>
<tr>
<th>Types of Analysis</th>
<th>Description</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influence of Logo Sign Presentation Format on Accuracy</td>
<td>Relationship of a continuous response and categorical predictors. Response: target identification accuracy Predictors: age, number of panels, logo familiarity, and logo format</td>
<td>ANOVA</td>
</tr>
<tr>
<td>Simple Effect of Miles Driven in the Past Year on Accuracy Under Various Logo Sign Presentation Formats</td>
<td>Relationship of two categorical variables. Response: target identification accuracy Predictor: miles driven in the past year.</td>
<td>Chi-square (contingency tables)</td>
</tr>
</tbody>
</table>
7.0 RESULTS

For all analyzes a significance level of $\alpha=0.05$ was used to determine the significance of simple and main effects. All graphics in the next subsections show the untransformed mean response, unless otherwise noted, and error bars showing one standard deviation from the mean.

7.1 Influence of Logo Sign Presentation Format on Accuracy

7.1.1 Food

Descriptive statistics of the untransformed accuracy for food targets are presented in Table 7.1 under the various conditions of independent variables. As it can be seen in Table 7.1, all means are above 80%, except for the condition of nine-panel sign and unfamiliar logo for which the mean is 55%.

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Hit Signal Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Number of Panels</td>
<td>Logo Familiarity</td>
</tr>
<tr>
<td>6</td>
<td>Familiar</td>
</tr>
<tr>
<td>6</td>
<td>Unfamiliar</td>
</tr>
<tr>
<td>9</td>
<td>Familiar</td>
</tr>
<tr>
<td>9</td>
<td>Unfamiliar</td>
</tr>
</tbody>
</table>

Parametric and nonparametric ANOVAs were conducted with food target accuracy, the model included the effects of age group, number of panels, logo familiarity, and the interactions between those independent variables. Because the results of both the ranked and the
untransformed data were similar, the following results are based on ANOVA conducted on untransformed data (Montgomery, 1991).

The two-way interaction of age group and number of panels (F(2, 167)=0.55, p=0.5782) as well as the three-way interaction of age group, familiarity, and number of panels (F(2, 167)=0.01, p=0.9869) were found not to be significant. Significant main effects include age group (F(2, 167)=45.06, p<0.0001), familiarity (F(1, 167)=16.85, p<0.0001), and number of panels (F(1, 167)=22.84, p<0.0001). Significant interactions were found to be familiarity and number of panels (F(1, 167)=20.41, p<0.0001) and familiarity and age group (F(2, 167)=5.42, p=0.0052).

Figure 7.1 shows that accuracy is significantly higher for familiar logos than for unfamiliar logos. It can be seen in Figure 7.2 that participants had a better accuracy when looking for targets on six-panel signs than on nine-panel logo signs. Figure 7.3 shows the relationship between accuracy and age group. As it can be seen from the plot, there is a trend of decreasing accuracy for elder drivers (who had only 54% accuracy). Post-hoc analysis was conduct on the data and demonstrated significant difference between the elder group and the other groups as shown in in the bottom of the bars in Figure 7.3 (Young: M=89%, SD=22%; Middle: M=81%, SD=30%; and Elderly: M=54%, SD=38%).
Figure 7.1 Food Target Accuracy Versus Familiarity

Figure 7.2 Food Target Accuracy Versus Number of Panels
Figure 7.3 Food Target Accuracy Versus Age Group

Figure 7.4 shows the two-way interaction of familiarity and number of panels. Note in the plot that accuracy drastically decreases from familiar to unfamiliar in the nine-panel sign configuration. Post hoc comparison using the Tukey HSD test showed that drivers performed worse when the target was unfamiliar on a nine-panel sign than for the other interactions as shown in Table 7.2.
Figure 7.4 Food Target Accuracy Versus Interaction of Familiarity and Number of Panels

Table 7.2 Significance Groupings of Interaction of Familiarity and Number of Panels

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>Number of Panels</th>
<th>Significance Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar</td>
<td>Six-panel</td>
<td>A</td>
</tr>
<tr>
<td>Familiar</td>
<td>Nine-panel</td>
<td>A</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>Six-panel</td>
<td>A</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>Nine-panel</td>
<td>B</td>
</tr>
</tbody>
</table>

Figure 7.5 shows the two-way interaction of familiarity and age group. Observe in the plot that accuracy decreases from familiar to unfamiliar for both the young and middle age groups. Unexpectedly, the performance of the elder group slightly improved in the presence of unfamiliar targets, but is not a significant difference. As Table 7.3 shows, post hoc comparison using the Tukey HSD test showed that young and elder drivers belong to distinctly significance
groupings while the middle age group has some overlapping with both the young and elder groups.

Figure 7.5 Food Target Accuracy Versus Interaction of Familiarity and Age Group

Table 7.3 Significance Groupings of Interaction of Familiarity and Age Group

<table>
<thead>
<tr>
<th>Familiarity</th>
<th>Age Group</th>
<th>Significance Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiar</td>
<td>Young</td>
<td>A</td>
</tr>
<tr>
<td>Familiar</td>
<td>Middle</td>
<td>A, B</td>
</tr>
<tr>
<td>Familiar</td>
<td>Elderly</td>
<td>E</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>Young</td>
<td>B, C</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>Middle</td>
<td>C, D</td>
</tr>
<tr>
<td>Unfamiliar</td>
<td>Elderly</td>
<td>D, E</td>
</tr>
</tbody>
</table>
7.1.1.1 Simple Effect of Number of Panels Within Levels of Logo Familiarity

According to the ANOVA full model for food targets, the number of panels was found significant with nine-panel logo signs having lower target identification accuracy than six-panel signs. However, the two-way interaction between number of panels and logo familiarity was also found to be significant. According to this interaction, there is no difference between six and nine-panel signs when analyzing only familiar logos. The significant difference between six and nine-panel signs was detected only for unfamiliar logos. In this case, unfamiliar logos on a nine-panel sign led to a very low accuracy of 55% which unfamiliar logos on a six-panel sign resulted in an 81% accuracy.

To better understand whether the number of panels is a significant factor on accuracy, a simple effect analysis was performed to assess the effect of number of panels within the two levels of logo familiarity. For familiar logos, number of panels was not found to be significant (F(1,118)=0.02, p=0.8910). In contrast, the simple effect model for unfamiliar logos showed that number of panel has significant effect on target identification accuracy (F(1,114)=24.20, p<0.0001).

These results are in accordance with the two-way interaction between number of panels and familiarity. This shows that although the main effect number of panels was significant in the full model, the two-way interaction should be considered in the discussion of the results because it better represents the data collected.
7.1.2 Attraction

Descriptive statistics of the untransformed hit signal ratio for attraction targets are presented in Table 7.4 corresponding to the two levels of logo format: symbol logos versus text-based logos. Table 7.4 shows that all means are above 89%.

**Table 7.4 Mean and Standard Deviation of Target Identification Accuracy Across Different Conditions**

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logo Format</td>
<td></td>
</tr>
<tr>
<td>Symbol</td>
<td>89%</td>
</tr>
<tr>
<td>Text</td>
<td>96%</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td>Std.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td>10%</td>
</tr>
</tbody>
</table>

Parametric and nonparametric ANOVAs were conducted on attraction target accuracy with the models including the effects of age group, logo format, and the interactions of logo format and age group. Because both results of ranked and untransformed data were similar, the following reported results are based on ANOVA conducted on untransformed data (Montgomery, 1991).

Neither age group (F(2,52)=2.36, p=0.1047) nor the interaction of age group and logo format (F(1,52)=0.44, p=0.6453) have a significant effect on hit signal ratio. Logo format was found to be a significant main effect (F(1,52)=8.28, p=0.0058). Accuracy increased somewhat for text-based logos in comparison to symbol ones, which can be seen in Figure 7.6 below.
7.2 Simple Effect of Miles Driven in the Past Year on Accuracy Under Various Logo Sign Presentation Formats

Participants were asked to indicate how many miles they drove in the past year. There were 5 possible options:

- < 5,000 miles
- 5,000 to 10,000 miles
- 10,000 to 15,000 miles
- 15,000 to 20,000 miles
- > 20,000 miles
The simple effects of miles driven in the past year on target identification accuracy were analyzed separately for food and attraction targets because they cover different independent variables.

### 7.2.1 Food

The simple effect of miles driven in the past year on food target identification accuracy was investigated under the different levels of number of panels per sign (six and nine-panel) and logo familiarity (familiar and unfamiliar logos).

The results showed that miles driven in the past year has a significant simple effect on accuracy for six-panel logo signs ($\chi^2(4)=17.944, p=0.0013$). Figure 7.7 shows accuracy by miles driven in the past year for six-panel signs as well as the significance groupings. Drivers who were on the road for 5,000 to 15,000 miles in the past year had significantly lower accuracy than the other drivers.

![Figure 7.7 Accuracy by Miles Driven in the Past Year for Six-Panel Logo Signs](image-url)
The results showed that miles driven in the past year has a significant simple effect on accuracy for nine-panel logo signs ($\chi^2(4)=11.400$, $p=0.0224$). Figure 7.8 shows accuracy by miles driven in the past year for nine-panel signs as well as the significance groupings. Drivers who were on the road for up to 15,000 miles in the past year had significantly lower accuracy than the drivers on the road for 15,000 to 20,000 miles. Note that drivers on the road for fewer than 5,000 miles last year had only a 50% accuracy.

![Nine-Panel Logo Sign](image)

**Figure 7.8 Accuracy by Miles Driven in the Past Year for Nine-Panel Logo Signs**

The results showed that miles driven in the past year has a significant simple effect on accuracy for familiar logos ($\chi^2(4)=23.567$, $p<0.0001$). Figure 7.9 shows accuracy by miles driven in the past year for familiar logos as well as the significance groupings. Drivers who were on the road for 5,000 to 15,000 miles in the past year had significantly lower accuracy than other drivers. Note that the trend shown in Figure 7.9 is the same as Figure 7.7.
The results showed that miles driven in the past year had a significant simple effect on accuracy for unfamiliar logos ($\chi^2(4)=9.560$, $p=0.0485$). Figure 7.10 shows accuracy by miles driven in the past year for unfamiliar logos as well as the significance groupings. Drivers who were on the road for up to 15,000 miles in the past year had significantly lower accuracy than other drivers. Note that the trend shown in Figure 7.10 is the same as in Figure 7.8 and that drivers who were on the road for less than 5,000 miles had the worst accuracy (only 48%).
Figure 7.10 Accuracy by Miles Driven in the Past Year for Unfamiliar Logos

7.2.2 Attraction

The simple effect of miles driven in the past year on attraction target accuracy was investigated under different levels of logo formats: symbol and text-based logos. The results showed that miles driven in the past year was found not to be significant for either symbol-based ($\chi^2(4)=6.914$, $p=0.1405$) or text-based logos ($\chi^2(4)=3.391$, $p=0.4947$).

7.3 Dependence of Target Identification on Driving Performance and Visual Behavior

7.3.1 Food

Overall, participants correctly identified food targets 75% of the time. Logistic regression was conduct to predict correct identification of food targets using speed deviation, lane deviation, maximum off-road glance duration, and fixation to AOI as predictors. However, three of the
predictors (speed deviation, lane deviation, and fixation to AOI) were removed from the model due the lack of significance. Maximum off-road glance duration was found to be significant in the identification of targets ($\chi^2(1)=5.42$, $p=0.0199$). The estimator ($\beta_1$) indicates that when the maximum off-road glance durations increases by 1 second, the odds ratio is 1.21 times more likely to correctly identify the target (a 21% increase in the chance of correctly identifying the target).

Figure 7.11 shows that correct target identification requires more attention allocation from drivers than when they answered incorrectly. Note that the mean maximum road glance duration is less than 2 seconds for both conditions: correct and incorrect identification of the target.

![Figure 7.11 Mean Maximum Off-Road Glance Duration Versus Food Target Identification](image)
7.3.2 Attraction

Overall, participants correctly identified attraction targets 90% of the time. Logistic regression was conducted to predict correct identification of attraction targets using speed deviation, lane deviation, maximum off-road glance duration, and fixation to AOI as predictors. However, none of the predictors was found to have a significant effect on attraction target identification.

7.4 Discussion

Hypothesis 1 (quick reference in Table 7.5) was partially supported by the data. In general, participants had higher accuracy for six-panel than for nine-panel signs, which is consistent with the findings of Dagnall et al. (2013) and Hummer and Maripalli (2008) in contrast to the Hypothesis 1. Both the present study and Hummer and Maripalli (2008) used familiar and unfamiliar logos as targets (Dagnall et al. (2008) study used a proportion of familiar and unfamiliar logos on the signs, but it is not clear whether or not all logo targets were familiar).

However, the two-way interaction between number of panels and familiarity was found to be significant as well. When analyzing only familiar logos, there is no significant difference between six and nine-panel logo signs and accuracy is above 80% for both logo sign configurations. But when only unfamiliar logos are analyzed, participants had significantly higher accuracy for six-panel than for nine-panel logo signs. While the accuracy was 81% for unfamiliar logos on a six-panel sign, the accuracy dramatically reduced to 55% for unfamiliar logos on a nine-panel. A simple effect analysis of the effect of number of panels on accuracy within logo familiarity was conducted and its results are in accordance with the interaction findings.
Therefore, when considering only familiar logos, Hypothesis 1 was supported: there is no difference between six and nine-panel logo signs. This finding is in accordance with the two articles that were used to draw Hypothesis 1: Zhang et al. (2013) and Kaber et al. (2015). These two studies used only familiar food logos as targets and found the number of panels not to be a significant factor and also that target identification accuracy was above 95% for both of the six and nine-panel logo sign configurations.

Hypothesis 2 was partially supported by the data. Age group was shown to be a significant factor on accuracy of food targets hits, but it was not significant for attraction targets hits. In the case of food targets, elder participants had significantly lower accuracy than did the young and middle age groups. For attraction targets, there was no significant difference among the three age groups. Those results might be explained by the fact that drivers had to scan the whole logo sign (six or nine-panel) in search of the food target while the attraction target was always present in the bottom row of a two-service logo sign. It thus could be that elder drivers have more difficulty scanning a whole sign than only checking one row as was the case for the attraction logos.

Hypothesis 3 was not supported by the data. It stated that the middle age group would have significantly higher accuracy than both the young and elder groups. However, considering the food targets, both the young and middle age group belong to the same significance grouping (A). In addition, young drivers performed slightly better than did the middle age group. With respect to attraction targets, as previously cited, there was no significant difference between the age groups.
Hypothesis 4 was partially supported by the data. The food target analysis showed that, indeed, elder drivers had significantly lower accuracy than did the two other age groups. While the young and middle age groups had a target identification accuracy above 80%, elders had only 54%. However, the attraction target analysis found that age group was not a significant factor.

Hypothesis 5 was supported by the data. Familiarity was shown to be a significant factor on accuracy performance. Familiar logos had 12% higher accuracy than did unfamiliar logos. When analyzing only nine-panel logo signs, logo familiarity dramatically impacts accuracy: familiar logos have an 81% accuracy while unfamiliar logos have only a 55% accuracy. These results are in accordance with the findings of Hawkins and Rose (2005). Moreover, the present results indicate that the suspicion of Hummer and Maripalli (2008) is valid: drivers might more easily identify an unfamiliar logo throughout the process of elimination when it is the only one among other familiar logos. When the present study used a combination of 67% familiar and 33% unfamiliar logos on food logo signs, this issue was eliminated.

An unexpected fact about the familiarity results is that, in contrast to the young and middle age groups, elder drivers had a better accuracy performance for unfamiliar logos than they did for familiar. However, this difference was not significant and only 4%.

Hypothesis 6 was supported by the data. The results revealed that logo format is a significant factor on accuracy performance and, indeed, text-based logos had a better performance. In general, participants had a good performance for both text and symbol-based targets and the absolute difference (7%) might not be a reason for concern. The results are in accordance with the findings of Dagnall et al.
These results may be explained by the fact that while symbol-based logos can contain a considerable amount of information (such as different colors, forms, and even text) in a limited space (in this case, the logo panel), they might interfere with driver performance, especially when unfamiliar. On the other hand, text-based logos follow the MUTCD (FHWA, 2009) standard that requires blue background with white text and, in addition, a minimum letter size of 8 inch for logo signs on the Interstate. These features might facilitate the identification of a business by drivers.

Hypothesis 7 was partially supported by the data. Drivers who were on the road for more miles in the previous year (above 15,000 miles) had a better performance than did drivers who were on the road for less than 15,000 miles with nine-panel logo signs as well as with unfamiliar logos. In both cases, drivers who drove fewer than 5,000 miles only had about 50% accuracy. However, the trend changed when the simple effect of miles driven in the past year was analyzed with six-panel signs and with familiar logos. In those cases, drivers who were on the road for 5,000 to 15,000 miles had significantly lower accuracy than drivers who were on the road for less than 5,000 miles or more than 15,000 miles.

The major difference lies in the performance of the group who drove less than 5,000 miles: for nine-panel signs and unfamiliar logos, their accuracy was around 50% while for six-panel logo signs and familiar logos the accuracy was 94% (almost double). In this particular group, the majority of the participants were young, and it is possible that this is what brought about the results. In general, young drivers performed well, however they were the most affected by the familiarity and number of panels when compared to other age groups. In other words, when
young drivers were exposed to unfamiliar logos and/or nine-panel logo signs, their accuracy significantly decreased.

Hypothesis 8 was partially supported by the data. The analysis of the food target showed that correct identification of a food target was dependent upon maximum off-road glance duration. When the maximum glance duration increased by 1 second, there was a 21% increase in the chance of correctly identifying the target. These results are in accordance with Hawkins and Rose (2005), Hummer and Maripalli (2008), and Dagnall et al. (2013) who concluded that participants increased their accuracy when the target exposure time was increased.

According to NHTSA (2012), off-road glance durations of longer than 2 seconds may increase unsafe conditions to drivers. However; as observed in the present study, the mean maximum off-road glance duration when participants correctly identified a target was 1.7 seconds which is below the 2 seconds standard and, therefore, did not represent a risk to drivers’ safety. With respect to the correct identification of attraction targets, either maximum off-road glance duration or off-road fixation frequency was found to be significant. This might be explained by the fact that attraction targets were always located in the bottom row of a logo sign rather than being randomly distributed among the six or nine panels of the whole logo sign. Because of this unique configuration, less visual attention might have been required to correctly identify an attraction target.

Table 7.5 shows a summary of the hypotheses, the references that they were based on, and whether or not those hypotheses were supported by the data.
<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>References Based on</th>
<th>Supported by the Data?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Number of panels would not have a significant effect on accuracy</td>
<td>Zhang et al. (2013) and Kaber et al. (2015)</td>
<td>Partially</td>
</tr>
<tr>
<td>2. Age would have a significant impact on accuracy</td>
<td>Dingus et al. (1989), Chen et al. (2007), Hummer and Maripalli (2008), Edquist et al. (2011), Kaber et al. (2012), and Dagnall et al. (2013)</td>
<td>Partially</td>
</tr>
<tr>
<td>3. Middle age group would have significantly higher accuracy than both young and elder groups</td>
<td>Chen et al. (2007), Hummer and Maripalli (2008), and Edquist et al. (2011)</td>
<td>Rejected</td>
</tr>
<tr>
<td>4. Elder group would have significantly worse performance than both young and middle age groups</td>
<td>Dingus et al. (1989), Kaber et al. (2012), and Dagnall et al. (2013)</td>
<td>Partially</td>
</tr>
<tr>
<td>5. Logo familiarity would have significant effect on accuracy and familiar logos will have higher accuracy</td>
<td>Hawkins and Rose (2005)</td>
<td>Supported</td>
</tr>
<tr>
<td>6. Logo format would have significant effect on accuracy and text-based logos will have higher accuracy</td>
<td>Dagnall et al. (2013)</td>
<td>Supported</td>
</tr>
<tr>
<td>7. Drivers who drove more miles in the past year would have significantly higher accuracy than drivers who drove less miles in the same period of time</td>
<td>-</td>
<td>Partially</td>
</tr>
<tr>
<td>8. There would be dependence of correct target identification upon visual behavior (maximum off-road glance duration and/or fixation frequency to AOI)</td>
<td>Hawkins and Rose (2005), Hummer and Maripalli (2008), and Dagnall et al. (2013) studies.</td>
<td>Partially</td>
</tr>
</tbody>
</table>
8.0 CONCLUSIONS

The main objective of the present study was to assess how accurately drivers from different age groups were able to identify logo targets on logo signs under three different logo sign presentation formats: number of panels, logo familiarity, and logo format. In addition, the simple effect of miles driven in the past year on accuracy under different logo sign presentation formats was explored, as well as the dependency of accuracy on driving performance (speed and lane deviation) and visual behavior (fixation frequency to AOI and maximum off-road glance duration). Participants drove a driving simulator and the following response measures were collected: accuracy, speed deviation, lane deviation, fixation frequency to AOI (area of interest), and maximum off-road glance duration. The differences in target accuracy under different signage conditions were assessed through a set of statistical analyses. Results showed that the number of panels on a logo sign, logo familiarity, drivers’ age, and logo format have significant impacts on drivers’ accuracy.

Both number of panels and logo familiarity as well as the interaction between them were found to be significant factors on drivers’ accuracy. The results showed that the number of panels did not affect accuracy when drivers were looking for familiar targets. However, when the targets were unfamiliar, increasing the number of panels on a logo sign from six to nine had a negative impact on drivers’ accuracy (26% lower accuracy for nine-panel logo signs). With respect to logo familiarity, drivers had lower accuracy for unfamiliar logos than they did for familiar logos.

Although number of panels was significant in effect on accuracy for unfamiliar logos, the accuracy is almost the same for both six and nine-panel signs when the logo target was familiar.
According to a field survey conducted by Dagnall et al. (2013) on I-95 in Virginia, it was found that from a total of 286 logos registered (lodging, food, and gas), 80% to 82% were familiar logos. Similarly, the field survey conducted by our research team on I-40 and I-85 in North Carolina (see section 5.2) found that from 131 businesses (lodging, food, and gas) present on logo signs, about 80% were familiar. Those surveys revealed that most of the businesses that participate in the Logo Signing Program are familiar to drivers, and therefore, an increase from six to nine the number of panels on a sign would not have major effect on drivers’ accuracy. Therefore, with respect to accuracy, this study concludes that there is no reason not to permit the use of nine-panel logo signs.

Drivers’ age is also an important factor to consider when analyzing drivers’ ability to identify a logo target on a logo sign. Overall, elder drivers had only 54% accuracy for food targets, which was significantly lower than both the young and middle age groups. With respect to attraction signs, there was not a significant difference between elder and both young and middle age groups. These results suggested that elder drivers could more easily identify a logo located in a single row of a two-service logo sign (as the case of gas/attraction logo sign) rather than scanning the whole logo sign (six or nine-panel) in search of a logo (as the case of food logo sign). This indicates that the use of two-service logo signs might be indicated on interchanges where the demand for businesses is not high in order to increase elder drivers’ accuracy.

Along the same line of reasoning, according to NCDOT (Logo signs, n.d.), only 2% of the logos installed in North Carolina are attraction businesses. Based on this information and on the high accuracy for attraction targets found in this study, the NCDOT might consider the
regular use of attraction logos in combination with another category (food, lodging, gas, attraction, or camping) on a two-service logo sign to increase drivers’ target identification accuracy.

Another strategy that can be adopted by the NCDOT is to increase the size of logo signs with the goal of improving elder drivers’ accuracy. The current NCDOT six-panel logo sign dimension is 15 x 10 feet (width x height) while the Wyoming Department of Transportation has a 17 x 10 feet (width x height) six-panel logo sign (Specific service signs, n.d.). With respect to the dimensions of the logo itself (not the sign), the NCDOT uses a standard of 48 x 36 inches (width x height) while both the West Virginia Department of Transportation (WVDOT, 2005) and the Idaho Transportation Department (ITD, 2007) adopt the maximum logo dimensions allowed by the MUTCD (FHWA, 2009) which is 60 x 36 inches (width x height).

With respect to logo format, although the results indicated that drivers had significantly higher accuracy for text-based than for symbol-based logos, business still might want to represent themselves though symbol logos. According to Park et al. (2013), symbol logos are more effective in attracting customers than are text-based logos and they also better represent the brand’s value. In this case, local and small businesses might want to use symbol-based logo instead text-based as a long-term plan to attract more customers.

In summary, when evaluating drivers’ accuracy under new configurations of logo signs, (e.g., number of panels and logo format) not only should the logo sign presentation format itself should be considered, but also drivers’ age, with special attention to elder drivers who had the lowest accuracy among the three age groups. In addition, it would be interesting to define a
minimum acceptable accuracy for a logo sign that is in accordance with the expectations of the businesses that participate in the Logo Signing Program. In the case that drivers have lower accuracy than expected, NCDOT should reconsider an investment in that specific logo sign presentation format as it is not as efficient as the current standard (e.g., six-panel logo sign).
9.0 RECOMMENDATIONS

The literature shows a set of studies performed to assess driver accuracy and performance under different logo sign presentation format during daylight. However, there has yet to be a study to verify how accurately and safely drivers perform at night, under limited light, or under severe weather such as heavy rain. Based on this, further research should be performed to verify the impact of driver’s age, number of panels, logo format, and logo familiarity under four different scenarios: daylight, night, good weather (sunny), and severe weather (heavy rain).

With respect to the maximum number of panels on a logo sign, our study showed that variables such as logo familiarity and driver’s age have significant impacts on driver accuracy for six and nine-panel logo signs. Reviewed literature did not reach an agreement with respect to this subject. Therefore, additional research should be conducted to determine definitively whether or not nine-panel logo signs are efficient and do not have a negative impact on drivers’ safety.

More research to compare text- and symbol-based logos should be performed to refine the results from this study. As previously explained, logo format was assessed by using attraction logos on the bottom row of a two-service sign. A previous study, Dagnall et al. (2013), conducted a computer-based experiment to compare logo signs that contained either all text-based logos or all symbol-based logos. However, as discussed previously, a computer-based experiment does not simulate real driving conditions and tasks (lane maintenance, speed control, and acceleration). Also, no data were collected on visual workload and demand in respect to the text and symbol-based logo signs. Thus, further research should be performed using a driving simulator to compare an entire six-panel or nine-panel logo sign with either
100% text-based logos or 100% symbol-based logos and data on visual demand should be collected as well.

The medium-fidelity driving simulator proved to be a valuable tool in assessing driving performance under different conditions and enabling the collection of a set of variables that goes beyond speed and lane deviation, (such as deceleration, acceleration, and lane changing). However, one limitation encountered is the fact that the driving simulator could not reproduce body movement sensations which result from driving. An option would be to adopt a high-fidelity driving simulator that which is able to simulate the sensations of breaking, accelerating, and turning (NADS, n.d.). An example of high-fidelity simulator is the one located in University of Iowa. However, such apparatus requires a substantial amount of investment and, therefore, researchers must analyze its feasibility according to the project objectives and budget.

With respect to the eye tracking equipment and software, they are as valuable as the driving simulator. However, we had problems in our recent study with the mal-function of the eye-tracking equipment during tests with participants who wore glasses (the FaceLAB software could not capture the participant’s eyes movement). It will be necessary to make improvements in order to avoid the future loss of data of participants who wear glasses. Both driving simulator and eye-tracking system are recommend for future logo sign studies.

Finally, collaboration between transportation engineering and human factors researchers will be essential in conducting logo sign presentation format studies that ensure an appropriate and efficient logo sign design to promote driver safety.


10.0 REFERENCES


Oregon Travel Information Council (OTIC) (2010). [Delve Results]. Unpublished raw data.


APPENDICES
APPENDIX A  NCDOT LOGO SIGNING PROGRAM

A.1 GENERAL INFORMATION

Logo Signing Programs were approved by the Federal Highway Administration (FHWA) through the Highway Beautification Act of 1965 to support the placement of signs in advance of strategic interchanges that allow businesses to promote marketing by placing their logos on these signs. These large blue signs are now located along freeways, interstates, and exit ramps and are referred to as logo signs.

DOTs must meet the criteria for logo signs that were established in the MUTCD (FHWA, 2009), which include a maximum of six logos per sign and business categories that include only lodging, food, gas, attraction, and camping. However, other characteristics of the program might vary from one state to another such as fees and size of the sign (still respecting the minimum size specified in the MUTCD, (FHWA, 2009)).

Revenue

The North Carolina Department of Transportation (NCDOT) has its own Logo Signing Program. The program is nonprofit and was created to be self-sufficient. Therefore, there is an annual participation fee of $300.00 per year per logo that businesses pay which covers the installation of the logo on signs as well as NCDOT’s administrative costs (Logo signing program, n.d.). Usually a business places its logo in four locations per interchange: one in each mainline direction (two total) and one on each exit ramp (two total). As a result, the total annually cost per business per interchange is about $1,200.00 (four times $300.00).
Estimated Number of Interchanges in NC

Using the North Carolina 2013-14 Official State Transportation Map, it was possible to estimate the number of interchanges in NC. Among all the transportation features displayed on the map, the focus was given to fully-controlled access interchanges located on Interstates, US Routes, and State Routes. Figure A.1 shows the map used in this study. The pink highlights represent the interchanges located on Interstates. The yellow highlights represent the interchanges located on US Routes and State Routes.

![Map of North Carolina with highlighted interchanges](image)

**Figure A.1 North Carolina 2013-14 Official State Transportation Map**

By counting those interchanges, the approximate number of interchanges in the state is about 676 of which 482 are located on Interstates, 187 are located on US Routes, and 7 are located on State Routes. Table A.1 shows how the interchanges are distributed among the many routes in NC. The first column indicates the route classification (Interstate, US, or State Route). The
second column identifies the routes through their ID. Finally, the third column indicates the number of interchanges located along each one of those routes.

Table A.1 Distribution of Interchanges in NC

<table>
<thead>
<tr>
<th>Route Classification</th>
<th>Route ID</th>
<th>Number of Interchanges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstates</td>
<td>I-95</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>I-40</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td>I-77</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>I-74</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>I-85</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>I-795</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>I-26</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>I-440</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>I-540</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>I-485</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td><strong>SUBTOTAL</strong></td>
<td><strong>482</strong></td>
</tr>
<tr>
<td>US Routes</td>
<td>US-70</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>US-258</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>US-17</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>US-264</td>
<td>12</td>
</tr>
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<td></td>
<td>US-64</td>
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<tr>
<td></td>
<td>US-52</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>US-321</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td><strong>SUBTOTAL</strong></td>
<td><strong>187</strong></td>
</tr>
<tr>
<td>State Route</td>
<td>147</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>676</strong></td>
</tr>
</tbody>
</table>
Average Number of Business per Interchange

A field survey was performed along portions of Interstates I-40 and I-85. On Interstate I-40 (in both West and East directions), all interchanges between Exits 287 and 224 were field surveyed; the survey resulted in 29 interchanges. On Interstate I-85 (North and South), data were collected between Exits 179 and 229, over a total of 17 interchanges. A total of 46 interchanges had their logo signs recorded through photography. The logo signs identified along these routes included the following configurations: three-panel, six-panel, nine-panel, and overflow combination.

Table A.2 shows the total number of businesses logos that were observed at these 46 field surveyed interchanges, organized by the category of the business. Not surprisingly, the dominant category was food, followed by gas, and then lodging. Based on the field survey, there are 341 businesses logos on the Logo Signing Program that are distributed among 46 interchanges, which results in an average of 7.4 businesses logos per interchange. Last column of Table A.2 also shows the average of logos per interchange per category.

<table>
<thead>
<tr>
<th>Logo Category</th>
<th>Number of Logos</th>
<th>Average Logos per Interchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lodging</td>
<td>68</td>
<td>1.5</td>
</tr>
<tr>
<td>Food</td>
<td>184</td>
<td>4.0</td>
</tr>
<tr>
<td>Gas</td>
<td>89</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>341</strong></td>
<td><strong>7.4</strong></td>
</tr>
</tbody>
</table>
**Estimated Number of Businesses in NC**

Given that there are approximately 676 total interchanges in NC and that the average number of businesses per interchange is 7.4, it can be inferred that there are about 5,000 food, lodging, and gas businesses that participate in the NCDOT Logo Signing Program state wide.

**Total Revenue**

Given that there are about 5,000 businesses participating in the Logo Signing Program and that the average revenue per business is $1,200.00 annually, NCDOT obtains approximately $6 million of revenue from its Logo Signing Program.

**Benefits**

According to the Logo Signing Manual (NCDOT, 2006), businesses that participated in the program reported having a significant increase in their sales. In addition, businesses using the program do not need to be concerned with sign maintenance because the cost of this service is included in the annual program fee ($300 per logo).

Among the benefits of participating in the Logo Signing Program is the fact that drivers rely more on businesses that participate in the logo program because those signs are state-sponsored, are larger, and are exceedingly visible. Small business can also enable their logo to become better known by displaying them on logo signs; that way, even drivers from other areas will be aware of the options nearby. Another benefit provided by the logo program is that the signs located on the exit ramps provide drivers with important information about the business location (direction and distance).
Requirements

To participate in the Logo Signing Program, businesses must satisfy a set of criteria according to the category to which they belong. These criteria are described in the Section 2J.01 of the MUTCD (FHWA, 2009). It is also important to note that there might be small differences from one DOT to another. A simple example is that the Virginia Department of Transportation (VDOT) requires food businesses to be open at least 12 consecutive hours to qualify while NCDOT requires 8 hours.

Drivers who are aware of the minimum requirements established by DOT’s can make better decisions when choosing which business to frequent. However, drivers are not often aware of these requirements. To determine which expectations drivers have in relation to food businesses shown on logo signs an interesting study was conducted by O’Leary et al. (1999) in Virginia. The method used by the authors was to distribute surveys in rest areas and welcome centers. After analyzing 520 completed surveys, they concluded that most drivers looked for restaurants close to interchanges (within three miles) and that they expected these businesses to be open for long hours per day. Some of the requirements to participate in the VDOT Logo Signing Program are the same as those surveyed, which showed that the drivers’ expectations were aligned with the program requirements. On the other hand, most drivers did not expect all the food business to serve breakfast, which is also one of the program requirements.

Based on these findings, DOTs might develop an advertising program to better inform drivers about what they can expect from businesses participating in the Logo Signing Program. They might also conduct a similar survey focusing on other business categories that participate in
the program (lodging, gas, camping, and attraction) to assess the drivers’ perceptions about them for their particular state. Thus, the results of these surveys could be used to identify possible flaws in the requirements of the program.

Attractions

Relative to the NCDOT logo sign business, attraction logos are relatively new when compared with others categories such as lodging, food, and gas. From the total of 14,733 installed logos in North Carolina, only 284 (1.9%) are attraction businesses (Logo signs, n.d). If desired, NCDOT might increase the participation of attraction businesses by demonstrating that the Logo Signing Program is less costly to the business than providing their own sign. To illustrate, in 2009 the NCDOT Secretary Gene Conti gave an interview to WRAL where he stated “While it may cost $15,000 to $30,000 to have a winery sign erected, it only costs about $1,200 to $1,500 a year to participate in the Logo Program depending on the number of actual logos.” (Hinchcliffe, 2009). An additional advantage is that businesses do not have to be concerned with the maintenance of the sign as this is included in the annual fee paid to NCDOT.
APPENDIX B  PARTICIPANT INSTRUCTIONS

[ ] indicates required actions.

An experimenter needs to read to a participant the text in *italics* in the tables.

**[Begin instructions in Ergonomics Conference Room (D456).]**

1. **Checklist before starting Introduction**

<table>
<thead>
<tr>
<th>No.</th>
<th>List</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>STISIM driving simulator is operational</td>
<td>☐</td>
</tr>
<tr>
<td>2</td>
<td>FaceLab system is operational</td>
<td>☐</td>
</tr>
<tr>
<td>3</td>
<td>EyeWorks system is operational</td>
<td>☐</td>
</tr>
<tr>
<td>4</td>
<td>Driving simulator controllers (e.g., steering box, pedals, etc.) are operational</td>
<td>☐</td>
</tr>
<tr>
<td>5</td>
<td>Simulator steering wheel has been cleaned with alcohol and all displays are clear of dust.</td>
<td>☐</td>
</tr>
<tr>
<td>6</td>
<td>Informed Consent forms are available</td>
<td>☐</td>
</tr>
<tr>
<td>7</td>
<td>Demographic Questionnaire is available</td>
<td>☐</td>
</tr>
<tr>
<td>8</td>
<td>Sign training presentation is loaded on the FaceLab computer</td>
<td>☐</td>
</tr>
<tr>
<td>9</td>
<td>Simulator Sickness Questionnaire forms are available</td>
<td>☐</td>
</tr>
<tr>
<td>10</td>
<td>SDT recording forms are available</td>
<td>☐</td>
</tr>
<tr>
<td>11</td>
<td>Payment forms are available</td>
<td>☐</td>
</tr>
</tbody>
</table>

## Preparing Equipment

**[Start up all equipment]**

Turn on all equipment, including the three STISIM desktop computers, speakers, and the FaceLab eye-tracking system laptop.

**[THREE STISIM DESKTOP COMPUTERS]**

To avoid the sleep mode on the three screens, press channel 1 on the KVM, and move the mouse. The same procedure can be followed for channels 2 and 3 on the KVM. The STISIM scenarios are controlled from channel 2, so leave channel 2 activated (center screen).

Please refer to how to start the STISIM hardware using this website:

http://www.ise.ncsu.edu/ergolab/driving/STISIM_Training.php
2. Orientation

a. Introduction

[Escort a participant into the conference room (D456).]

*Thank you for participating in this experiment. First, please understand this experiment is not a test of your personal ability or driving skills. The objective of this research is to better understand driver use of roadway signs.*

b. Informed Consent Form

[Hand the participant the informed consent form and a pen.]

*This form summarizes information you need to know about the experiment. Please read the document and feel free to ask any questions you may have.*

[Give the participant some time to read the form.]

*If you consent to participate in this study, please sign and date the form. You will be provided with a copy of the form to take with you in the event that you have any questions about your participation in the future.*
Before we start, please turn off your cell phone and place your watch in your pocket. You will be able to take breaks between trials, but in order to prevent distractions, your phone needs to be deactivated during testing and training.

c. Demographic Questionnaire

[After signing the informed consent form, present the DQ.]

Now you will complete a driver background questionnaire. There are three sections to the questionnaire, including demographic information, driving experience, and video game experience. In the first section (demographics), you will provide basic information, such as your name, age, gender, occupation and corrected vision. For the driving experience section, you will answer questions about your driving activity and prior record. If you feel uncomfortable providing information on traffic violations or tickets, please circle “NO.” However, we ask that you provide as much information as possible in completing the form. Lastly, the video game experience section asks how many hours you play video games.

[Verify that a participant completes all information correctly. Once complete, mark the participant number at the end of the form.]

d. Simulator Sickness Questionnaire (SSQ)

[Open the SSQ using the FaceLab laptop computer in the lab]
[Escort participant to driving simulator and ask participant to sit at computer with SSQ loaded on the screen]

This form assesses your risk of developing simulator sickness caused by divergence between the visual sense of body orientation and motion, and realistic (kinesthetic) sensations of physical motion. Symptoms include disruptions in balance and coordination, nausea, dizziness, eye-strain, and headaches. If you demonstrate simulator sickness symptoms during the experiment that exceed your baseline responses, you will be provided with an additional 20-minute rest period before resuming the experiment. If symptoms persist, your participation will be terminated and you will be compensated for any time provided.

There are 16 symptoms in the form. We will go through each symptom and you need to give a rating from 0 to 4, where 0 represents no symptoms and 4 represents severe symptoms. This represents your feelings RIGHT NOW. You will be asked fill-out this form again after the training session and after every two test trials.
[Enter the participants’ answers onto the spreadsheet. Verify that the participant answered all information correctly and that they are not exhibiting significant symptoms (see below SSQ grading procedure).]

**Grading SSQ**
- If any column is >25, or if the sum of the columns is >50, the participant may have simulator sickness and the experiment should be suspended until their symptoms have decreased. If symptoms do not improve sufficiently, the participant should be escorted out of the experiment.

---

e. Equipment Introduction

**[START Equipment Familiarization]**

*In this experiment, we will use a high-fidelity driving simulator with a wide field of view, realistic cab and controls, etc.* **[POINT OUT CAB AND CONTROLS]** *The cab includes a driver’s seat and set of full-size driving controls, including accelerator, brake pedal, steering wheel, and turn signals.* **[POINT OUT STEERING]** *The steering provides a speed-sensitive feel. We can move the seat forward or backward based on how you would normally sit in your car when driving.* **[IDENTIFY SPEAKER SET]** *The cab also integrates audio speakers for roadway sounds and driver warnings.* **[IDENTIFY MONITORS]** *You will see the roadway appear on these three monitors.*

---

3. Training Session

**[START Training Scenario]**
- Turn on cab dashboard light so the participant can see the speedometer
- Make sure the center screen source is “HDMI 1”
- Load scenario or project file:
  - “…\Desktop\DOT_2014_2015\training\Training.evt”
- Enter “S##_Training.Dat” as output file name

*The first training scenario will present a normal freeway driving situation requiring lane maintenance and speed control. You will learn how to use each element of the simulation controller, including the steering wheel and pedals. We ask that you maintain a consistent position of your vehicle in the right lane of the freeway and that you maintain speed at the posted speed limit. The simulation will be automatically terminated at the end of the trial. Please read the displayed instructions first. When you are ready, I will start the experiment.*

**[Turn off lights in lab]**
[Click “Run a Simulation” (The car icon).]

[Ask participant to stand-up briefly at the close of the training trial.]

I am going to check your speed and lane deviation to ensure it meets our criteria for drivers.

After the training session, drag Training.Dat from DOT_2014-2015/Data to the Desktop (be sure that the file on the Desktop to be named "Training.Dat"). Double click on STISIM_Training_Assessment.exe. A window will appear that shows the lane deviation and speed variance, along with the criteria that need to be met. A participant whose training performance remains unacceptable after three consecutive trials should not be retained for further training or be included in experimental trials. In this case, thank the participant for their participation and proceed to Section 6 (Debrief).

a. Training on Business Panel Identification

[Change the center screen’s source to “HDMI 2” and click “Present” on the Google Presentation.]

[Only use PPT file for this part of the training session.]

Now we will show you some of the signs you will see and use during the trials. First is a speed limit sign. You must maintain your speed according to the speed limit while driving.

[Go to next slide] These are examples of logo signs. On these signs you may see food, lodging, or gas. You will also see that some signs contain a section for gas businesses and attraction businesses. Sometimes the attraction businesses will be presented via a symbol logo and at other times they will be simply containing the name of the attraction.

[Go to next slide] Next is a distance sign. This type of sign provides you with three destinations and the distances in miles to the destinations.

[Go to next slide] This sign is a ½ mile exit guide sign. This sign indicates that you are ½ mile from the next interchange, and it tells you what cities are at that interchange.
4. Calibration of Eye Tracking System

**[Switch the center monitor to Facelab Eye-tracking system. IDENTIFY THE EYE-TRACKING CAMERAS.]**

* A FaceLab eye-tracking system is integrated with the simulator and is used to capture your gaze patterns. The Eye-tracking system provides real-time data on your gaze direction as well as eye closure and blink rates. We will calibrate the system to your eyes now.

**[Calibrate Eye-tracking System]**
- Ask the participant to sit upright and look forward at the center of the screen.
- Adjust cameras to capture participant’s face
- Ask participant to exit the cab, then calibrate the cameras by clicking on “Recalibrate” in the “Controls” window
- Ask the participant to re-enter the driver’s seat
- In FaceLab, go to "SET MODEL"
- Take snapshot
- Allow the participant to look around at the screens for 10 to 15 seconds for in order for the FaceLab system to make adjustments.
- For each new participant, go to "New Head Model" (Manual) under the "Head Model" group.
- Save the participant’s head model under their Participant ID.
- Verify that the reference points are accurate to the eye and mouth corners.
- Verify feature templates; make sure that no features, such as glasses, hair, or features that may change (e.g., dimples), are selected by the system.
- Under calibrate, follow the on-screen instructions as participants look directly into each camera.
- Finish the head model calibration.
- In the world model, go to "calibrate."
- Verify the center TV is showing in the FaceLab interface.
- Complete the eye-calibration to the world model.
- Change the TV setting back to the STISIM.

5. Test Trials

a. Preparing Simulator and Equipment (i.e., STISIM, Eye tracking)

**[Load DOT2014 Configuration]**
- C:\STISIM\DOT2014

**[Load appropriate scenario]**
- …\Desktop\DOT_2014_2015\Freeway_Experiment\FreewayScenario_T1.ev*
[Insert “OUTPUT” Data File Name]
- Select the file name based on the participant number, trial identifier and date.
  - e.g., Participant 1, Trial 1, May 20, 2015 → S01_T1_0520.dat

[Open EyeWorks Record]
Once the “Blue page” is shown to the participant do the following:
- Press Alt+ tab -> now click on the “start” icon on the bottom left of the screen.
- Select “Eyeworks” from the start menu.
- Confirm that the new save file is appropriately named to match the STISIM save file.
- Confirm that the frame rate is 10 frames per second.
- Press “start.”
  - The EyeWorks “start” bottom should be pressed at the same time as the number 1 at the Facelab window (Control window/login/number 1 at the bottom of the window)

Close all files except STISIM, Eyeworks, and SSQ-template.xls.

b. Test Trials

(Follow the instructions below for each condition. Check the scenario file name and the output data file name before starting a test trial to verify correct selection.)
along the Interstate, you will be searching the specific service signs for restaurants and attractions. Please recall that you need to maintain the posted speed limit at all times. Stay in the right lane. During the course of each trial, you must indicate when you see a specific service sign containing your target restaurant or attraction. For example, if you are searching for McDonalds, you could say “There is a McDonalds at exit X.” If you do not see the business on a sign, please indicate the business was not present. For example, you could say “There is no McDonalds at exit X.”

For this drive, do not take an exit where you see the specified business on the sign. Instead, you must indicate that you have seen a logo for the business and where that restaurant is located. [Show participant target sheet for the upcoming trial] In this scenario, you are searching for a [restaurant] business panel and a [attraction] attraction panel.

<table>
<thead>
<tr>
<th>#</th>
<th>Panels</th>
<th>Familiarity</th>
<th>Attraction</th>
<th>Food Target</th>
<th>Attraction Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>Familiar</td>
<td>Text</td>
<td>Dunkin’ Donuts</td>
<td>Holiday World</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>Familiar</td>
<td>Logo</td>
<td>Dunkin’ Donuts</td>
<td>Clif’s Amusement Park</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>Unfamiliar</td>
<td>Text</td>
<td>Bobo’z</td>
<td>Village Garden</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>Unfamiliar</td>
<td>Logo</td>
<td>Space Aliens</td>
<td>Pain Amusement Park</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>Familiar</td>
<td>Text</td>
<td>Dunkin’ Donuts</td>
<td>World of Fun</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>Familiar</td>
<td>Logo</td>
<td>Dunkin’ Donuts</td>
<td>Theme Park World</td>
</tr>
<tr>
<td>7</td>
<td>9</td>
<td>Unfamiliar</td>
<td>Text</td>
<td>Sonoma Greens</td>
<td>Everest</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>Unfamiliar</td>
<td>Logo</td>
<td>Casa Cafe</td>
<td>NC Museum of Natural Science</td>
</tr>
</tbody>
</table>

Please read the displayed instructions first. When you are ready, I will start the experiment.

[AT THE END OF THE TRIAL]
[Ask the participant to get out of the driver’s seat and stretch their legs.]

c. Recording target identification data

[How to record observations on the SDT Form]
- Food signs appear before each exit (11, 14, 17).
- When a participant passes a logo sign, the experimenter must enter one of the following into the data collection spreadsheet:
o “0” if the participant says that the target is not on the sign
o “1” if the participant says that the target is on the sign
o “N” if the participant forgot to say anything at all (give them a friendly reminder that they are expected to say their observation out loud).

d. Simulator Sickness Questionnaire (SSQ)

[Conduct SSQ every two trials.]
- Informed consent form
- DBQ
  - SSQ (Baseline)
- Training
  - SSQ 1
- Trial 1
- Trial 2
  - SSQ 2
- Trial 3
- Trial 4
  - SSQ 3
- Trial 5
- Trial 6
  - SSQ 4
- Trial 7
- Trial 8
  - SSQ 5

[SSQ Grading] Please see Section 2-d for detailed information.

6. Debrief

a. Payment Form

[Hand the participant a Payment Form and a pen.]
[Calculate the total compensation for the participant. Multiply $20.00 x (number of hours + (number of minutes / 60))]
[Give the participant the payment form.]

Now the experimental session has finished. Please fill in the payment form. The compensation for you today is $XX.XX.

[Let the participant fill out the payment form then have an experimenter sign.]
[Copy the payment form for Lab records.]
b. Copy of the Consent Form

[Prepare the copy of the consent form.]

The data collected today will be used to study the effects of different types of roadway signage on driver visual attention and performance. If you are interested in future information about this study or have any questions, please contact Dr. Kaber. His contact information is listed in the consent form that you will take home today.

[Give the participant a copy of the consent form and an original copy of the payment form.]

Thank you for participating in this study.

[Escort the participant to Bill Irwin in Daniels 400.]
APPENDIX C  CONSENT FORM

North Carolina State University

INFORMED CONSENT FORM for RESEARCH

This consent document is valid April 24, 2015 through April 24, 2016

Title of Study

Effects of Format and Familiarity of Freeway Logo Sign Panels on Attention Allocation and Driving Performance

Principal Investigator                           Faculty Sponsor (if applicable)

David B. Kaber

What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in this study. Research studies also may pose risks to those that participate. In this consent form, you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?

The research is examining the role of driver familiarity with current logo symbols on “blue” freeway signs in terms of visual processing and vehicle control. The objective of this study is
to test logo sign familiarity, format and content on driver distraction and vehicle control as well as the content and format of guide signs.

What will happen if you take part in the study?
If you agree to participate in this study, you will be asked to complete a training session and experimental test trials in the Ergonomics Lab in Daniels Hall (room 457). In training, you will be asked to perform a simulated drive on a freeway including horizontal and vertical curves. In this trial, you will learn how to identify specific text or logos when you see roadway signs.

Before and after the training session, Simulation Sickness Questionnaires (SSQ; Kennedy et al., 1993) will be administered to assess your risk of developing simulator sickness. You will be given a 5-minute break after the training session.

Before formal experimental testing, you will work with experimenters to calibrate an eye-tracking device to track your gaze pattern during the driving simulation. You will sit on a chair and be asked to look straight ahead or at some specific locations on simulator display screens. The eye tracker will not touch your eyes and will not harm your vision in anyway.

During experiment testing, you will complete eight driving trials. Each trial will last approximately 10 minutes. During a drive, you will be instructed to complete vehicle maneuvers while identifying sign content. Other factors to be manipulated in the experiment trials include the number of panels in specific service signs, target familiarity and formatting of signs. We will videotape the procedure for all eight experimental trials. Your performance will be recorded by the driving simulator software and eye gaze patterns will be recorded by
the eye-tracking system. During each trial, an experimenter will also record your responses to specific roadway signs. After every trial, a SSQ will be administrated to assess the risk of your developing simulator sickness symptoms. Five-minute breaks will be provided after every trial outside of the simulator cab. If you demonstrate simulator sickness symptoms above baseline responses (recorded at the outset of the study), you will be provided with an additional 20-minute rest period. If symptoms persist, your participation will be terminated and you will be compensated for any time provided. Lastly, you will fill out a payment form and depart the lab.

**Risks**

The risks associated with participation in this study are unlikely and minimal. The risks may include potential visual fatigue from viewing simulator imagery on HDTVs for extended periods, soreness of shoulders and arms from controlling a steering wheel, and some fatigue from pushing foot pedals. There is also a risk of simulation sickness due to the immersive nature of the virtual reality driving system used in this study. In the event that you indicate fatigue or discomfort during the experiment, a rest period will be provided. If abnormal physiologic conditions persist, your participation in the experiment will be terminated. With respect to the use of the FaceLab eye-tracking system, infrared lights are used to create reflections on the surfaces of your eyes in order to capture gaze patterns. However, the system does not pose any harm to your eyes and does not accelerate eye fatigue during use.

Your driving experience and history will be collected, including information about accidents, driving under the influence and other moving violations. This information is generally a part of the public record, and the researchers are protecting your identity by using a code number
on data collection materials instead of your name. This code number is linked to your identity on a “master list” that is kept separately from other data.

**Benefits**

There is no direct benefit of this research to you. You may learn about driving simulator technology and human factors research methods.

**Confidentiality**

The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely in a locked cabinet and password-protected computers in the Ergonomics Lab in Daniels Hall (room 457). No reference will be made to your identity in oral or written reports. Your identity will be protected by the use of a code number that is linked to your identity during data collection. The video recordings will be digitized and stored in password-protected computers located in the Ergonomics Lab. If the video will be shown as academic demonstration, the image related to your identity will be blurred and protected. The video files will be destroyed at the conclusion of the study.

**Compensation**

For participating in this study you will receive compensation at the rate of $20/hour. It is expected that the study will take 3 hours and that you will receive $60. If you withdraw from the study prior to its completion, you will receive compensation at a rate of $20/hour for the time committed to the experiment up to that point.
**Emergency Medical Treatment**

If you need emergency medical treatment during the study session(s), the researcher(s) will contact the University’s emergency medical services at 515-3333 for necessary care. There is no provision for free medical care for you if you are injured as a result of this study.

**What if you are a NCSU student?**

Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

**What if you are a NCSU employee?**

Participation in this study is not a requirement of your employment at NCSU, and your participation or lack thereof, will not affect your job.

**What if you have questions about this study?**

If you have questions at any time about the study or the procedures, you may contact Dr. David Kaber, at the Department of Industrial and Systems Engineering, Box 7906, North Carolina State University, or (919) 515 0312.

**What if you have questions about your rights as a research participant?**

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).
Consent To Participate

“I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled.”

Subject's signature_______________________________ Date __________________

Investigator's signature__________________________ Date __________________
APPENDIX D  DEMOGRAPHIC FORM

Driver Background Questionnaire (DBQ)

Please check one box only (for multiple choice questions) unless otherwise indicated.

Section A: Demographic

1. Name (e.g., first last): ___________________ __________________ 

2. Please write your age in years: __________________________

3. Please select your gender:     Male □  Female □

4. Please write your current corrected vision (e.g., 20/20): 
   Left __________ Right __________

Section B: Driving Experiences

5. Please write the year when you obtained your full license? _________

6. About how many days per week do you drive nowadays?
   a. 1-2 days per week □
   b. 3-4 days per week □
   c. 5-6 days per week □
   d. Everyday □

7. Estimate roughly how many miles you personally have driven in the past year:
   a. Less than 5,000 miles □
b. 5,000-10,000 miles ☐
c. 10,000 – 15,000 miles ☐
d. 15,000 – 20,000 miles ☐
e. Over 20,000 miles ☐

8. Please state which of these types of road you use frequently (check one or more boxes as appropriate):
   a. Freeways ☐
b. Other main roads ☐
c. City streets ☐
d. Country two-lane roads ☐

9. During the last three years, how many minor road accidents have you been involved in?
   (A minor accident is one in which no-one required medical treatment, AND cost of damage to vehicles and property were $1,000 or less).

   Number of minor accidents ____ (if none, write 0)

10. During the last three years, how many major road accidents have you been involved in?
    (A major accident is one in which EITHER someone required medical treatment, OR costs of damage to vehicles and property were greater than $1,000, or both).
Number of major accidents ____ (if none, write 0)

11. During the last three years, have you ever been convicted of DRIVING UNDER INFLUENCE OF ALCOHOL OR DRUGS?
   Yes ☐ No ☐
   a. If yes, how many times did this occur? ______________

12. During the last three years, have you received a ticket for CARELESS OR DANGEROUS DRIVING?
   Yes ☐ No ☐
   a. If yes, how many times did this occur? ______________

13. During the last three years, have you received a ticket for SPEEDING?
   Yes ☐ No ☐
   a. If yes, how many times did this occur? ______________

14. During the last three years, have you received a ticket for OTHER MOVING VIOLATION?
   Yes ☐ No ☐
   a. If yes, please specify ______________
   b. If yes, how many times did this occur? ______________
Section C: Video Game Experience

15. How many hours per week do you play video games?

___________________ hours per week.

a. How many of these hours are spent on driving-simulator like games?

___________________ hours per week.