ALTERNATIVE INFORMATION SIGNS: AN EVALUATION OF DRIVER COMPREHENSION AND VISUAL ATTENTION

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16. Abstract

The effectiveness of a traffic sign is collectively influenced by the sign's understandability, legibility distance, glance legibility, and learnability; however, understandability has been repeatedly identified as a one of the most important measures of effectiveness. This study contributes to best practices for evaluating traffic sign understandability by using a variety of online survey questions and driving simulation tasks to assess the understandability of alternative Tourist Information signs in Oregon. To achieve this goal, the understandability of five alternative Tourist Information signs were first tested in an online survey with 142 participants, resulting in the identification of the four best-performing alternatives. The understandability of these alternatives was then tested in the OSU Driving Simulator with 42 participants. The "INFO" Sign was found to be correctly understood by 95.7% of the driving simulator subjects. The two "i" Sign alternatives had the second and third highest comprehension rates for driving simulator subjects with 72.8% for signs without a circular border and 75.4% for signs with a circular border. There was a statistical difference, at the 95% level, between the comprehension results of the online survey and the driving simulator test of the "?" Sign. However, it is likely that comprehension rates for the "i" Sign will continue to increase in the future due to its prolific usage in a wide variety of contexts.

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List of Abbreviations

PacTrans: Pacific Northwest Transportation Consortium
WSDOT: Washington State Department of Transportation
ODOT: Oregon Department of Transportation
GRA: Graduate Research Assistant
NCUTCD: U.S. National Committee on Uniform Traffic Control Devices
CUTCDC: Council on Uniform Traffic Control Devices for Canada

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Chapter 1 Introduction

Tourism is a major source of revenue worldwide. In the last nine years, the number of international inbound tourists in the United States has risen from 41.2 million (2003) to 67.0 million (2012) (The World Bank 2014). For example, the Gross Domestic Product of the travel industry in the State of Oregon was $3.5 billion in 2013, placing it among the three largest export-oriented industries in the state (Dean Runyan Associates 2014). The travel industry also has a significant secondary effect on employment in Oregon. In 2013, the re-spending of travel-related revenues by businesses supported 42,300 additional jobs outside of the travel industry (Dean Runyan Associates 2014). Intuitive access to visitor information centers is a vital contributing factor to the potential economic impacts of tourism in Oregon and elsewhere. Tourist Information signs are intended to direct roadway users to nearby tourist information centers (MUTCD 2009). However, for these signs to work effectively, they need to be easily interpreted and understood by a wide variety of visitors.

Because of the economic importance of tourism and a wide variability in sign display, there is a significant interest in the comprehension rate of Tourist Information signs. It has been hypothesized that a symbolic message may elicit a higher comprehension rate than a text-based message because of its language independent nature and the minimal space needed to deliver the intended message (Walker et al. 1965). Previous research has been conducted on information sign comprehension using surveys and on sign legibility using a sign simulator (Katz, et al. 2008). In contrast, the study described in this paper is distinct from the work by Katz, et al. (2008) because driver comprehension was tested with open-ended survey questions, rating survey questions, and open-ended interview question while subjects were engaged in a simulated driving task. This experimental design provided information about not only the comprehension of the information sign, but also the best practices for determining sign comprehension.

Chapter 2 Literature Review

To strengthen the argument for the above-mentioned research focus and to set the stage for the experimental design, a brief review of literature relevant to Tourist Information signs and traffic sign comprehension is provided. The findings are presented in four focus areas: tourist information sign standards and contexts, relevant research on traffic signs, in general, and the “i” sign, specifically, and sign comprehension testing methods.

2.1 Tourist Information Sign Standards

The information message, (which is intended to inform visitors that information is available to them), is used in a wide variety of contexts including tourism, shopping, and software help, and general information. The Tourist Information sign [D9-10] is defined as a General Service Guide Sign by the Manual on Uniform Traffic Control Devices (MUTCD), which sets standards for traffic control devices including signage in the United States (FHWA 2009). Internationally, alternative Tourist Information signs have been recommended and adopted. For example, the United Nations World Tourist Organization Executive Council (UNWTO) adopted four possible sign symbols (Figure 2.1) to indicate the location of an information center on November 30, 2000 (UNWTO 2000). Despite their differences, these symbols have one commonality: the use of a lower case letter “i”.

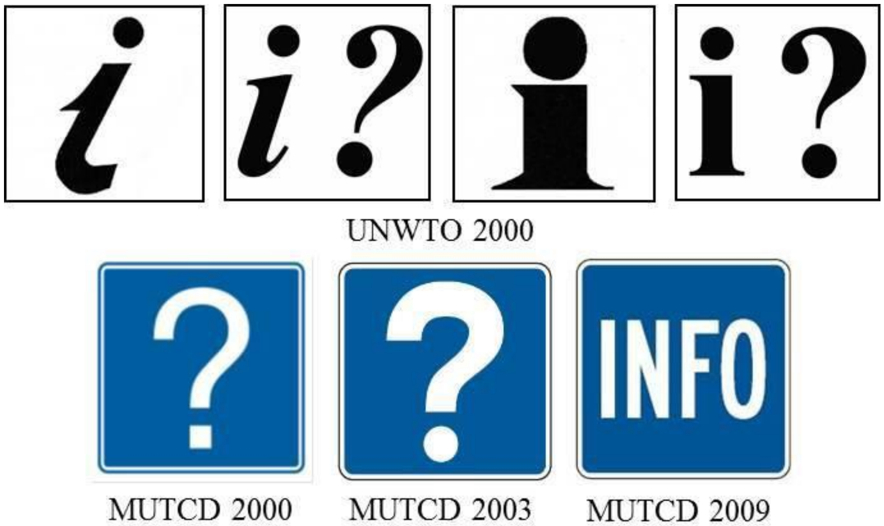


Figure 2.1: UNWTO recommended and MUTCD required Tourist Information signs

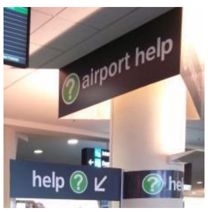
While the MUTCD and the UNWTO have both proposed information sign standards, other symbols have been used in a variety of transportation and non-transportation related contexts. Hence, it is important to observe other symbols that have been used to indicate locations where information is available and to observe what messages the symbols in Figure 2.1 have been used to represent.

2.1.1 Information Signs and Symbols in Different Contexts

The numerous contexts of information signs and symbols necessitate additional investigation to inform transportation and travel related applications. The contexts range from smart phones to internet enabled mapping sites to airports. The most common approach, based on a review of the literature, is the use a lower-case letter “i” or “?” as the information symbol. While there are a variety of “i” signs used in several different contexts, it should be noted that many of these presentations include a circular background surrounding the “i”. Another common approach is the use of a “?” to indicate the availability of information. About half of the“?” signs use a circle as an element of the symbol. The “i” symbol and the “?” symbol have been used in a variety of contexts and typically have been used to indicate that information is available (Figure 2.2). Many of these symbols have also been used internationally to communicate meanings.

Alternative Applications

Airport:



Christchurch Airport, Christchurch, New Zealand

Portland International Airport, Portland, OR

Sydney International Airport, Sydney, Australia

Hawaii International Airport

Roadway:

Road sign, New Zealand

Tourist Information Center, Oxford, UK

Tourist Information Hokitika, New Zeland

Authur’s Pass National Park, New Zeland

Other:

Public Library, Washington, D.C.

Siri Onscreen Guide, iPhone User Guide

Store Map Ikea, Portland, OR

In-Page Analytics, Google Analytics

Figure 2.2: Example information signs and symbols from alternative contexts

2.1.2 Relevant Traffic Sign Research

It has been postulated that certain inherent characteristics are required for traffic signs to perform effectively. Numerous studies have been conducted to describe these characteristics, including three seminal studies: Dewar, 1988, Smiley et al., 1998, and Castro et al., 2004 (Figure 2.3).

Dewar interviewed four groups of experts, ranging from 12 to 30 participants per group, with expertise in traffic control devices or traffic engineering, asking them to rate six traffic sign design criteria. Each participant was asked to rank, on a 10-point scale, the importance of legibility distance, understandability, conspicuity, learnability, glance legibility, and reaction time, as defined in Figure 2.3. From the participant rankings, learnability was consistently rated least important, among the provided criteria, across all sign types. With reference to information signs, conspicuity was ranked as most important followed by understandability.

In 1998, the Ministry of Transportation in Ontario, Canada designed a new tourist signing system. In the development of the system, they used the following criteria to develop the signing system (Smiley et al., 1998): Comprehension, conspicuity, information load, legibility, and driver response as defined in Figure 2.3. The authors also claimed that the last factor, driver response, is much more critical for regulatory signs than for guidance signs. While they did not provide the reasons for their criteria choices, it is interesting to note that their five chosen criteria were also the top five ranked criteria determined by Dewar in 1988.

Castro et al. (2004) proposed that four sequential stages exist when a road user interacts with a traffic sign and each stage has a key consideration. In each of the four stages: detect, read, understand, and respond, as defined in Figure 2.3, the driver uses some aspect of the sign to accomplish the necessary interaction (Castro et al. 2004).

Dewar, 1988	Smiley et al., 1998	Castro et al., 2004
Legibility Distance- The greatest distance at which the symbol can be clearly interpreted.	***Legibility***- At what distance can drivers read the sign?	***Detect***- The sign must be both visible and conspicuous.
Glance Legibility- The ease with which the symbol can be interpreted when it is seen for only a fraction of a second.	***Conspicuity***- Does the sign attract attention given the background in which it is placed?	***Read***- The sign needs to be legible at an adequate distance and in the time available.
Conspicuity- The extent to which a sign can be easily detected or seen in a visually complex environment.	***Comprehension***- Do drivers understand the meaning of the sign message and any pictographs or abbreviations used?	***Understand***- The sign must be comprehensible, unambiguous, and precise.
Understandability- The ease with which the symbol can be understood.	***Information Load***- Do drivers have sufficient time to take in all the information included on the sign?	
Reaction Time- How quickly the meaning of the sign can be identified.		
Learnability- The extent to which the meaning of a symbol can be learned and remembered.	***Driver Response***- Do drivers make the desired action as a result of reading the sign?	***Respond***- The sign must be credible, correct, appropriate, and timely to elicit the correct response.

Figure 2.3: Critical sign characteristics and their relation between studies over time

2.1.3 "i" Sign Research

The "i" symbol was tested for comprehension and legibility by Katz et al. (2008), who compared the "i" symbol with the "INFO" word message and the "?" symbol. The comprehension research was conducted with open ended and multiple choice survey questions administered to 174 participants, and legibility distances were determined in a SignSim laboratory consisting of a projector with a zoom lens with 48 participants. The comprehension and legibility results are included in Table 2.1.

Table 2.1: Comprehension and Legibility Results for Information Symbols (adapted from Katz et al., 2008)

Sign Type:	**Comprehension Survey Questions:**		**Legibility Distance:**
	Open Ended	**Multiple Choice**	
"i" Symbol	56%	95%	Approximate range of 200 to 250 feet
"?"Symbol	68%	92%	Approximate range of 200 to 250 feet
"INFO" Symbol	96%	76%	157 feet as tested; predicted at 251 with increase in letter height

From an exclusively domestic survey sample, Katz et al. found that 56% of the subjects understood the correct meaning of the "i" symbol as compared to 68% with the "?" symbol and 96% with the "INFO" symbol when presented with the open-ended test. The multiple choice questions included four alternatives: use caution, wireless internet availability, medical assistance, and traveler information. The multiple choice questions resulted in 95% of subjects correctly understanding the "i" symbol, 92% with the "?" symbol and 76% the "INFO" message. The most significant risk for the transferability of multiple-choice traffic sign comprehension surveys is the quality and plausibility of distractor questions (Wolff and Wogalter 1998). As such, the observation that several of the distractors were not selected for some of the sign alternatives, may bring into question their plausibility. Additionally, Katz et al. found the “i” Symbol and the “?” Symbol had a statistically greater legibility distance than the “INFO” Sign as tested, but it was predicted that the legibility distance of the “INFO” sign could be increased to 251 feet if the height of the letters was increased from five to eight inches.

Chapter 3 Methodology

This section describes the research objectives and experimental methods used to evaluate alternative information signs in Oregon. Specifically, the methods included (1) an online survey to determine general public understanding and preference for information signs and (2) a human factors assessment of actual response to the signs in a driving simulator. The online survey produced data from both open-ended and rating comprehension questions. Data from both parts of the online survey was analyzed across subject demographics. The driving simulator data provided measurements of visual attention and accuracy of verbal responses.

3.1 Research Objectives

The primary objective of this research is to determine which tourist information sign has the highest level of understandability by evaluating the comprehension and glance patterns between sign alternatives and test methods. Specifically, the four null hypotheses examined were:

1. There is no difference in driver's comprehension between each sign alternative;
2. There is no difference in the driver's glance patterns or fixation points between each sign alternative;
3. There is no difference in the driver's glance patterns or fixation points between correct, partially correct, and incorrect responses; and
4. There is no difference in driver's comprehension between each sign alternative in the online survey and in the driving simulator.

3.2 Online survey

Qualtrics (Qualtrics, Provo, UT) was used to develop an online survey which consisted of demographic questions, open-ended sign comprehension questions (Figure 3.1a), and rating questions (Figure 3.1b). Open-ended questions were used, as they are the recommended practice of the American National Standards Institute (ANSI) Z535.3 and also to avoid the impact of poorly selected distractors (Wolff et al. 1998).The rating questions were included due to the findings of Zwaga (1989) which showed that subject estimates of population comprehension can reliably be used as an early indicator for the usefulness of a symbol.

Subjects who were younger than 18 years, older than 75 years, or who had not been a licensed driver for more than one year, were excluded from the study.

a b

Figure 3.1: Example images of comprehension (a) and rating (b) questions for the "i" Sign

For the open-ended comprehension questions, subjects were presented with five alternative information signs (Table 3.1) on one of two different authentic Oregon roadway backgrounds to provide an authentic context, as the presentation of signs in a realistic context was shown to greatly facilitate comprehension (Wolff et al., 1998). The order of sign alternatives and backgrounds presented to each subject were randomized.

Table 3.1: Alternative signs tested

"i" Sign:	**"i" Sign with circle:**	**"INFO" Sign:**	**"?" Sign:**	**"?" Sign with circle:**
				

As seen in Table 3.1, three basic sign types were selected for the survey based on those found in the literature review: the "i" Sign, the "?" Sign, and the "INFO" Sign. A slight variation was included for both the "i" Sign and the "?" Sign. In addition to the symbol, a circle around the symbol was also considered. The inclusion of no more than one variation of an individual symbol for each subject is consistent with the ANSI Z535.3 recommendation.

Prior to beginning the rating questions (Figure 3.1b), subjects were presented with the following description of tourist information centers, provided by Travel Oregon: "Tourist Information Centers provide brochures, directions, and information about the surrounding area. This information includes local and regional activities and tourist attractions, as well as information about local restaurants and lodging." Subjects were then asked to, "Select the percentage of the population you think will understand the following signs to represent a Tourist Information Center." As with the comprehension questions, all five of the sign alternatives (Table 3.1) were presented in a random order to each subject.

3.3 Driving Simulator Study

During the driving simulator experiment, the subject's comprehension of alternate Tourist Information signs was assessed while they were engaged in a simulated driving task. The same signs were tested in the driving simulator experiment as those that were tested in the online survey, except for the "?" Sign. The "?" Sign was removed because it consistently generated the lowest comprehension rates. In a brief follow-up survey, subjects were given an online survey to rate the four signs they encountered during the driving simulator experiment, according to the percentage of the drivers in the United States that would correctly understand the sign.

3.3.1 Driving Simulator

The Oregon State University (OSU) Driving Simulator is a high-fidelity simulator, consisting of a full 2009 Ford Fusion cab mounted on top of a pitch motion system (Figure 3.2a and 3.2b). The pitch motion system accurately models acceleration and braking. Three projectors produce a 180-degree front view and a fourth projector displays a rear image for the driver's center mirror. The two side mirrors have LCD displays. The vehicle cab instruments are fully functional and include a steering control loading system to accurately represent steering torques based on vehicle speed and steering angle. The simulator software can record performance measures such as speed, position, braking and acceleration at a sampling rate of 60Hz.

a b c

Figure 3.2: Views from a) outside the simulator and b) from inside the OSU Driving Simulator and c) subject wearing eye-tracking device.

As can be seen in Figure 3.2a and 3.2b, the driving simulator provides an immersive, built environment and an authentic driving task that allows individual variables to be examined in isolation while controlling for confounding factors. The human factors assessment was performed in the driving simulator with an ASL Mobile Eye Tracking system (Figure 3.2c) and think aloud interviews.

3.3.2 Eye Tracking

Eye-tracking data were collected using the Mobile Eye-XG platform from Applied Science Laboratories (Figure 3.2c). The advanced Mobile Eye-XG allows the subject to have unconstrained eye movement and unconstrained head movement, generating a sampling rate of 30 Hz and with an accuracy of 0.5 to 1.0 degree. The subject's gaze is calculated based on the correlation between the subject's pupil position and the reflection of three infrared lights on the eyeball. Eye movement consists of fixations and saccades. Fixations occur when a subject focuses on a point in their visual field for a short period of time and saccades occur when the eye moves from one point to another. The Mobile Eye-XG system records a fixation when a subject's eyes have paused in a certain position for more than 100 milliseconds. Saccades are not recorded directly but are calculated based on the dwell time between fixations. However, in this paper, driver saccades were not analyzed.

3.3.3 Scenario Layout

The scenarios presented in the driving simulator were modeled after realistic presentations of Tourist Information signs in Oregon. The subjects were exposed to Tourist Information signs in two contexts; first, on a freeway exit and secondly, at an intersection of local roads (Figure 3.3). The four sign alternatives that performed best in the online survey were selected as the signs tested in the driving simulator.

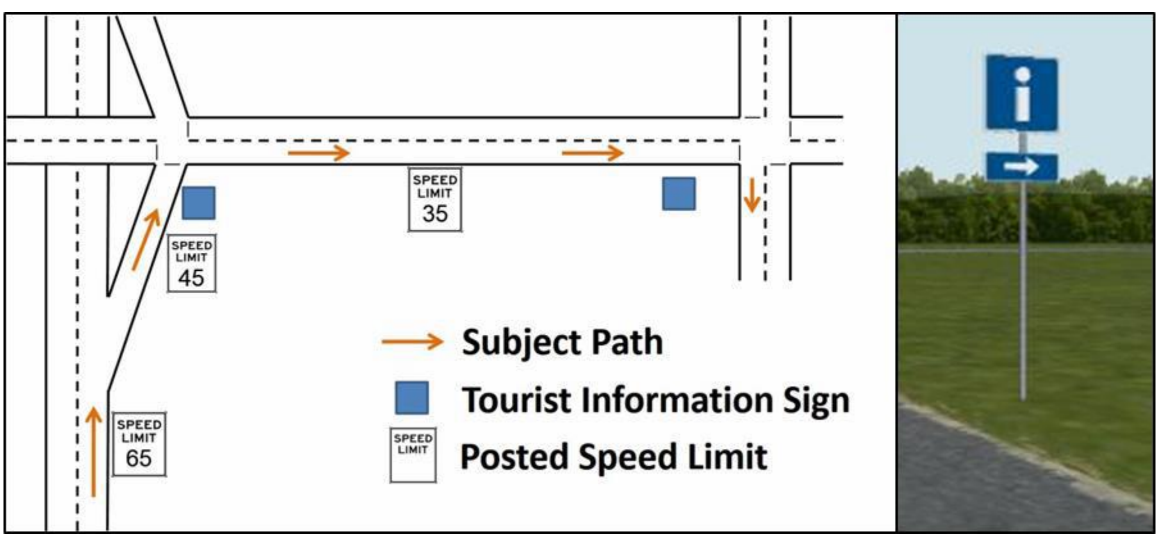


Figure 3.3: Driving simulator track (not to scale) and example "i" sign presented in the simulator

The route taken by the subjects included traveling northbound along a freeway, departing the freeway by an exit ramp, and then turning right twice along local roads. Before the test, each subject was instructed to take the first exit, make a right turn onto the local road followed by a right at the final intersection. Each subject drove through the environment a total of four times. During the first two drives, the subject was shown each of the four signs in one of the two sign positions shown in Figure 3.3 while eye-tracking data was collected. During the second two drives, the subject drove through the environment again with the signs displayed in a different order. Throughout each drive, data were collected on the subject's lane position and speed. On the last two drives, as the subject approached each sign, they were asked to describe the meaning of the sign while they continued to drive through the environment, as to not unduly influence their glance patterns.

A variety of equipment was used to record and track their responses. Verbal responses were recorded on a Zoom H2n Handy Recorder. The subjects wore the ASL Mobile Eye XG equipment through each of the four drives to record the visual attention of the subjects. Specifically, the fixations of the subject were measured to find the total number of dwells and the average dwell duration on each alternative sign. A fixation was designated as a visual glance by the subject in one area for more than 0.1 seconds. A single dwell was calculated as the sum of multiple, uninterrupted fixations on a single area. Fixations were calculated using ASL Mobile Eye post processing software.

Chapter 4 Results and Analysis

This section describes the qualitative and quantitative data collected from the online survey and driving simulator experiment, the data reduction procedure, and the statistical methods used to analyze the data. All datasets were created as comma separated value (csv) files and imported into Microsoft Excel (Microsoft, 2013) and R (R Core Team, 2014). Data visualization was performed in both Microsoft Excel and R, while the statistical analysis was performed solely in R.

4.1 Online Survey

One hundred and forty two (68 male and 74 female) subjects responded to the online survey. The sample size complies with the ANSI Z535.3 recommendation for testing a minimum of 50 subjects for sign comprehension. The subjects' ages ranged from 19 to 73 years (average age of 34.3). Information on the highest level of education completed, amount of driving in the previous year, and number of years as a licensed driver were also collected. When compared to Oregon DMV records, the subject demographics are representative of the population of Oregon drivers.

4.1.1 Open-Ended Survey Questions

The 142 responses to the open-ended questions were scored independently by five researchers as 1 if correct, 0.5 if partially correct, and 0 if incorrect. This constituted discrete panel data. The use of multiple reviewers, all familiar with the symbol messages, is supported by previously conducted research (Wolff and Wogalter, 1998). Open ended responses were defined as correct if the subject demonstrated an understanding that the sign indicated that an information center was available nearby that could provide local information related to tourist activities. If a subject only demonstrated a partial understanding, the response was defined as partially correct. If a subject did not demonstrate an understanding, the response was defined as incorrect. To insure proper inter-rater reliability, any individual item that was not consistently scored by all five researchers was flagged. Those items were reexamined and discussed by the researchers until a consensus was reached.

In addition to the comprehension score, critical confusions were considered. A confusion was considered critical if the comprehension of the sign is dramatically different from the intended comprehension (ANSI Z535.3). Multiple comparisons were made with the results including differences between gender, age, highest level of education completed, the number of miles driven last year, the frequency of recreation or pleasure travel, the order that the signs were displayed, and whether the symbolic signs contained circular borders. The generated p-values were adjusted for the multiple comparisons through the Benjamini and Yekutieli adjustment.

There were multiple recurring, wrong answers by the respondents. The most common incorrect interpretations were that the “i” symbols indicated pedestrians and that the blue background indicated a hospital sign. Misinterpretations of the signs indicating that a hospital was nearby were marked as critical confusions because of the potential to misguide someone in an emergency. An ANCOVA test was used to test for differences in the means, when considering the factors collected, followed by T-tests if a significant difference was found (Ramsey and Schafer, 2013). A full model (Equation 4.1) was created by including all factors as additive variables.

$$�� ������� ��� ������� = \beta_0 + \beta_1 * �g�� �� + \beta_2 * Ag� + \beta_3 * ���� ��� + \beta_4 * �g ������ + \beta_5 * Y�� ��� ������ + \beta_6 * ������ ��� ��� ������� + \beta_7 * ���� ����i ������ Y�� + \beta_8 * ��g� \quad (4.1)$$

A reduced model was found by comparing the full model with reduced versions until only significant variables remained (Equation 4.2).

$$�� ������� ��� ������� = \beta_0 + \beta_1 * �g�� �� + \beta_2 * ��������� �������Y �� \quad (4.2)$$

The reduced model that emerged showed a significant impact of the sign type and of the miles driven in the previous year ($p < 0.001$ and $p = 0.010$, respectively). T-tests were then performed on the sign alternatives to determine which signs differed from the others; the results of which are shown in Table 4.1.

Table 4.1: Open ended test t-test p-values

Sign Alternatives:	**"i" Sign:**	**"i" Sign with circle:**	**"INFO" Sign:**	**"?" Sign:**	**"?" Sign with circle:**
"i" Sign	1.000	-	-	-	-
"i" Sign with circle	**0.070**	1.000	-	-	-
"INFO" Sign	**< 0.001**	**< 0.001**	1.000	-	-
"?" Sign	0.684	**0.029**	**< 0.001**	1.000	-
"?" Sign with circle	0.365	0.362	**< 0.001**	0.238	1.000

*Bolded values are statistically significant ($p < 0.05$).

The statistical results presented in Table 4.1 show that the “INFO” Sign was comprehended better than all other sign alternatives. The “i” Sign with circle alternative also outperformed the “?” Sign alternative.

Out of the eight driver demographics considered, only the miles that the subject drove in the previous year emerged as significant. The average comprehension score and standard deviation for each grouping of the miles driven in the previous year was 0.76 (0.42) for 0-5,000 mi, 0.85 (0.36) for 5,000-10,000 mi, 0.86 (0.35) for 10,000-15,000 mi, 0.88 (0.33) for 15,000-20,000 mi, and 0.72 (0.44) for more than 20,000 mi. Generally, the comprehension rate rises as the number of miles driven in the previous year rises, with the exception of the group who drove more than 20,000 miles in the previous year.

4.1.2 Rating Task Survey Questions

Panel data with a continuous dependent variable was generated from the rating task when subjects were asked to rate each sign with the percentage of the United States population that would correctly understand each of five information sign alternatives. 10 outliers, which are defined as data points outside 1.5 times the interquartile range above the upper quartile and below the lower quartile, were found and removed before the analysis was conducted. Box and whisker plots were created for each of the signs in the rating task (Figure 4.1), and illustrate the comparison between each sign alternative. The “INFO” Sign alternative was consistently rated best compared to the other tested alternatives.

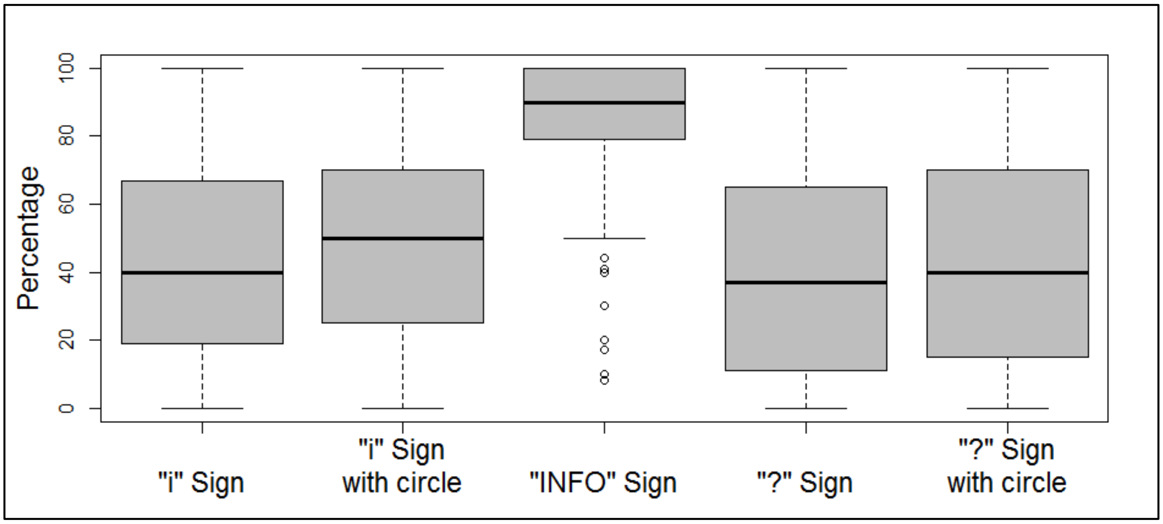


Figure 4.1: Sign comprehension scores from the rating task

Both random and fixed effects models were considered to fit the online survey rating task panel data. A two-way model was chosen to account for the bias that may have occurred due to subjects making multiple observations. The Hausman Test was conducted on the additive model and it was found that the random effects model fit the data better (P-value > 0.05). The number of years licensed was excluded from the model because it was highly correlated with age. The full model considered was an additive model with the remaining seven demographic variables. The model was reduced by removing the least significant terms until the model was found to be significantly different from the full model. The final reduced model included the sign alternative and age. Table 4.2 shows the estimates of these variables in comparison with a base value for each variable.

Table 4.2: Online survey rating task reduced model

Reduced Model Variables:	Levels:	Estimate:	p-value:
Sign Alternative	**"i" Sign**	**-7.85**	**0.020**
	"i" Sign with circle	Base Value	-
	"INFO" Sign	**37.91**	**< 0.001**
	"?" Sign	**-10.39**	**0.002**
	"?" Sign with circle	**-8.63**	**0.011**
Age	-	**-0.227**	**0.002**

*Bolded values are statistically significant ($p < 0.05$).

As seen from Table 4.2, the "INFO" sign was rated higher than all other alternatives and the "i" Sign with circle was rated second highest. The circular border was not found to have a statistically significant effect on the comprehension rates of the "i" Sign and the "?" Sign**.**

4.2 Driving Simulator

Subjects were recruited through email lists and posters in community areas located within Corvallis, OR and Albany, OR. Fifty one subjects (28 male and 14 female) with an age range of 21 to 72 years (average age of 38.7) participated in the driving simulator experiment. Nine subjects, all of which were female, did not complete the experiment due to the occurrence of simulator sickness, representing a simulator sickness rate of 17.7 percent. Of the 42 subjects who completed the experiment, eye tracking data was not collected for eight subjects, one male and seven females, due to an inability to calibrate the equipment. As such, 42 subjects provided useable comprehension data and 34 subjects provided useable eye tracking data.

4.2.1 Driver Comprehension during Simulated Driving

The 42 usable comprehension responses were scored as 1 if correct, 0.5 if partially correct, and 0 if incorrect, resulting in panel data with a discrete dependent variable. The identical, inter-rater reliability procedure used for the survey comprehension questions was implemented for the purpose of reducing the driving simulator comprehension data. In addition to the comprehension score, critical confusions were considered. The data was initially observed by comparing descriptive statistics of each alternative (Table 4.3).

Table 4.3: Driver comprehension scores during simulated driving

Sign Alternative:	Mean:	Standard Deviation:	Critical Confusions:
"i" Sign	0.73	0.44	2.38%
"i" Sign with circle	0.76	0.43	4.76%
"INFO" Sign	0.95	0.22	0.00%
"?" Sign with circle	0.53	0.40	4.76%

Multiple recurring, wrong answers were identified in the subject responses to the comprehension questions. The most common incorrect interpretations were that the "i" symbols indicated that a gas station was nearby or that the blue background indicated it was a hospital sign. Again, the misinterpretation of the sign indicating a hospital nearby was considered a critical confusion. A complete list of the incorrect answers and their frequency is shown in Table 4.4. This table does not include subject responses that failed to include a specific guess.

Table 4.4: Incorrect Tourist Information sign comprehension during simulated driving

Sign alternative:	**"i" Sign:** 	**"i" Sign with circle:** 	**"INFO" Sign:** 	**"?" Sign with circle:** 
Total (Percent)	7 (16.7%)	9 (21.4%)	3 (7.1%)	0 (0%)
Incorrect Answers	 x1	 x2	 x2	
	 x1	 x3	 x1	
	 x1	 x1		
	 x1	 x1		
	 x1			

Three commonalities exist between the different incorrect answers (1) words that also start with the letter "i" (interstate or intersection), (2) signs with an identical blue background (hospital or gas station), and (3) signs that have vertical and or white symbols in the center (airport or pedestrian).

An ANCOVA test was used to assess differences in the means when considering the factors collected: sign alternative, driver age, level of education, sign order, number of years as a licensed driver, frequency of recreation/pleasure travel, and number of miles driven in the previous year. If significant differences were found, the ANCOVA test was followed by T-tests as recommended by Ramsey and Schafer (2013). A full model was created by including all factors as additive variables. A reduced model was then found by comparing the full model with reduced models until only the significant variables remained. The reduced model that emerged showed a significant impact of the sign type and of the order the signs were displayed, $p < 0.001$ and $p = 0.045$, respectively. Two-tail T-tests were performed to determine the comprehension differences between sign alternatives (Table 4.5).

Table 4.5: Driving simulator test t-test p-values

Sign Alternatives:	**"i" Sign:**	**"i" Sign with circle:**	**"INFO" Sign:**	**"?" Sign with circle:**
"i" Sign	1.000	-	-	-
"i" Sign with circle	0.754	1.000	-	-
"INFO" Sign	**0.021**	**0.032**	1.000	-
"?" Sign with circle	**0.042**	**0.024**	**< 0.001**	1.000

*Bolded values are statistically significant ($p < 0.05$).

The statistical results showed that in the driving simulator experiment the "INFO" Sign alternative demonstrated the highest comprehension rate. The two "i" Sign alternatives did not perform differently at a statistically significant level. The "?" Sign with a circle performed worse than all other alternatives at a statistically significant level. These results, as well as 95 percent confidence intervals, are shown graphically (Figure 4.2).

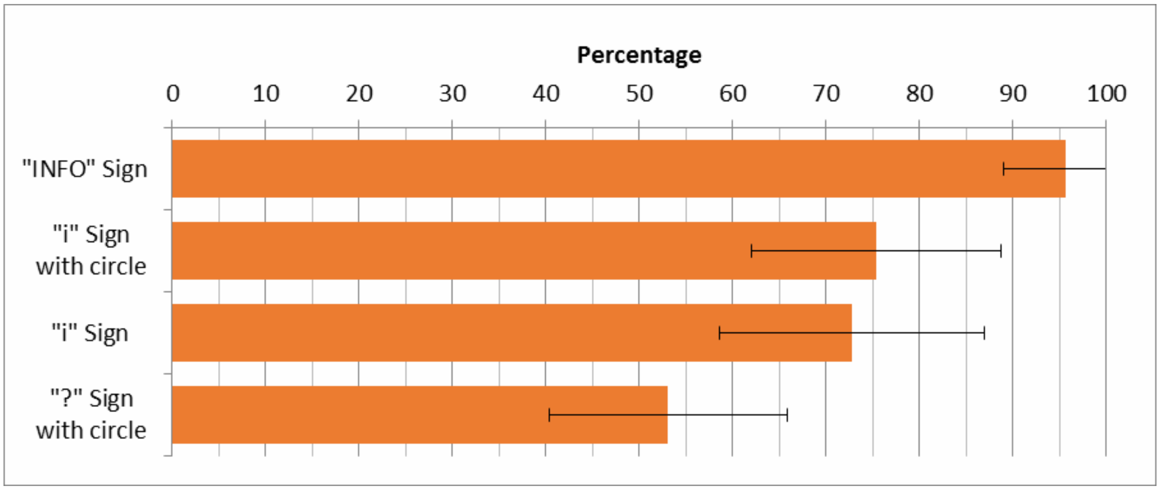


Figure 4.2: Driving simulator task averages with confidence intervals

4.2.2 Visual Attention during Simulated Driving

Differences in visual attention between subjects with correct and incorrect responses were investigated. Initially, descriptive statistics of the total dwell time were calculated for correct (mean 3.96 sec and 1.74 sec standard deviation), partially correct (mean 3.85 sec and 1.30 sec standard deviation), and incorrect (mean 4.28 sec and 1.88 sec standard deviation) subject comprehension. Additionally, a panel linear model was developed to describe the differences between total dwell durations. A model that fit the data was not found for the data and the score did not have a significant impact on the total dwell time. Ultimately, no connection was found between the visual attention of subjects and the correctness of their responses.

4.2.3 Post Drive Survey Rating Task

The rating task question was identical to the rating task question used in the online survey, with the sole modification that it did not include the "?" Sign without the circle as that alternative was identified as the least effective alternative in the online survey and was not presented in the driving simulator experiment. Box and whisker plots were created for each of the signs in the rating task (Figure 4.3).

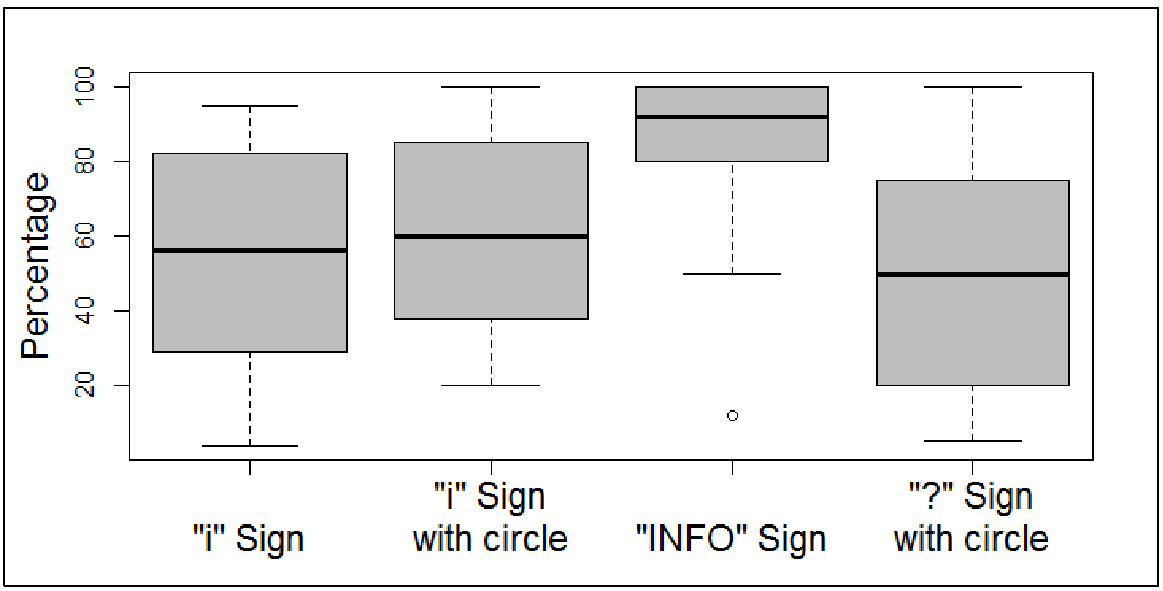


Figure 4.3: Sign comprehension scores from the rating task

In the rating task, the "INFO" Sign performed best followed by the "i" Sign alternatives and then the "?" Sign with a circular border. The "INFO" Sign was consistently predicted to have the best comprehension rate when compared to the other alternatives. Both random and fixed effects models were considered to fit the rating task panel data. A two-way model was chosen to account for the bias that may have occurred due to subjects making multiple observations. A Hausman Test was conducted on the additive model and it was found that the random effects model fit the data better (P-value > 0.05). The number of years licensed was excluded from the model because it was highly correlated with age. The full model (Equation 4.3) considered was an additive model with the remaining seven demographics.

$$[illegible] = \beta_0 + \beta_1 * [illegible] + \beta_2 * Ag[illegible] + \beta_3 * [illegible] + \beta_4 * [illegible] + \beta_5 * Y[illegible] + \beta_6 * [illegible] + \beta_7 * [illegible] \quad (4.3)$$

A reduced model was found by comparing the full model with reduced versions and removing the least significant terms until only significant variables remained. The final reduced model (Equation 4.4) included the sign alternative, the miles driven in the previous year, and age.

$$[illegible] = \beta_0 + \beta_1 * [illegible] + \beta_1 * Ag[illegible] + \beta_2 * [illegible]\,Y[illegible] \quad (4.4)$$

Table 4.6 shows the estimates of these variables in comparison with a base value for each variable.

Table 4.6: Driving simulator rating task reduced model

Reduced Model Variables:	**Levels:**	**Estimate:**	**p-value:**
Sign Alternative	"i" Sign	-8.57	0.112
	"i" Sign with circle	Base Value	-
	"INFO" Sign	**25.87**	**< 0.001**
	"?" Sign with circle	**-14.51**	**0.007**
Miles Driven in the Previous Year	0 – 5,000 miles	-12.94	0.600
	5,000 – 10 miles	Base Value	-
	10,000 – 15,000 miles	-8.43	0.126
	15,000 – 20,000 miles	**-22.09**	**< 0.001**
	More than 20,000 miles	-6.92	0.355
Age	**-**	**-0.30**	**0.013**

*Bolded values are statistically significant ($p < 0.05$).

The "INFO" Sign was rated higher than all other alternatives and the "i" Signs, with and without the circular border, were rated as second highest (Table 4.6). The "?" Sign with a circular border was predicted to have the lowest comprehension rate. The performance difference between the "INFO" Sign, the "i" Sign alternatives, and the "?" Sign with the circular border were all significant. There was not a significant difference between the comprehension of the "i" Sign without the circular border and the "i" Sign alternative with the circular border.

4.3 Test Methods Comparison

Using the research results from this study of alternative information signs in Oregon, the two testing methods for traffic sign comprehension (online survey and driving simulator study) were compared. The driving simulator comprehension results were considered as the baseline for this study because it presents the most authentic simulation of the actual driving task. The results from each testing method follow the same general ranking of sign alternatives (Figure 4.4).

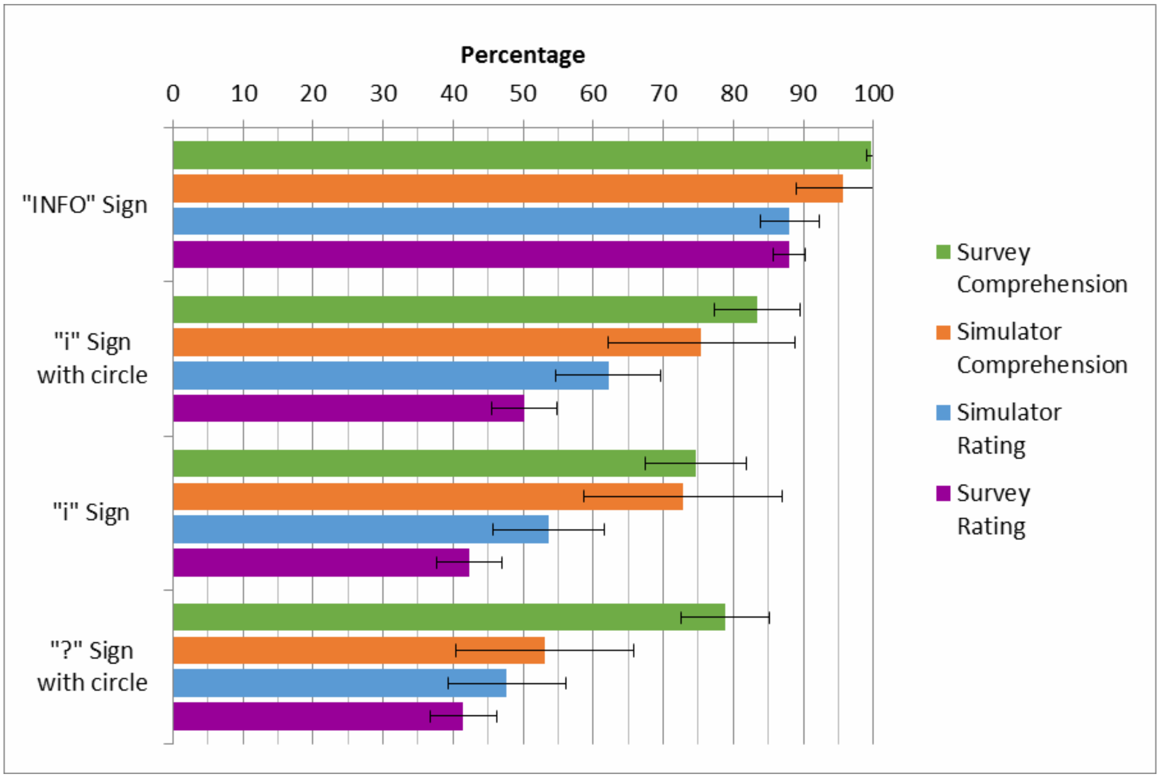


Figure 4.4: Testing method results comparison

Statistical differences were identified between test methods. The “i” Sign results were significantly different in the rating task (p-value = 0.032) and the “?” Sign with circle results were significantly different between the open ended comprehension methods (p-value < 0.001). Each test found the “INFO” Sign alternative to be statistically superior to all of the other alternatives. With the exception of the online survey rating task, each test also agreed that the miles driven by the subject in the previous year was the only significant secondary factor. Because the driving simulator most accurately recreates the driving task, it is the preferred method to test sign comprehension prior to field installation, and represents the most authentic experimental task from this study. The open-ended comprehension test also appears to closely match the comprehension task while driving.

Chapter 5 Discussion

Before traffic signs are installed in the field or more broadly adopted by standards or manuals, their understandability, conspicuity, reaction time, legibility, and learnability should be well documented. In particular, traffic signs need to be intuitively comprehended by the vast majority of the traveling public that will encounter them. Previous guidelines (ANSI Z535.3) have suggested a minimum threshold of 85% for acceptable sign comprehension. Significant previous research has been concerned with the determination of comprehension rates and other performance measures for particular traffic signs using a variety of techniques. Multiple methodologies were used in this study to ensure that an accurate measure of comprehension for alternative Tourist Information signs in Oregon was established. Additionally, a comparison of the results of these methodologies identified a preferred methodology for reliably determining driver comprehension of traffic signs.

5.1 Driver Related Factors

Multiple driver-related factors were collected and analyzed to test for differences between subject groups and sign alternatives. The factors analyzed included gender, age, highest level of education completed, number of miles driven last year, frequency of recreation or pleasure travel, primary language, and home state. In all of the tests, except for the online survey rating task, only the miles driven in the previous year variable was found to be significant. In the online survey rating task, the highest level of education completed and the subject's age were statistically significant. In general, the subjects who drove more than 5,000 miles in the previous year performed better than the subjects who drove less than 5,000 miles. This evidence suggests that subjects who drive a small amount a year will likely have lower comprehension rates for Tourist Information alternative signs.

5.2 Traveler Information Sign Comprehension

The primary research objective was to determine the comprehension rates of alternative Tourist Information signs. Through each of the test methodologies, the “INFO” Sign alternative outperformed all other alternatives in terms of comprehension at a statistically significant level. The “INFO” Sign was the only sign alternative considered to meet the ANSI standards of comprehension greater than 85% and critical confusions less than 5%.

Three categories of incorrect comprehension emerged from subject responses. These included a misinterpretation of the blue background, misinterpreting the message communicated by the “i”, or mistaking the “i” as a different symbol. One of the advantages of word messages is the reduced rates of comprehension errors, whereas symbols can be more easily misunderstood (Katz et al., 2008). From the results of this experiment, 12 of the 15 confusions occurred with the “i” Sign alternatives. This provides evidence that symbol signs developed using single letters may negatively influence comprehension rates.

The general success of the “i” Sign alternatives may be due to the prevalence of the “i” symbol in other contexts, in particular, on the internet and other technologies. The “i” symbol has been widely adopted on the internet to inform users of various types of information and, due to its common appearance, is likely well understood in that context.

5.3 Traveler Information Sign Glance Patterns

Another consideration was the subjects' dwell times on sign alternatives. The total dwell time was compared in two instances; first, between the sign alternatives (research objective 2); and second, between correct, partially correct, and incorrect responses (research objective 3). The dwell time of subjects was not significantly different between any of the sign alternatives and was not significantly different between correct, partially correct, and incorrect responses. Therefore, subjects did not spend additional time looking at the sign when they do not know what the sign means. This could be because the message on each of the alternatives was simple enough that the subject did not find it beneficial to observe the sign more than the time necessary to determine the intended message.

5.4 Experimental Design Influence on Comprehension

The results from each of the test methods used in this study can also be compared. The fourth research objective, which states that there is no difference in driver's comprehension between each sign alternative in the online survey and in the driving simulator, was not rejected. There were significant differences in the results of the rating tasks in the online survey and the follow-up survey administered after the driving simulator experiment for both "i" Sign alternatives and significant differences in the open ended comprehension tasks in the online survey and simulator for the "?" Sign with the circular border. This indicates that the testing methodology can influence the results and a more realistic approach is preferred.

5.5 Comparison to Previous “i” sign research

The Tourist Information sign was previous studied by Katz et al. (2008). They found that 56% of drivers correctly understood the “i” symbol, 68% of drivers understood the “?” symbol, and 96% of drivers understood the “INFO” message compared to the comprehension rates of 74.7% (“i” Sign), 72.9% (“?” Sign), and 99.7% (“INFO” Sign) determined in this research. The results for the “?” symbol and the “INFO” message were slightly higher in this research than those report by Katz et al (2008). However, the percentage of drivers that correctly comprehended the “i” symbol was significantly different in the two experiments, which suggests, as one possibility, that the use of the “i” symbol has increased, leading to increased rates of comprehension. These results may also suggest regional differences in sign comprehension. Additionally, Katz et al. found the “i” Symbol and the “?” Symbol had a statistically greater legibility distance than the “INFO” Sign as tested.

The results from the driving simulator ANCOVA test revealed that there was no significant difference in the glance patterns between sign alternatives, implying that the time required by subjects to read and interpret the “INFO” Sign alternative was not significantly different than the time required by subjects to interpret the symbolic sign alternatives. These results fall in line with Ells and Dewar (1979), who found that there was not a significant difference in reaction time between symbolic signs and word signs with simple messages, like “HILL” or “BUMP”.

5.6 Study Limitations and Future work

The participants in this study and for the work of Kautz et al. (2008) were captured domestically, resulting in individuals who overwhelmingly use English as their primary language. Only 14 of the participants in the current study were bi-lingual. As such, caution should be applied when extrapolating the comprehension rates observed in these results to international tourists. While root words for information in many romance languages still begin with "info," numerous other written languages such as Chinese languages, Japanese, Korean, Persian, etc. do not share the same Latin roots. Hence, the increased comprehension rates for "Info" Sign may not translate to such international populations.

There is also the potential that some of the critical confusions of the squared off "i" sign examined in this project and the work of Kautz et al. (2008) could have been mitigated by an italicized or slanted "i" sign. For example, the most common visual cues of the "i" sign with the hospital or gasoline signs are vertical white lines, which could be avoided with the italicized presentation.

Because of these limitations, the research team recommends that future work on this subject (1) concentrate on the measurement of comprehension rates of international populations, particularly from countries with non-romance languages, and (2) evaluate italicized versions of the "i" sign as possible alternatives.

Chapter 6 Conclusions

This study compared a variety of online survey questions and driving simulation tasks to assess the understandability of alternative Tourist Information signs in Oregon. Consistent results were observed for each of the tests; however, the driving simulator provides the best representation of the driving experience. In all of these tests, the "INFO" Sign was shown to be the most understandable of the alternatives evaluated in this study by a significant margin, supporting its usage in the MUTCD over the "?" Sign. However, it is important to consider that a limitation of the "INFO" Sign is that its legibility degrades at greater distances (Katz et al., 2008), although it was recommended that larger font would improve the legibility distance. While, at this time, the INFO Sign performed better than alternative forms (e.g., "i" Sign), the prolific usage of "i" Signs in multiple contexts both domestically and internationally will likely improve its understandability within the context of driving in the near future. For example, this study has shown a significant increase in understandability of the "i" Sign compared to relatively recent findings by Katz et al. (2008). Hence, future research can evaluate whether the "i" Sign is a more suitable alternative in the future. Finally, it is recommended for public agencies to work toward consistency in deploying Tourist Information signs, which will improve understandability.

Bibliography

Allen, R. Wade, Zareh Parseghian, and Paul G. Van Valkenburgh. 1980. "A Simulator Evaluation of Age Effects on Symbol Sign Recognition." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 24: 471-475.

Al-Madani, Hashim. 2001. "Prediction of Drivers' Recognition of Posted Signs in Five Arab Countries." *Perceptual and Motor Skills*, 92: 72-82.

Brainard, Robert W., Richard J. Campbell, and Edwin H. Elkin. 1961. "Design and Interpretability of Road Signs." *Journal of Applied Psychology*, 45: 130-136.

Cahill, Mary-Carol. 1975. "Interpretability of Graphic Symbols as a Function of Context and Experience Factors." *Journal of Applied Psychology*, 60: 376-380.

Castro, C., Horberry, T., and Gale, A. (2004). "The effect of sematic and repetition priming on traffic sign recognition. Vision in Vehicles, VIII. Derby, Vision in Vehicles Press.

Chan, Alan H. S., and Annie W. Y. Ng. 2010. "Effects of Sign Characteristics and Training Methods on Safety Sign Training Effectiveness." *Ergonomics*, 53: 1325-1346.

Cole, B. L., and S. E. Jenkins. 1982. "Conspicuity of Traffic Control Devices." *Australian Road Research*, 12: 223-238.

Dean Runyan Associates (2014). "Oregon Travel Impacts 1991-2013p. Statewide Preliminary Estimates" *Oregon Tourism Commission*. 1-239.

Dewar, Robert. 1988. "Criteria for the Design and Evaluation of Traffic Sign Symbols." *Transportation Research Record: Journal of the Transportation Research Board*, 1160: 1-6.

Dewar, Robert E., and Jerry G. Ells. 1974. "Comparison of Three Methods for Evaluating Traffic Signs." *Transportation Research Record: Journal of the Transportation Research Board*, 503: 38-47.

Dewar, Robert E., and Jerry G. Ells. 1977. "The Semantic Differential as an Index of Traffic Sign Perception and Comprehension." *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 19: 183-189.

Dewar, Robert E., Jerry G. Ells, and Glen Mundy. 1976. "Reaction Time as an Index of Traffic Sign Perception." *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 18: 381-391.

Ells, Jerry G., and Robert Dewar. 1979. “Rapid Comprehension of Verbal and Symbolic Traffic Sign Messages.” *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 21: 161-168.

Federal Highway Administration (FHWA). 2000. “Manual on Uniform Traffic Control Devices.” United States Department of Transportation.

Federal Highway Administration (FHWA). 2003. “Manual on Uniform Traffic Control Devices.” United States Department of Transportation.

Federal Highway Administration (FHWA). 2009. “Manual on Uniform Traffic Control Devices.” United States Department of Transportation.

Green, Paul, and Richard W. Pew. 1978. “Evaluating Pictographic Symbols: An Automotive Application.” *Human Factors: The Journal of the Human Factors and Ergonomics Society,* 20: 103-114.

Hicks, Kevin E., Jennifer L Bell, and Michael S. Wogalter. 2003. “On the Prediction of Pictorial Comprehension.” *Proceedings of the Human Factors and Ergonomics Society Annual Meeting,* 47: 1735-1739.

Jacobs, R. J., A. W. Johnston, and B. L. Cole. 1975. “The Visibility of Alphabetic and Symbolic Traffic Signs.” *Australian Road Research,* 5: 68-86.

Katz, Bryan J., Gabriel K. Rousseau, and Davey L. Warren. 2003. “Comprehension of Warning and Regulatory Signs for Speed.” *Institute of Transportation Engineers 2003 Annual Meeting and Exhibit*, 1-10.

Katz, Bryan J., H. Gene Hawkins, Jr., Jason F. Kennedy, and Heather Rigdon Howard. 2008. “Design and Evaluation of Selected Symbol Signs.” TPF-5(065), Federal Highway Administration, McLean, VA.

Mackett-Stout, Janice, and Robert Dewar. 1981. “Evaluation of Symbolic Public Information Signs.” *Human Factors: The Journal of the Human Factors and Ergonomics Society,* 23: 139-151.

Microsoft. 2013. Microsoft Excel [computer software]. Redmond, Washington: Microsoft.

Ng, Annie W. Y., and Alan H. S. Chan. 2008. “The Effects of Driver Factors and Sign Design Features on the Comprehensibility of Traffic Signs.” *Journal of Safety Research,* 39: 321 – 328.

Paniati, Jeffrey F. 1988. “Legibility and Comprehension of Traffic Sign Symbols.” *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 32: 568-572.

Picha, Dale L., H. Gene Hawkins, Jr., Katie N. Womack, and Lewis R. Rhodes, Jr. 1997. “Driver Understanding of Alternative Traffic Signs.” *Transportation Research Record: Journal of the Transportation Research Board*, 1605: 8-16.

Plummer, Ralph W., John J. Minarch, and Ellis L. King. 1974. “Evaluation of Driver Comprehension of Word versus Symbol Highway Signs.” *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 18: 202-208.

Qualtrics. Veerson 12,018. 2009. Provo, Utah, USA. http://www.qualtrics.com/

R Core Team. 2014. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. http://www.R-project.org

Ramsey, F. L., and D. W. Schafer. *The Statistical Sleuth: A Course in Methods of Data Analysis.* Boston, MA: Brooks/Cole, 2013. Print

Razzak, Abdur, and Tanweer Hasan. 2010. “Motorist Understanding of Traffic Signs: a Study in Dhaka city.” *Journal of Civil Engineering*, 38: 17-29.

Shinar, David, Robert E. Dewar, Heikki Summala, and Lidia Zakowska. 2003. “Traffic Sign Symbol Comprehension: A Cross-Cultural Study.” *Ergonomics: An International Journal of Research and Practice in Human Factors and Ergonomics*, 46: 1549-1565.

Smiley, Alison, Carolyn MacGregor, Robert E. Dewar, and Chris Blamey. 1998. “Evaluation of Prototype Highway Tourist Signs for Ontario.” *Transportation Research Record: Journal of the Transportation Research Board*, 1628: 34-40.

The World Bank. 2014. “International tourism, number of arrivals.” *The World Bank*. Retrieved January 28, 2014, from http://data.worldbank.org/indicator/ST.INT.ARVL.

United Nations World Tourism Organization (UNWTO). 2000. “Recommendation on the Tourist Information Sign.” Executive Council Decision CE/DEC/6.

Walker, Ronald E., Robert C. Nicolay, and Charles R. Stearns. 1965. “Comparative Accuracy of Recognizing American and International Road Signs.” *Journal of Applied Psychology*, 49: 322-325.

Washington, Simon P., Matthew G Karlaftis, and Fred L. Mannering. *Statistical and Econometric Methods for Transportation Data Analysis.* Boca Raton: Taylor & Francis Group, 2011. Print.

Wolff, Jennifer S., and Michael S. Wogalter. 1998. "Comprehension of Pictorial Symbols: Effects of Context and Test Method." *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 40: 173-186.

Zwaga, Harm J. 1989. "Comprehensibility Estimates of Public Information Symbols; Their Validity and Use." *Proceedings of the Human Factors Society Annual Meeting*, 33: 979-983.

Zwaga, Harm J., and Theo Boersema. 1983. "Evaluation of a Set of Graphic Symbols." *Applied Ergonomics*, 14: 43-54.

Zwaga, Harm J., Theo Boersema, and Henriette C. M. Hoonhout. 1998. "Visual Information for Everyday Use: Design and Research Perspectives." CRC Press. 285 – 304.

Zwahlen, Helmut T., Xiaohong Hu, Murali Sunkara, and LuAnn M. Duffus. 1991. "Recognition of Traffic Sign Symbols in the Field during Daytime and Nighttime." *Proceedings of the Human Factors Society Annual Meeting*, 35: 1058-1062.

Appendix A: Information Message from Different Contexts

Numerous contexts of a sign necessitate the need for additional information to be made available to end users. The contexts range from cell phones to way finding internet sites to airports. Example information symbols, meanings, sources, and responsible organizations have been documented in Tables A.1 through A.3.

The most common approach is to use a lower-case letter “i" (Table A.1) or “?” (Table A.2) as the information symbol. These images were found using “The Handbook of Pictorial Symbols” by Rudolf Modley and “The Symbol Sourcebook” by Henry Dreyfuss. Additional sources include Rachel Vogt, Michael Olsen, the Apple iPhone User Guide, and the Irfanview Program.

Table A.1 shows a variety of “i" Signs used in several different contexts. Images are shown from software packages (IrfanView and Apple iPhone), a retail furniture store (Ikea), the Portland International Airport (PDX), and several road or railway signs used in Sweden, the Netherlands, Canada, and the United States. Note that many of these symbols also include a circular background.

Table A.1: Examples of "i" Signs

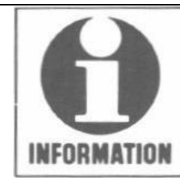
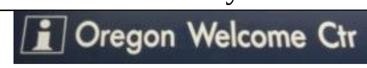
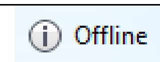
 **Meaning:** Information **Used By:** KFAI Sweden	 Information Netherlands Railroad	 Information Transport Canada, Airports	 Information International Union of Railways
 Information Swedish Standard Recreation Symbols	 Image Information IrfanView	 Store Map Ikea, Portland, OR	 Information Center Portland International Airport, Portland, OR
 Siri Onscreen Guide Apple iPhone User Guide	 Video Information Fox News Video	 Webpage Information Google Analytics: In- Page Analytics	 Printer Information Windows Operating System

Table A.2 shows a variety of signs that use a "?" to indicate information is available. About half of the signs use a circle as part of the symbol; one sign uses a diamond instead of a circle as a background. These signs include samples from Japan, Australia, as well as from several agencies in the United States. One sample was also included from the Picto'grafics Company.

Table A.2: Examples of “?” Signs

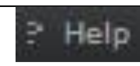
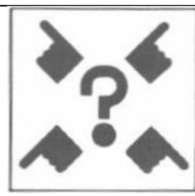
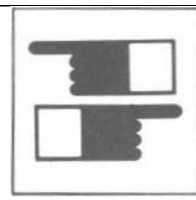
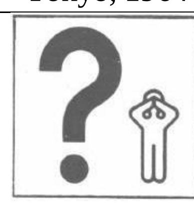
 **Meaning:** Information **Used By:** Dallas – Fort Worth	 Information Denver Airport, Denver, CO	 Information International Air Transport Association	 Information Picto’grafics
 Information National Park Service	 Information Portland International Airport, Portland, OR	 Information Seattle Tacoma Airport	 Information Tokyo Airport
 Information Expo 70, Osaka	 Information Portland International Airport, Portland, OR	 Information British Airports Authority, Australian Department of Civil Aviation	 Video Help CNN News Video

Table A.3 shows alternative symbols used to indicate information is available. The question mark is commonly incorporated into the symbols shown in Table A.3. Five symbols are included in Table A.3 that specifically apply to passenger flight information, hotel information, and the lost child office. Four of the symbols shown were used in the Olympic Games in 1964, 1968, 1972, and 1974. This is particularly informative because symbols used for the Olympic Games must cater to a population made up of a wide variety of nations.

Table A.3: Other information sign presentations

 **Meaning:** Information **Used by:** Port Authority of New York and New Jersey	 Information Olympic Games, Mexico, 1968	 Information Olympic Games, Munich, 1972	 Information German Airport Authority
 Information International Civil Aviation Organization	 Information Winter Olympic Games, Sappro, 1972	 Information Olympic Games, Tokyo, 1964	 Information Olympic Games, Munich, 1974
 Passenger Flight Information International Air Transportat Association	 Hotel Information Department of Transportation, 1974	 Lost Child Office Olympic Games, Munich, 1972	

From Tables A.1, A.2, and A.3, it can be seen that the “i” symbol and the “?” symbol have been used in a variety of contexts and typically have been used to indicate information is available. Many of these symbols have been used to communicate internationally.

Figure A-1 provides examples of Tourist Information signs observed at various locations throughout the world. Some images were provided by an internet search by Travel Oregon. Other images (e.g., United States, New Zealand, United Kingdom, Australia) were photographs taken in 2013 and 2014. These images highlight the widespread usage of the “i"-sign to communicate Tourist Information.

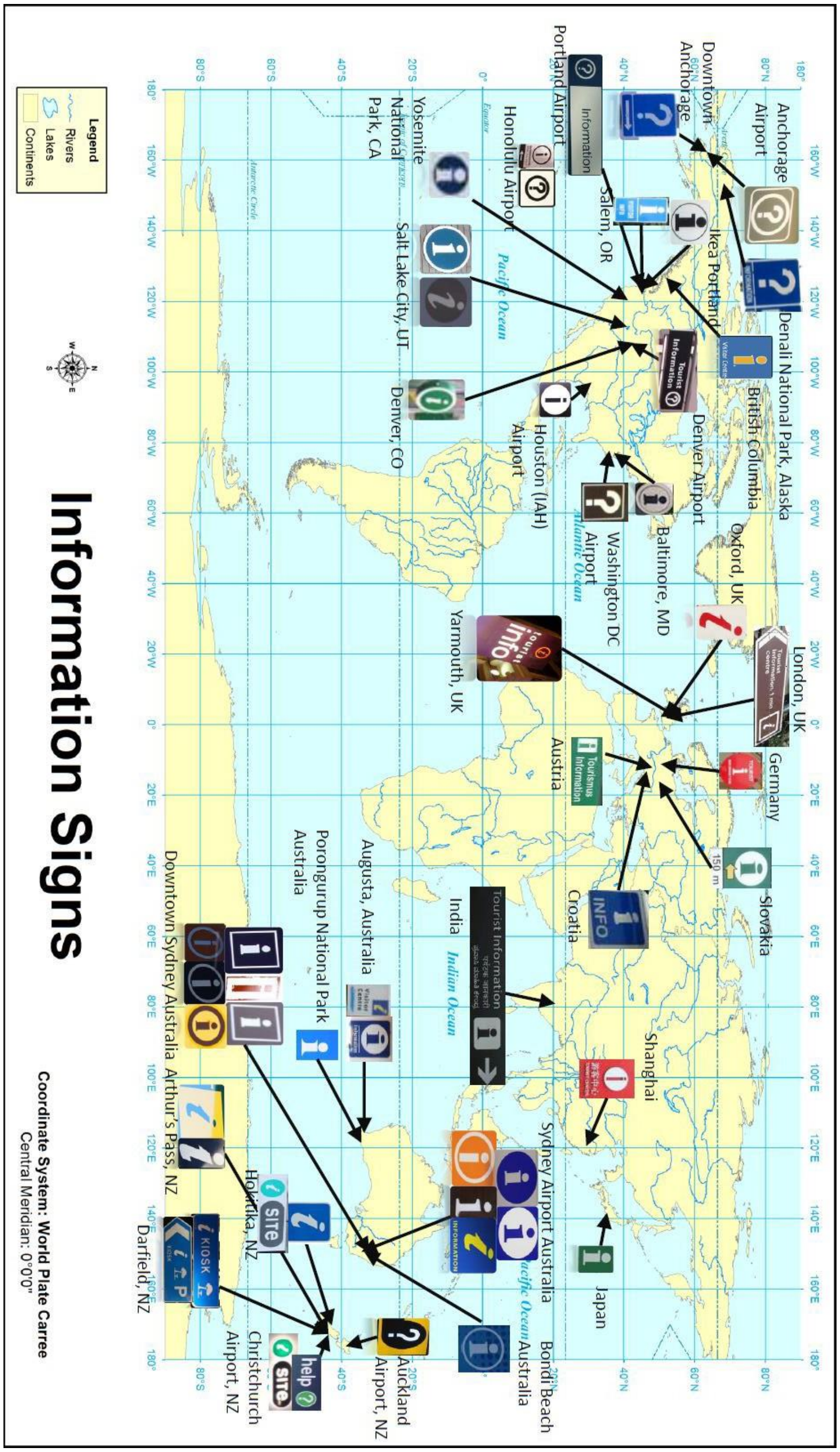


Figure A.1: Examples of Information Messages from around the World

Appendix B: Past Research

Significant research has been completed to understand whether one of these symbols or a word message will likely perform better in the context of the Tourist Information sign. Previous research has investigated many facets of traffic signs, including:

1. The interpretation or comprehension of such signs (Brainard et al. 1961, Dewar et al. 1976, Dewar at al. 1977).
2. Symbol comprehension (Shinar et al. 2003, Smiley et al. 1998, Zwaga et al. 1983).
3. Sign design (Dewar et al. 1974, Hicks et al. 2003, Mackett-Stout et al. 1981). On a similar note, research has also developed a number of design factors for symbol signs (Dewar 1988, Zwaga et al. 1998).
4. Sign conspicuity (Cole et al. 1982) and sign legibility (Zwahlen et al. 1991).
5. Word and symbol signs have been compared in numerous research efforts as well, including:
    a. Reaction time (Ells et al. 1979),
    b. Legibility (Jacobs et al. 1975, Paniati 1988),
    c. Comprehension (Plummer et al. 1974, Walker et al. 1965)

Research has also been completed to discover the process roadway users experience while they interact with roadway signs. Castro et al. (2004) found four stages exist when a roadway user interacts with a roadway sign and each stage has a key consideration. In each stage, the driver uses some aspect of the sign to accomplish the necessary interaction (Castro et al., 2004):

1. ***Detect*** - the sign must to be both visible and conspicuous.
2. ***Read*** - the sign needs to be legible at an adequate distance and in the time available.
3. ***Understand*** – the sign must be comprehensible, unambiguous, and precise.
4. ***Respond*** – the sign must be credible, correct, appropriate, and timely to elicit the correct response.

The importance of these characteristics is exemplified through the expert opinions gathered by Robert Dewar in 1988. Dewar interviewed four groups with expertise in traffic control devices or traffic engineering, asking them to rate six traffic sign design criteria. Table B.1 describes the composition of the four groups interviewed.

Table B.1: Group composition

Group:	Participants:	Qualification:
I	20	Members of U.S. National Committee on Uniform Traffic Control Devices (NCUTCD)
II	30	Members of Council on Uniform Traffic Control Devices for Canada (CUTCDC);
III	29	Practicing traffic engineers from the United States
IV	12	Practicing engineers from Canada

A survey was given to each participant where they were asked to rank, on a 10-point scale, the importance of the following six criteria:

1. ***Legibility Distance*** – The greatest distance at which the symbol can be clearly interpreted.
2. ***Understandability*** – The ease with which the symbol can be understood.
3. ***Conspicuity*** – The extent to which a sign can be easily detected or seen in a visually complex environment.
4. ***Learnability*** – The extent to which the meaning of a symbol can be learned and remembered.
5. ***Glance Legibility*** – The ease with which the symbol can be interpreted when it is seen for only a fraction of a second.
6. ***Reaction Time*** – How quickly the meaning of the sign can be identified.

The definitions of the criteria included above were provided to the participants at the beginning of the survey. The participants first rated the criteria without reference to any particular sign type, and then rated the criteria with reference to warning signs, regulatory signs, and information signs. The survey also asked participants to provide an open-ended response with any additional criteria that they considered important to the design of traffic signs. The surveys were distributed in hard copy by mail to the participants.

The results are listed in Table B.2 (Dewar 1988), which shows the mean importance ratings displayed to two decimals and the criteria rankings in parentheses.

Table B.2: Mean important ratings (ranking)

Criteria:	General Signs:	Warning Signs:	Regulatory Signs:	Information Signs:
Legibility Distance	3.06 (5)	2.82 (4)	3.06 (4)	3.65 (3)
Understandability	2.41 (1)	2.08 (1)	2.09 (1)	2.91 (2)
Conspicuity	2.88 (3)	2.64 (3)	2.56 (2)	2.67 (1)
Learnability	3.90 (6)	3.56 (6)	3.52 (6)	4.98 (6)
Glance Legibility	3.00 (4)	2.92 (5)	3.05 (3)	4.22 (4)
Reaction Time	2.66 (2)	2.54 (2)	3.19 (5)	4.29 (5)

* Low ratings indicate high degree of importance
* Low rankings indicate high degree of importance

As can be seen from these rankings, learnability is rated least important, among the provided criteria, consistently and across all sign types. With reference to Information Signs, conspicuity is ranked as most important followed by understandability.

In 1998, the Ministry of Transportation in Ontario [Canada] designed a new tourist signing system. In the development of the system, they used the following criteria to develop the signing system (Smiley et al. 1998).

1. ***Comprehension*** – Do drivers understand the meaning of the sign message and any pictographs or abbreviations used?
2. ***Conspicuity*** – Does the sign attract attention given the background in which it is placed?
3. ***Information Load*** – Do drivers have sufficient time to take in all the information included on the sign?
4. ***Legibility*** – At what distance can drivers read the sign?
5. ***Driver Response*** – Do drivers make the desired action as a result of reading the sign?

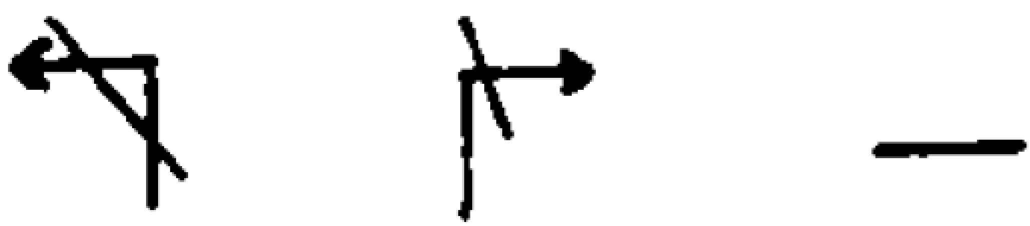
The authors also claimed that the last factor, Driver Response, is much more critical for regulatory signs than for guidance signs. While they did not provide the reasons for their criteria choices, it is interesting to note that their five chosen criteria were the top five ranked criteria as found by Dewar in 1988.

B.1 Symbol vs. Word Signs

The strengths and weaknesses of symbol and word signs can be examined within each of the six elements of sign design identified by Robert Dewar in 1988.

B.1.1 *Understandability*

Walker et al. (1965) tested the difference in comprehension for symbol and word signs by presenting U.S. students with different word and symbol signs. Seventy students at a U.S. university were presented “No Left Turn”, “No Right Turn”, and “Do Not Enter” signs in both word and symbol form. The symbol versions of the signs are shown in Figure B.1.



No Left Turn | No Right Turn | Do Not Enter

Table B.3: Word sign symbol equivalents

The symbols were shown in black on a white background. Subjects were shown the six signs in a randomized order with a blank slide inserted into the test to control for guessing. Subjects were shown the seven stimuli and then given a 30 second break before they were shown the stimuli again in a new random order. In each trial, the subjects were able to identify the symbol signs with more accuracy than the word signs, as shown in Table B.4.

Table B.4: Total correct stimuli identified

Gender:	**Total Number of Subjects:**	**Possible Number of Correct Answers:**	**Trial 1:**		**Trial 2:**	
			Symbols:	**Words:**	**Symbols:**	**Words:**
Males	26	78	63	32	66	42
Females	44	132	107	70	121	86
All Subjects	70	210	170	102	187	128

Hence, Walker et al. (1965) concluded that drivers more correctly identify signs with symbol messages as compared to signs with word messages.

This result was also confirmed by Plummer et al. (1974). Plummer et al. tested two groups of 10 subjects on their understanding of the symbol signs and corresponding word signs for ten warning signs. One group of subjects had no prior knowledge of or special education in highway symbol signs. The second group of subjects acted as a control group due to special training they had received concerning highway symbol signs prior to the experiment. The specific warning sign stimuli used were “HILL”, “SIGNAL AHEAD”, “SCHOOL BUS STOP

AHEAD", "SLIPPERY WHEN WET", "FARM MACHINERY", "DEER CROSSING", "BIKE CROSSING", PEDESTRIAN CROSSING", "TWO WAY TRAFFIC", and "DIVIDED HIGHWAY." Subjects were initially given one sign, either word or symbol, and were subsequently given three signs of the opposite type to match the initial sign with.

This study found that subjects made fewer errors when matching word answers to a symbol sign than they did when matching symbol answers to a word sign, indicating that subjects were able to more accurately identify symbol signs than they were able to identify word signs.

It should be noted that the "i" symbol has been tested in previous research. Katz et al. (2008) compared the "i" symbol with the "INFO" word message and the "?" symbol. This research was conducted in two steps. First, subjects were shown the symbol with context and were asked to provide the meaning of the symbol in an open-ended manner. Subjects were then given a multiple choice test and asked to select the answer they thought best represented the sign. Katz et al. found that 56% of the subjects understood the correct meaning of the "i" symbol as compared to 68% with the "?" symbol and 96% with the "INFO" message when presented with the open-ended test. The results of the multiple choice portion are shown in Table B.5.

Table B.5: Multiple choice results – Adopted from (Katz et al. 2008)

Choice:	**"i" symbol:**	**"?" symbol:**	**"INFO" message:**
Use Caution	4%	0%	0%
Wireless Internet Available	20%	0%	0%
Medical Assistance	0%	8%	5%
Traveler Information	76%	92%	95%

From the results in Table B.4, it is conceivable that the distractors (incorrect multiple choice answers) provided were of low plausibility. The most significant risk for the transferability of multiple choice traffic sign comprehension surveys is the quality and plausibility of distractor questions (Wolff et al. 1998).

B.1.2 *Conspicuity*

The conspicuity of a sign is the sign's property of being clearly discernable or noticeable. Cole et al. (1982) tested the conspicuity of traffic control devices by presenting pictures of typical urban and suburban situations to 17 subjects. The subjects were allowed to view each picture for 500 milliseconds, while experimenters recorded their verbal observations. They found that symbolic signs are more conspicuous than word signs. 55% of the possible symbolic warning sign observations were made compared to only 45% of the possible word warning sign observations ($t = 3.254$, $p < 0.0025$ for a one tailed test).

B.1.3 *Reaction Time*

Ells and Dewar (1979) found symbol signs to be generally superior to word signs in two unique experiments. In the first experiment, six female and six male undergraduate students from the University of Calgary were presented with four symbolic regulatory, four symbolic warning, four word regulatory, and four word warning signs. These images were presented to the subjects on a 95 cm square screen 6 m from the subject. The signs formed a visual angle of 0.57 degrees, which corresponds to the visual angle of a regulatory sign at a distance of 59 m, which is the approximate stopping distance of a vehicle traveling 80 km/h. For each sign, the researcher would read aloud a traffic sign message to the subject before showing a sign to the subject. If the sign matched the traffic sign message that was read to them, they were to answer "yes" otherwise they responded with "no." Before beginning the experiment, it was confirmed that the subject could identify each of the signs being researched. The results of experiment one can be found below in Table B.6.

Table B.6: Mean reaction times (ms) – Adopted from (Dewar 1979)

Message Type:	Sign Type:	"Yes" Response:	"No" Response:
Warning Signs			
Symbolic	Hill	542	548
	Bump	564	630
	Pavement Ends	629	**618**
	Winding Road	541	565
	Mean	569	599
Word	Pavement Narrows	750	772
	Yield Ahead	648	659
	Soft Shoulder	606	692
	Fresh Oil	568	666
	Mean	643	697
Regulatory Signs			
Symbolic	No U Turn	590	685
	No Trucks	572	623
	Turn	534	768
	No Right Turn	680	**641**
	Mean	594	679
Word	No Left Turn	720	**704**
	Two-Way Traffic	635	720
	Do Not Pass	652	691
	No Parking	721	822
	Mean	682	734

*Bolded values indicate the Word sign is less than the Symbol sign for the same case.

In the second experiment, twelve male students and twelve female students from the University of Calgary were presented with signs in the same manner as outlined in the first experiment. However, in the second experiment, subjects viewed the signs while wearing non-corrective goggles with glass lenses. Signs were viewed in “degraded” and “non-degraded” conditions. “Non-degraded” conditions were achieved without modification to the goggles. To create the “degraded” condition, 10 layers of thin plastic film, were placed over the goggles, resulting in a glare similar to that caused by oncoming vehicles’ headlights in fog and darkness. The results from the second experiment are summarized in Table B.7.

Table B.7: Mean reaction times (ms) – Adopted from (Dewar 1979)

Traffic Sign:	**“Yes” Responses:**				**“No” Responses:**			
	Non-Degraded		**Degraded**		**Non-Degraded**		**Degraded**	
	Symbol	Word	Symbol	Word	Symbol	Word	Symbol	Word
Warning Signs								
Dead End	629	644	663	797	667	680	711	846
Bump	610	**574**	645	742	651	**604**	741	810
Men Working	597	697	677	960	695	705	758	1054
Pavement Narrows	710	879	730	1015	696	807	714	868
Pavement Ends	723	792	910	1163	732	777	890	964
Hill	615	**579**	714	**711**	702	**655**	752	**744**
Divided Highway	643	821	774	1038	706	749	808	996
Mean	647	712	730	918	693	711	768	897
Regulatory Signs								
Truck Route	717	730	838	1028	897	**834**	867	1108
No Turns	743	825	880	1013	946	971	964	1005
No Left Turn	838	857	1017	**970**	995	1015	950	968
No Trucks	869	**857**	880	970	801	892	945	993
Do Not Pass	872	904	902	**890**	902	**885**	956	**893**
Keep Right	692	827	737	882	910	971	906	987
No Right Turn	858	867	846	1227	931	984	935	1198
Mean	798	838	871	997	912	936	932	1022

*Bolded values indicate the Word sign is less than the Symbol sign for the same case.

Ells and Dewar found symbol signs to be superior in vision-restricted cases and in visually degraded conditions. In non-restricted and non-degraded visual conditions, they found symbol signs to be generally superior, except in the case of some simple messages, where the word message was only one word such as “BUMP” or “HILL” (Ells and Dewar, 1979). This conclusion was reinforced by Smiley (1998) who determined that the number of words or symbols must be minimized as the driver divides his or her attention between the sign.

B.1.4 *Legibility*

In an effort to quantify the legibility differences between symbol and word signs, Paniati (1988) developed an apparatus capable of displaying signs as they would appear at distances ranging from 33.5 meters to 304.8 meters. This apparatus was used to display 22 symbolic warning signs to 32 subjects, who were divided into equal age groups of under 45 and over 55. The subject group also had an equal number of male and female subjects. Of the 22 chosen symbolic signs, eight had word sign alternatives. The word sign alternatives were included in the study to allow for a comparison between the two groups. The sign size was changed to simulate a driving speed of 50.8 km/h. Each subject was given a handheld button and was instructed to press the button when the sign’s features could be described. Once the button was depressed, the image was immediately extinguished and the subject was asked to describe the sign. If the subject could not provide a correct description, the trial resumed from the point of interruption. The results for the signs that had a word sign alternative are shown below in Table B.8.

Table B.8: Word versus symbol legibility distance data (m) - Adopted from (Paniati 1988)

Message:	Word:	Symbol:	Symbol / Word:
Divided Highway	134	584	4.4
Two-Way Traffic	115	465	4.0
Signal Ahead	164	655	4.0
Yield Ahead	162	613	3.8
Stop Ahead	189	524	3.3
Hill	181	274	1.5
Narrow Bridge	150	182	1.2
Pavement Ends	151	150	1.0
Mean	156	443	2.8

Hence, the legibility distance for these symbol signs can be equal or up to 4.4 times greater than the legibility distance of the equivalent word signs (Paniati, 1988). However, Table B.8 clearly shows that the relative effectiveness between symbol and word signs needs to be determined individually.

B.1.5 *Learnability*

Chan and Ng (2010) researched how sign characteristics affect the learnability of symbols. To this end, they presented 26 safety signs from the National Standards of the People's Republic of China for Safety Signs (1996) with guessability ratings lower than 60% to 30 male subjects and 30 female subjects. All subjects were screened with a red-green deficiency test prior to the test. The signs were presented as square (7cm x 7cm) images on a computer screen. Subjects completed a pre-test, training, an intervening task, a post-test, and finally a quantification of sign characteristics.

Subjects were shown a different sequence of signs for each of the five sessions. The pre- and post-tests provided five multiple answers for each sign. One answer was deemed correct, one deemed partially correct, and the other three answers as incorrect. Subjects were given two points for correct answers, one point for partially correct answers, and zero points for incorrect answers. Each subject was assigned to one of three training methods; paired-associate learning, recall training, or recognition training. During the intervening task, subjects were asked to subjectively rate, according to a 1 – 7 Likert scale, the training significance, training content, opportunity to practice, training speed, training duration, interest in the training, and overall preference. In the quantifying task, subjects were asked to subjectively judge each sign on the sign's familiarity, concreteness, simplicity, and meaningfulness. The subject was then shown the referent for the sign and asked to give a rating for semantic closeness. Chan and Ng found that a sign's characteristics do not have a significant impact on the learnability of the sign. They did find that the signs that were more familiar, more concrete, and more semantically related had higher initial comprehension rates.

B.1.6 *"i" Sign Research Gaps*

Some studies have investigated certain aspects of the "i" Sign. Table B.9 shows what research has been performed and which research topics are still lacking in order for the "i" Sign to be found adequate in all five critical design elements before it can be considered as a possible replacement for the current [D9-10] Tourist Information sign.

Table B.9: Status of previous Tourist Information sign research

Sign Design Element:	Previously Studied:	Researchers:	Research Results:
Comprehension	Yes	Katz, Hawkins, Jr., Kennedy, and Howard. 2008.	Found “INFO” is better comprehended than “?” or “i”
Conspicuity	No	Cole and Jenkins. 1982.	Symbolic warning signs perform somewhat better than verbal warning signs. No literature was found directly addressing the conspicuity of the Tourist Information sign.
Reaction Time	No	Ells and Dewar. 1979.	In general, Symbol signs elicit faster response times from subjects than verbal signs. No literature was found directly addressing the information load of the Tourist Information sign.
Legibility	Yes	Katz, Hawkins, Jr., Kennedy, and Howard. 2008.	Found the “i” Sign and the “?” Sign had a statistically greater legibility distance than the “INFO”
Learnability	No	Chan and Ng. 2010.	Found that while a sign’s characteristics affect its comprehension rate, it does not significantly impact the sign’s learnability. No literature was found directly addressing the information load of the Tourist Information sign.

As observed in Table B.9, there are multiple gaps in the current research focused directly on the Tourist Information sign. The largest of which is research on the interference of the driving task load on subjects.

B.2 Subject Testing Methods

The following section describes standards and recommendations for traffic sign comprehension testing, including the use of multiple choice vs. open ended questions as well as the context of the signs in an image.

B.2.1 *Testing Standards*

ANSI Z535.3 in 1998 and 2002 suggest testing a minimum of 50 subjects and that each subject is shown only one variation of each symbol being researched. The standard also suggests that each subject is not shown more than 20 different symbols in one given test. ANSI Z535.3 also states that a symbol must receive comprehension rates greater than 85% with not more than 5% critical confusions. (ANSI Z535.3) A confusion is considered critical if the comprehension of the sign is opposite of the intended comprehension. ANSI Z535.3 also suggests that open-ended comprehension tests are preferable.

B.2.2 *Question design*

In addition to standards of the acceptable comprehension levels and critical confusion rates, research has been conducted on the optimal methods to determine sign comprehension levels. Multiple-choice tests with more-plausible distractor answers and open-ended tests were found to have statistically lower comprehension rates than multiple-choice test with less-plausible distractor answers (Wolff et al., 1998). The following list describes the five concerns of multiple-choice tests for traffic sign comprehension:

1. Distractors which are carried over from earlier symbol versions may no longer be appropriate for the new symbol being tested.

2. There may not be enough plausible distractors for the symbol being tested.
3. In a multiple-choice test, subjects, who have no idea what the symbol means, can still guess and be correct 25% or 20% of the time (for three or four distractors) by chance alone.
4. Critical confusions are difficult to assess in multiple-choice tests. Detection of critical confusions is only readily accomplished in open-ended tests.
5. Multiple-choice tests do not realistically reflect the actual cognitive task that people perform with pictorial symbols in the real world. The open-ended test is ecologically valid; the multiple-choice test is not.

Wolff et al. also created a list of seven guidelines for open-ended traffic sign tests. These guidelines address appropriate ways to score the open-ended survey results and are included below:

1. More than one judge should score the survey results to ensure reliability.
2. Judges should be familiar with the intended meaning of the sign so they know what idea is trying to be conveyed.
3. Judges should be independent of one another, without cross-discussion during the scoring process, and should not have a stake in the outcome.
4. Decide on the scoring criteria and what kinds of answers will be acceptable before the survey is scored. A more-lenient criterion is likely more appropriate because individuals will use different verbiage to describe the same concept.

5. Judges should score the surveys blindly, i.e. without the knowledge of the sign version being described. Ideally, the judges should only see the subjects' responses and the criterion describing a correct answer.
6. Avoid extraneous demand characteristics that may unfairly benefit a particular sign version. No preference should be given to any version.
7. Judges should also record typical errors, while paying special attention to critical confusions.

Zwaga (1989) found that subject estimates of population comprehension are reliable to be used as an early indicator for the usefulness of a symbol. Zwaga tested 109 hospital symbols in five different sets. The open-ended comprehension of the symbols was gathered by presenting each subject with the referents on individual papers as part of a paper survey. Subjects were asked to give their opinion on the meaning of the symbols. To find the subject estimates of population comprehension, each subject was presented with five symbols at a time and was instructed to write down next to each symbol the percentage of the population they expected would understand the meaning of the symbol. The product-moment correlations between the estimate scores and comprehension scores for the five sets of symbols were 0.60, 0.57, 0.87, 0.85, and 0.87 and were all found to be statistically significant at $p < 0.01$.

B.2.3 *Questionnaire Strategies*

Multiple studies have implemented the suggestions of Wolff et al. for multiple choice tests into consideration for their research. Razzak and Hasan (2010), when researching the motorist understanding of traffic signs in Dhaka, Bangladesh, made sure that all of the multiple-choice distractor answers were plausible answers. They also provided a “not sure” answer to discourage guessing. Unfortunately, if the subjects still chose to guess they would have a 33% chance to choose the correct answer because Razzak and Hasan only provided two incorrect answers per sign. Razzak and Hasan found that 49% of subjects correctly understood the regulatory signs tested, 52% for warning signs, and 55% for informatory signs. From these results, they conclude that driver education efforts are needed.

A study performed by Al-Madani (2001) used a similar procedure. Al-Madani presented questionnaires to 4,774 drivers from five Arabian Gulf Cooperation States. In creating the questionnaire, the incorrect answers were carefully chosen to ensure no distractors could be easily ruled out. The distractors were also carefully chosen to ensure the distractors were highly plausible. Al-Madani used the study results to develop a model that uses driver demographics to predict sign comprehension rates. Al-Madani found that training programs for comprehension of traffic signs should be concentrated on drivers who are young females with low income and low education. Ng and Chan (2008) also developed a survey to test sign comprehension. The comprehension section of the survey presented subjects with four choices for each question; one correct response and three distractors designed to be plausible. Ng and Chan used the survey to develop sign comprehension levels, which they compared with symbol criteria in an effort to discover what connection existed between the two.

B.2.4 *Context*

Presenting signs in a context that replicates reality was shown to greatly facilitate comprehension (Wolff et al. 1998, Cahill 1975).

Wolff et al. (1998) sought out to discover the effect of sign context on comprehension levels. Subjects were presented with symbols with either no accompanying photographs or with three or four photographs showing a cross-section of environments where the symbol would likely appear. Wolff et al. found that the set of symbols tested using an open-ended test method resulted in 64% correct answers with context provided and 55% correct answers without context. Context was found to have a statistically significant effect on comprehension.

Cahill (1975) also found context to improve comprehension at a statistically significant level. Cahill found this result through showing 10 farm and industrial machinery symbols to 20 mechanical engineering students. Students were classified as either experienced or inexperienced depending on their previous experience with farm and industrial machinery.

B.2.5 *Questionnaire Design Framework*

Based on these findings, the project team recommends an open-ended test, preferably which includes a picture of the sign being tested with its correct context shown. A copy of the questionnaire is included in Appendix C.

Table B.10: Questionnaire design criteria for this study

Criterion:	**Acceptability/Preferred format:**	**Reference:**
Number of Subjects	Minimum 50	ANSI Z535.3
Comprehension Rate	>85%	ANSI Z535.3
Critical Confusion Rate	<5%	ANSI Z535.3
Question Type	Open-ended	Wolff et al. 1998, ANSI Z535.3

Appendix C: Online Survey

The aim of this survey is to gain insight on your understanding of traffic signs. It is important to ensure that roadway users understand sign messages before they are constructed. We are particularly interested in potential perception differences between individuals whose first language is English and individuals whose first language is not English.

Your participation in this survey is completely voluntary. Your responses will be strictly confidential and data from this survey will be reported only in the aggregate. Your information will be coded and will remain confidential.

The security and confidentiality of information collected from you online cannot be guaranteed. Confidentiality will be kept to the extent permitted by the technology being used. Information collected online can be intercepted, corrupted, lost, destroyed, arrive late or incomplete, or contain viruses.

There are no risks concerning your participation in this online survey. There are no direct benefits, but the information collected in this survey will give insight into the understanding of sign comprehension.

This online survey is expected to take approximately 10 minutes and you will not be allowed to skip any of the questions. If you wish to end the survey before you finish, simply close the window.

If you have any questions about the research, contact David Hurwitz at David.Hurwitz@Oregonstate.edu or (541) 737 – 9242.

If you have any questions about your rights or welfare as research participants, feel free to contact the Oregon State University Institutional Research Board by phone at (541) 737-8008 or by email at IRB@oregonstate.edu.

Thank you for your participation.

☐ I have read and understood the above information.

Please answer the following questions.

1. Gender M ☐ F ☐

2. Age ____________________

3. What is your highest level of education?
   - ○ High School Diploma
   - ○ Some College
   - ○ Associates Degree
   - ○ 4 year Degree
   - ○ Master's Degree
   - ○ PhD Degree
   - ○ Other

4. Is English your first language? Y ☐ N ☐

5. Are you a licensed driver? Y ☐ N ☐

6. How many years have you been a licensed driver?
   - ○ 0 - 1 year
   - ○ 1 – 5 years
   - ○ 6 – 10 years
   - ○ 11 – 15 years
   - ○ 16 – 20 years
   - ○ More than 20 years

7. How many miles did you drive last year?
   - ○ 0 – 5,000 miles
   - ○ 5,000 – 10,000 miles
   - ○ 10,000 – 15,000 miles
   - ○ 15,000 – 20,000 miles
   - ○ More than 20,000 miles

8. What is your highest level of education? (only asked if the subject answers "other" to #3)

9. What is your first language? (only asked if the subject answers "no" to #4)

10. What does this sign mean to you?

11. What does this sign mean to you?

12. What does this sign mean to you?

13. What does this sign mean to you?

14. What does this sign mean to you?

15. What does this sign mean to you?

16. What does this sign mean to you?

17. What does this sign mean to you?

18. What does this sign mean to you?

19. What does this sign mean to you?

20. Select the percentage of the population you think will understand the following signs to represent a Tourist Information center.

Tourist Information Centers provide brochures, directions, and information about the surrounding area. This information includes local and regional activities and tourist attractions, as well as information about local restaurants and lodging.