AN ABSTRACT OF THE THESIS OF

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The number of international inbound tourists to the United States has risen steadily. To serve these and other tourists best, traffic signs need to communicate information correctly across a potential language barrier. Of particular interest is the traffic sign intended to communicate directions to Tourist Information centers. While the general effectiveness of traffic signs relies on the sign's conspicuity, understandability, legibility distance, glance legibility, reaction time, and learnability, this study focused on the understandability of Tourist Information signs. To achieve this goal, several alternative signs were tested in an online survey (n = 142) and in the OSU Driving Simulator (n = 42) to compare their understandability. The "INFO" Sign was found to be best understood with 95.7% of the driving simulator subjects comprehending the sign correctly. The "i" Sign alternatives had the second highest comprehension rates for driving simulator subjects with 72.8% for the "i" Sign without a circular border and 75.4% for the "i" Sign with a circular border. A statistical difference was found between the results of the online survey and the driving simulator test.

# Evaluation of Alternative Information Signs in Oregon

by
Justin Michael Neill

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

______________________________________________

Justin Michael Neill, Author

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## 1. INTRODUCTION

Intuitive access to visitor information centers is vital to tourism. The Manual on Uniform Traffic Control Devices (MUTCD) includes a Tourist Information sign (D9-10) intended to direct roadway users to nearby tourist information centers. For these signs to work effectively, they need to be easily interpreted and understood by visitors from around the world. 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). The Gross Domestic Product of the travel industry in Oregon was $3.4 billion in 2012, placing it among the three largest export-oriented industries in the state. The travel industry also has a significant secondary effect on employment in Oregon. In 2012, the re-spending of travel-related revenues by businesses supported 41,000 additional jobs outside of the travel industry.

There is a significant interest in the comprehension rate of the current Tourist Information sign, particularly by drivers who are not fluent in English. It has been hypothesized that a symbolic message may elicit a higher comprehension rate than a text-based message. There are multiple reasons for the increased comprehension rate of a symbolic message, one such characteristic being their language independent nature. Symbols also require less space to deliver their intended message. One alternative Information Center sign of particular interest is a symbolic version with a lower case “i” as the symbol. The “i” Sign uses the first letter of the word information as a symbolic replacement. The “i” Sign provides a possible alternative, because of its widespread use and its simplicity. The “i” symbol has been used in numerous contexts, such as on the internet, in software, and as direction signs, to convey the information is available. The “i” Sign already has widespread use as a traffic sign in the European Union especially because the United Nations World Tourism Organization has decided to make it the official symbol for its member nations.

This research studied the comprehension rate of the current Tourist Information sign as compared with possible alternatives signs from variety of different contexts in the literature. Demographics were collected throughout the research on each subject’s age, gender, education, and primary language. These demographics give us insight into the driver characteristics that affect comprehension of the Tourist Information sign.

Previous research has been conducted on traffic sign comprehension and on sign legibility in survey form and with driving simulation. The comprehension rates of the “i” Sign, specifically, have been previously researched with an open-ended survey and a multiple-choice survey. This research effort is unique because driver comprehension was tested both with an open-ended survey, a rating task, and while subjects were engaged in a simulated driving task. Each subject’s own comprehension was tested with an open-ended survey followed by a ranking task, in which they estimated what percentage of the United States population would correctly understand each tested symbol. A different set of subjects participated in the follow-up driving simulator experiment. These subjects' comprehension was tested on the sign alternatives while engaged in an authentic simulated driving task. Specifically, the subjects encountered the Tourist Information sign alternatives while navigating a freeway exit and then again while navigating a suburban environment. The presentation order of the alternatives in the simulated environment was counterbalanced to

## 2. LITERATURE REVIEW

This literature review considers topics critical to the determination of the optimal presentation for Tourist Information signs in the state of Oregon. Tourist Information signs are used to guide people to information centers; however, various types of signs are found throughout the world. Even within Oregon, multiple icons are used, which may potentially be a source of confusion for tourists. The literature review is divided into the following sections:

- A history of standard presentations for the Tourist Information sign in a transportation context as well as alternative contexts is detailed.
- Prior Tourist Information sign research is examined, with the specific intent of identifying strengths, weaknesses and existing gaps in knowledge that may inform signage practices in Oregon.
- The strengths and weaknesses of using a symbol instead of a word message for roadway signing are also considered.
- Best practices for the development and execution of an online-survey and driving simulator experiment investigating driver comprehension of the Tourist Information sign is also examined.

## 2.1 Tourist Information Message

The information message, which is intended to inform individuals that relevant information to their situation is available, is used in a wide variety of contexts. The focus of this document is the presentation of the Tourist Information message to drivers on surface roads in Oregon. Many other contexts exist, though, and should be considered when contemplating alternatives for the existing Tourist Information sign.

### *2.1.1 Tourist Information General Service Signs*

The Tourist Information sign [D9-10] documented in the Manual on Uniform Traffic Control Devices (MUTCD), which sets standards on all traffic control devices including signage, as a Guide sign, and is further specified as a General Service sign. The MUTCD (FHWA 2009) defines Guide signs as providing the following seven functions:

1. Give directions to destinations, or to streets or highway routes, at intersection or interchanges;
2. Furnish advance notice of the approach to intersections or interchanges;
3. Direct road users into appropriate lanes in advance of diverging or merging movements;
4. Identify routes and directions on those routes;

5. Show distances to destinations;
6. Indicate access to general motorist services, rest, scenic, and recreational areas; and
7. Provide other information of value to the road user.

The last three versions of the MUTCD (2000, 2003, and 2009) have included three different iterations of the Tourist Information sign; although the 2000 and 2003 versions are very similar (see Figure 1).


MUTCD 2000 MUTCD 2003 MUTCD 2009

**Figure 1:** Current and past MUTCD Tourist Information signs

Internationally, alternative Tourist Information signs have been adopted. For example, the United Nations World Tourist Organization Executive Council (UNWTO) adopted four possible sign symbols (see Figure 2) 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.

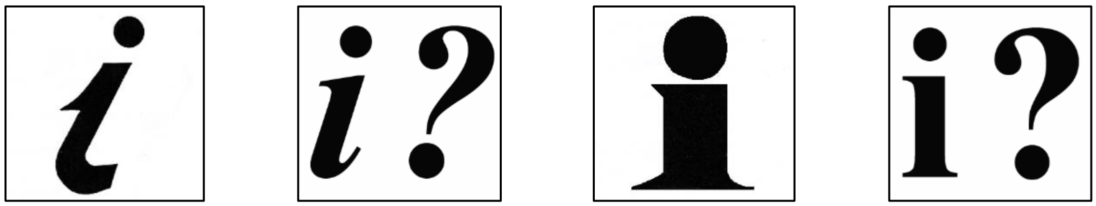


**Figure 2:** United Nations World Tourist Organization Tourist Information signs

While the MUTCD and the UNWTO have both created standards, other symbols have been used. 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 1 and Figure 2 have been used to represent.

*2.1.2 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 Table 1 through3.

The most common approach is to use a lower-case letter “i" (Table 1) or “?” (Table 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 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 1:** Examples of “i” Signs

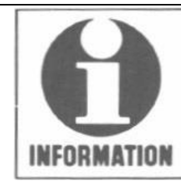
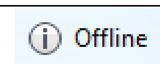
| | | | |
|---|---|---|---|
| <br>**Meaning:** Information<br>**Used By:** KFAI Sweden | <br>Information<br>Netherlands Railroad | <br>Information<br>Transport Canada, Airports | <br>Information<br>International Union of Railways |
| <br>Information<br>Swedish Standard Recreation Symbols | <br>Image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

Table 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 2:** Examples of "?" Signs

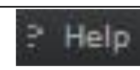
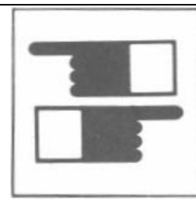
| | | | |
|---|---|---|---|
|  **Meaning:** Information **Used By:** Dallas – Fort Worth |   Information Denver Airport, Denver, CO |  Information International Air Transport Association |  Information Picto'grafics |
|  Information National Park Service |   Information Portland International Airport, 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 3 shows alternative symbols used to indicate information is available. The question mark is commonly incorporated into the symbols shown in Table 3. Five symbols are included in Table 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 3:** Other information sign presentations

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

From Table 1, Table 2, and Table 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.

## 2.2 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 4 describes the composition of the four groups interviewed.

**Table 4:** 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 5 (Dewar 1988), which shows the mean importance ratings displayed to two decimals and the criteria rankings in parenthesis.

**Table 5:** 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.

## <u>2.3 Symbol vs. Word Signs</u>

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.

### *2.3.1 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 3.

No Left Turn No Right Turn Do Not Enter

**Figure 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 6.

**Table 6:** 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 **7**.

**Table 7:** 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 7, 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).

### *2.3.2 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).

*2.3.3 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 8.

**Table 8:** 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 9.

**Table 9:** 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.

*2.3.4 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 10.

**Table 10:** 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 10 clearly shows that the relative effectiveness between symbol and word signs needs to be determined individually.

*2.3.5 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 a higher initial comprehension rates.

### *2.3.6 "i" Sign Research Gaps*

Some studies have investigated certain aspects of the "i" Sign. Table 11 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 11:** 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 11, 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.

## 2.4 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.

### *2.4.1 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.

### *2.4.2 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 $p < 0.01$.

### *2.4.3 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.

### *2.4.4 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.

### *2.4.5 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 A. The questionnaire results will be discussed in chapter 4.

**Table 12:** 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 |

## 2.5 Summary

The current literature generally provides a clear picture of the best practices for traffic sign research and development. However, potentially important gaps in knowledge were identified, which will be addressed by this study:

1. Much of the traffic sign comprehension work has been conducted with multiple choice tests, which are not as representative as an open-ended test, especially when the plausibility of distractor questions are low.
2. Critical design aspects such as conspicuity, reaction time, and learnability have yet to be resolved for the Tourist Information sign.
3. The influence of an authentic driving task on sign comprehension has yet to be examined.

We intend to address Gap #1 through a questionnaire, which will enable subjects to respond to an open ended question about their interpretation of various versions of the Tourist Information sign. We also intend to allow subjects to indicate what percentage of the population will correctly interpret each presented version of the Tourist Information sign.

We intend to fill Gaps #2 and #3 by presenting subjects with the Tourist Information sign in the Oregon State University driving simulator, enabling us to test a subject's comprehension and reaction to the Tourist Information sign while under the demand of the driving task.

# 3. METHODOLOGY

This section describes the experimental methods used in this project to evaluate alternative information signs in Oregon. Specifically, this study 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 an open-ended comprehension task and a rating task. Data from both parts of the online survey was analyzed across subject demographics. The driving simulator data provided measurements of visual attention and correct and incorrect verbal responses.

## 3.1 Research Objectives

Multiple objectives were developed to guide this research. These objectives surrounded the comprehension and glance patterns between sign alternatives and test methods. The four null hypotheses examined throughout this research are:

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 was used to develop the online survey which consisted of demographic questions, open-ended sign comprehension questions, and one sign comparison question. Demographic fields included "gender", "age", "education", "state of residence", "length of residence in United States", "if English is the subject's primary language", "if the subject is a licensed driver", "approximate driven miles in the previous year", "frequency of recreation or pleasure travel", and "years as a licensed driver". The exclusion criteria included subjects who were not between the ages of 18 to 75 and were not a licensed driver for over one year. Examples of the images from the open ended comprehension questions section of the survey are included in Figure 4 and Figure 5, and the entire survey can be found in Appendix A.

**Figure 4:** Example “i” Sign comprehension question image

Figure 4 shows an example of the image shown to subjects during the open-ended response section of the survey. The image was presented in conjunction with the question, “What does this sign mean to you?” Subjects were presented with five different sign designs (Table 13) on one of two different authentic backgrounds from Oregon to provide context. The sign order and background presented to each subject were randomized.

**Table 13:** Alternative signs tested

| "i" Sign: | "i" Sign with circle: | "INFO" Sign: | "?" Sign: | "?" Sign with circle: |
|---|---|---|---|---|
|  |  |  |  |  |

As seen in Table 13, 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 was included to draw additional attention to the symbol.

Also included in the survey was a rating task in which the subject was asked to score each the five signs in Table 13 according to what percentage of the population they thought would understand the sign correctly. An example of the rating task is included in Figure 5.

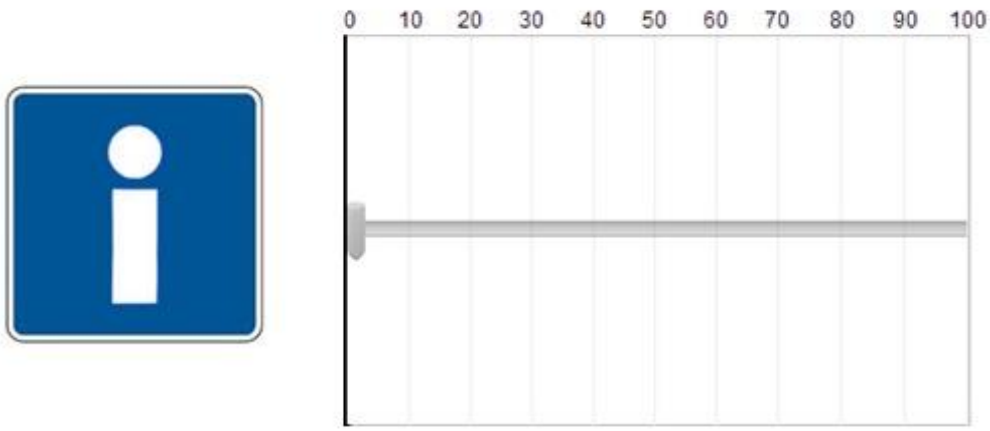



**Figure 5:** Survey sign rating task

At the beginning of the rating task, subjects were provided with a description of Tourist Information Centers: “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.” for all five sign alternatives presented in a random order to each subject.

After the results from the open ended survey were collected, they were analyzed independently by five researchers. The researchers aggregated the response into categories and ultimately defined the responses as correct, partially correct, or incorrect.

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. Inter-rater reliability was established in advance of the final data analysis. 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.

### 3.3 Driving Simulator

The OSU Driving Simulator (Figure 6) is a high-fidelity motion base simulator, which consists of a full 2009 Ford Fusion cab mounted on top of an electric pitch motion system. The vehicle cab is mounted on a pitch motion system with the driver's eye-point located at the center of the viewing volume. The pitch motion system allows for onset cues for acceleration and braking events. Three projectors are used to project a 180 degree front view and a fourth projector is used to display a rear image for the driver’s center mirror. The two side mirrors also have embedded 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 computer system consists of a quad core host running Realtime Technologies SimCreator Software with an update rate for the graphics of 60 Hz. The simulator software is capable of capturing and outputting highly accurate values for performance measures such as speed, position, brake, and acceleration.

**Figure 6:** Oregon State University driving simulator

As can be seen in Figure 6, the driving simulator provides an immersive built environment and an authentic driving task that allows individual variables to be examined in isolation while controlling confounding factors. The human factors assessment was performed in the driving simulator with an ASL Mobile Eye Tracking system and think aloud interviews.

3.4 Scenario Layout

The scenarios presented in the driving simulator were modeled after realistic presentations of Tourist Information signs in Oregon. The subjects experience Tourist Information signs in two contexts; first, on a freeway exit and secondly, at an intersection of local roads (Figure 7). The four sign alternatives that performed best in the online survey were selected as the signs to be tested in the driving simulator.

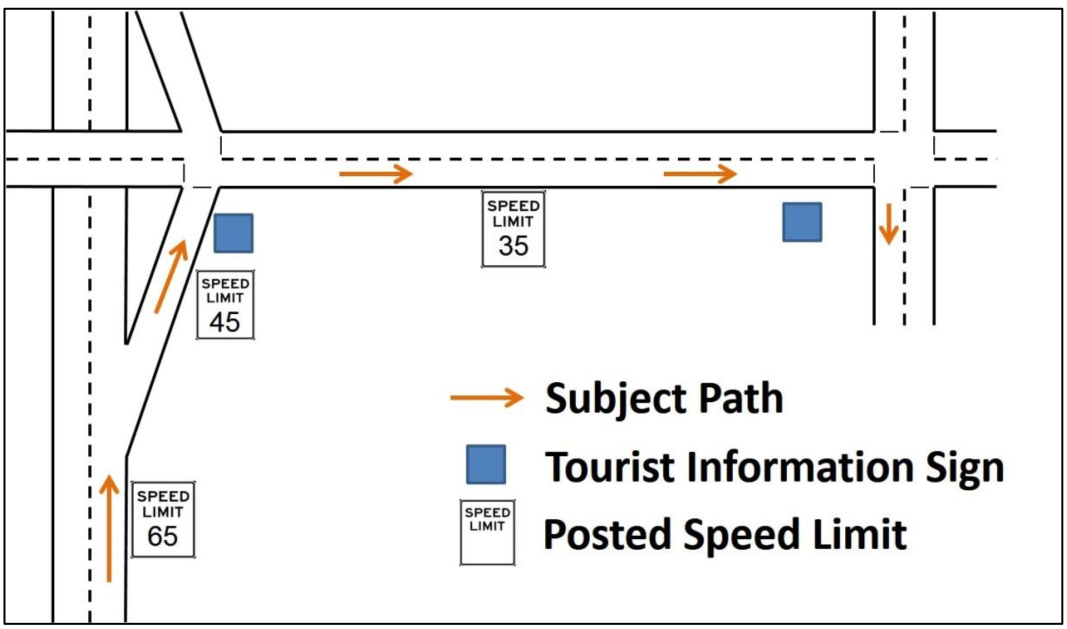



**Figure 7:** Driving simulator track (not to scale)

As can be seen from Figure 7, the route taken by the subjects includes traveling northbound along a freeway, departing the freeway by an exit ramp, and then turning right along local roads. Each subject was instructed before their test to take the first exit, make a right onto the local road and then make a right at the intersection. Figure 8 shows an example sign from the simulated environment.

**Figure 8:** Example sign from the simulated environment

Each subject drove through the environment a total of four times each. During the first two drives, the subject was shown each of the four signs in one of the two positions shown in Figure 8. During the second two drives, the subject drove through the environment again with the signs being displayed in a different order. Throughout each drive, data was collected on the subject's lane position and speed. On the second 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, which were recorded with an audio recording device. The subjects wore the ASL Mobile Eye XG equipment through each of the four drives. This equipment was used 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 is a visual glance by the subject in one area for more than 0.1 seconds. A single dwell is the sum of multiple, uninterrupted fixations on a single area. Fixations are calculated using ASL Mobile Eye post processing software, shown in Figure 9.

**Figure 9:** Example Area of Interest

As seen in Figure 9, Area of Interests (AOIs) are manually introduced to the eye tracking video in the ASL Results Plus software. These polygons are added to individual frames of video at varying intervals. For the purpose of this project AOIs were introduced around traffic sign alternatives every five to 10 frames. The Results Plus software then automatically calculates the number and duration of fixations in each AOI.

# 4. RESULTS AND ANALYSIS

This section describes the qualitative and quantitative data collected in this project, and the statistical methods used to analyze the data collected from an online survey and a driving simulator experiment. The data were plotted and visually inspected. The data collected from the online survey contained two distinctive data sets; one set of panel data with a discrete dependent variable and one set of panel data with a continuous dependent variable. The data collected from the driving simulator also contained two data sets; one with panel data with a discrete dependent variable and one set of panel data with a continuous dependent variable. The panel data sets with discrete dependent variables were analyzed with the ANCOVA test (Ramsey and Schafer 2013) and the panel data sets with continuous dependent variables were analyzed with two-way pooled random effects models (Washington et al 2011).

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, and the statistical analysis was performed in R.

## 4.1 Online Survey

The online survey was divided into two separate sections for analysis; the open ended comprehension task and the rating task. The online survey generated 142 useable subject responses. Subjects were collected through email lists and through posters in community areas in Corvallis, OR and in Albany, OR. The rating task data produced results on a scale of one to 100 and the open ended task produced results between zero and one.

### *4.1.1 Demographics*

Eight demographics were collected from each subject that participated in the online survey. The demographics (Table 14) included gender, age, level of education, years licensed, the amount of recreation or pleasure travel, miles driven last year, primary language, and home state.

**Table 14:** Online survey demographics

| Demographic: | Possible Responses: | Number of Participants: | Percentage of Participants: |
|---|---|---|---|
| What is your highest completed level of education? | High School Diploma | 6 | 4.23 |
| | Some College | 43 | 30.28 |
| | Associates Degree | 13 | 9.15 |
| | 4-year Degree | 56 | 39.44 |
| | Master's Degree | 17 | 11.97 |
| | PhD Degree | 3 | 2.11 |
| | Other | 4 | 2.82 |
| How many years have you been a licensed driver? | 1 - 5 years | 35 | 24.65 |
| | 6 - 10 years | 35 | 24.65 |
| | 11 - 15 years | 19 | 13.38 |
| | 16 - 20 years | 9 | 6.34 |
| | More than 20 years | 44 | 30.99 |
| How often do you travel for recreation or pleasure? | Daily | 2 | 1.41 |
| | 2-3 Times a Week | 16 | 11.27 |
| | Once a Week | 17 | 11.97 |
| | 2-3 Times a Month | 34 | 23.94 |
| | Once a Month | 27 | 19.01 |
| | Less than Once a Month | 45 | 31.69 |
| | Never | 1 | 0.70 |
| How many miles did you drive in the last year? | 0 - 5,000 miles | 29 | 20.42 |
| | 5,000 - 10,000 miles | 48 | 33.80 |
| | 10,000 - 15,000 miles | 45 | 31.69 |
| | 15,000 - 20,000 miles | 10 | 7.04 |
| | More than 20,000 miles | 10 | 7.04 |
| What is your primary language? | English | 129 | 90.85 |
| | Other | 13 | 9.15 |
| What is your home state? | Oregon | 121 | 85.21 |
| | Other | 21 | 14.79 |
| Gender | Male | 68 | 47.89 |
| | Female | 74 | 52.11 |
| Age | *Minimum* | *Average* | *Maximum* |
| | 19 | 34.30 | 73 |

As seen in Table 14, a wide range and diversity of the demographics were collected. Large numbers of males and females were collected with a wide range of ages represented in each gender. It can be seen that a wide variety of educational backgrounds were represented in the online survey.

#### *4.1.2 Open-Ended Comprehension Test*

The respondents provided 142 responses to each question in the open ended comprehension test. The responses were scored as 1 if correct, 0.5 if partially correct, and 0 if incorrect. In addition to the comprehension score, critical confusions were considered. 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. The data was initially observed by comparing descriptive statistics of each alternative (Table 15).

**Table 15:** Open ended test descriptive statistics

| Sign Alternative: | Mean: | Critical Confusions: | Median: | Range: | Standard Deviation: |
|---|---|---|---|---|---|
| “i” Sign | 0.75 | 0.70% | 1.00 | 0.00 – 1.00 | 0.44 |
| “i” Sign with circle | 0.84 | 0.70% | 1.00 | 0.00 – 1.00 | 0.37 |
| “INFO” Sign | 1.00 | 0.00% | 1.00 | 0.50 – 1.00 | 0.04 |
| ”?” Sign | 0.73 | 0.70% | 1.00 | 0.00 – 1.00 | 0.44 |
| ”?” Sign with circle | 0.79 | 0.00% | 1.00 | 0.00 – 1.00 | 0.38 |

There were multiple recurring wrong answers. The most common incorrect interpretations were that the “i” symbols indicated pedestrians and that the blue background indicated it was a hospital sign. All of the critical confusions were due to subjects interpreting the signs as indicating a hospital nearby. These were considered critical confusions because the subject would be misguided if they were looking for a hospital. 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 was created by including all factors as additive variables. A reduced model was found by comparing the full model with reduced models until only significant variables remained. 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 16.

**Table 16:** 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 16 show that the "INFO" sign was comprehended better than all other sign alternatives. The "i" Sign with circle alternative also outperformed the "?" Sign alternative (Figure 10).

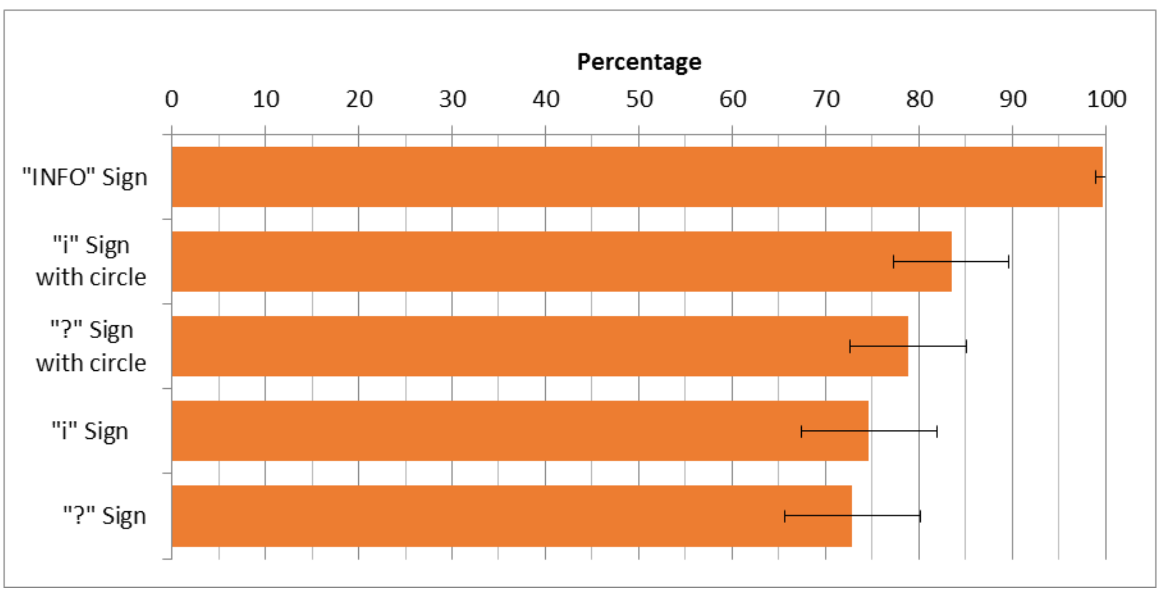



**Figure 10:** Open ended task averages with confidence intervals

As is clear in Figure 10, the "INFO" Sign alternative performs best at a statistically significant level.

Out of the eight driver demographics considered, only the miles that the subject drove in the previous year emerged as significant. The average score for each grouping of the miles driven in the previous year as well as other basic statistic values are shown in Table 17.

**Table 17:** Miles driven in previous year demographics

| Miles Driven in the Previous Year: | Mean: | Median: | Range: | Standard Deviation: |
|---|---|---|---|---|
| 0 – 5,000 | 0.76 | 1.00 | 0.00 – 1.00 | 0.42 |
| 5,000 – 10,000 | 0.85 | 1.00 | 0.00 – 1.00 | 0.36 |
| 10,000 – 15,000 | 0.86 | 1.00 | 0.00 – 1.00 | 0.35 |
| 15,000 – 20,000 | 0.88 | 1.00 | 0.00 – 1.00 | 0.33 |
| More than 20,000 | 0.72 | 1.00 | 0.00 – 1.00 | 0.44 |

As can be seen from Table 17, 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.

*4.1.3 Rating Task Statistics*

The rating task data was generated 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 were found and removed before the analysis. Descriptive statistics were calculated for each information sign alternative (Table 18).

**Table 18:** Rating task descriptive statistics

| **Alternative:** | **Mean:** | **Median:** | **Range:** | **Standard Deviation:** |
|---|---|---|---|---|
| "i" Sign | 42 | 40 | 0 – 100 | 28 |
| "i" Sign with circle | 50 | 50 | 0 – 100 | 28 |
| "INFO" Sign | 88 | 91 | 50 – 100 | 13 |
| "?" Sign | 40 | 37 | 0 – 100 | 28 |
| "?" Sign with circle | 42 | 40 | 0 – 100 | 29 |

As Table 18 shows, the "INFO" Sign alternative performed significantly different from the other alternatives. Box and whisker plots were created for each of the signs in the rating task and are shown in Figure 11.

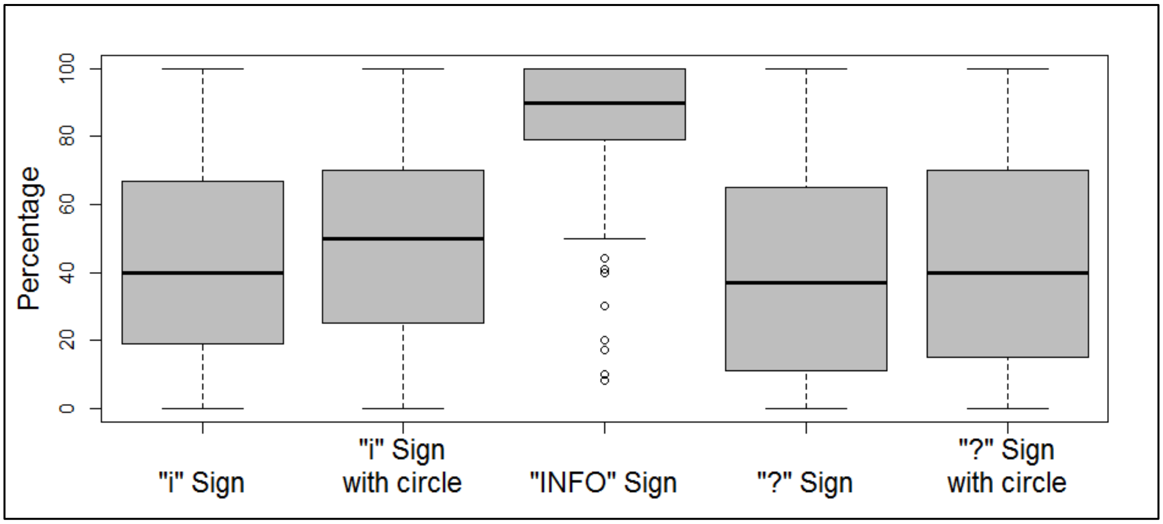



**Figure 11:** Sign comprehension scores from the rating task

Figure 11 illustrates the basic comparison between each sign alternative. The "INFO" Sign alternative was consistently rated best compared to the other tested alternatives.

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 previous model. The final reduced model included the sign alternative and age. Table 19 shows the estimates of these variables in comparison with a base value for each variable.

**Table 19:** 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 19, the “INFO” sign was rated higher than all other alternatives and the “i” Sign with circle was rated second highest. Figure 12 shows the mean rating with 95 percent confidence intervals for each sign alternative collected from the ranking task.

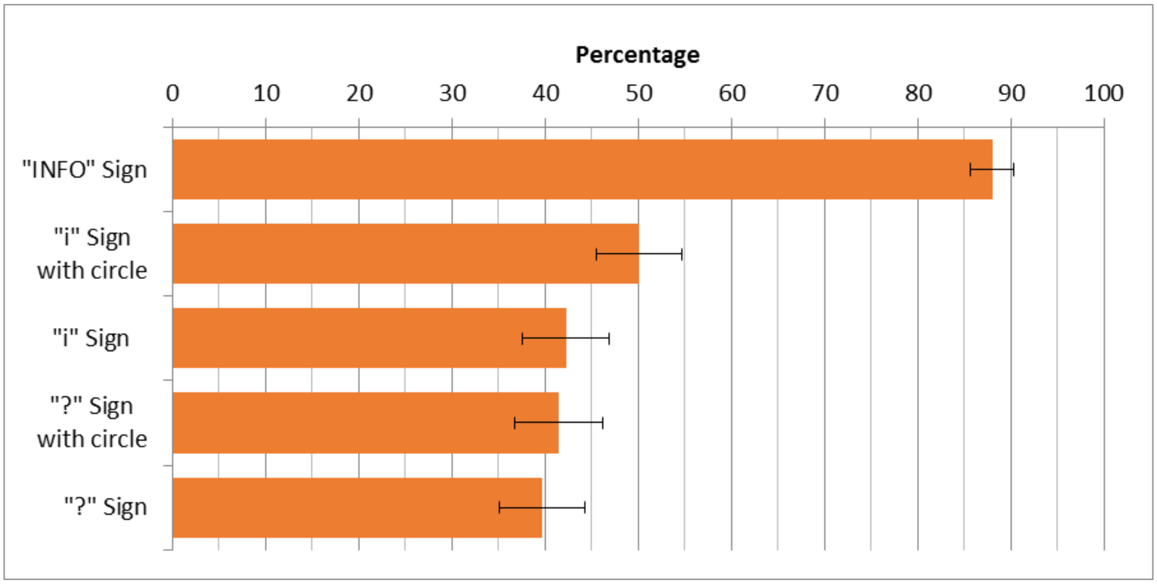



**Figure 12:** Rating task averages with confidence intervals

*4.1.4 Online Survey Summary*

An online survey was conducted to help identify the most promising information sign alternatives to be included in a follow-up driving simulator study. The survey performed in this research used both an open ended comprehension test and a rating task to determine driver comprehension rates for the Tourist Information sign. In both question types, the “INFO” Sign alternative performed best, and in the rating task, the “i” Sign with the circle performed second best. In the open ended test, the miles that the subject drove in the previous year was found to have a significant effect on increased comprehension. Age had a significant effect on the rating task. 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

During the driving simulator test, the subject’s comprehension of alternate Tourist Information signs was assessed while engaged in a simulated driving task. The same signs were tested in the driving simulator test as were tested in the online survey, except for the “?” Sign. One sign was removed to create a more balanced design in the driving simulator. The “?” Sign was selected to be removed because it performed worst in the online survey. In a brief follow-up survey, subjects were given an online survey to rate the four signs they interacted with during the driving simulator experiment according to the percentage of the drivers in the United States that would correctly understand the sign.

51 subjects participated in the driving simulator test. Subjects were collected through email lists and through posters in community areas in Corvallis, OR and in Albany, OR 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 and because no further statistical differences were being observed. Therefore, 42 subjects provided useable comprehension data and 34 subjects provided useable eye tracking data.

### *4.2.1 Demographics*

Demographics including gender, age, level of education, years licensed, the amount of recreation or pleasure travel, miles driven last year, primary language, and home state were collected. In addition, the total dwell time and average dwell time was collected during the driving simulation. The demographics are shown in Table 20.

**Table 20:** Driving simulator demographics

| Demographic: | Possible Responses: | Number of Participants: | Percentage of Participants: |
|---|---|---|---|
| What is your highest completed level of education? | High School Diploma | 2 | 4.76 |
| | Some College | 16 | 38.10 |
| | Associates Degree | 2 | 4.76 |
| | 4-year Degree | 10 | 23.81 |
| | Master's Degree | 9 | 21.43 |
| | PhD Degree | 2 | 4.76 |
| | Other | 1 | 2.38 |
| How many years have you been a licensed driver? | 1 - 5 years | 4 | 9.52 |
| | 6 - 10 years | 11 | 26.19 |
| | 11 - 15 years | 5 | 11.90 |
| | 16 - 20 years | 1 | 2.38 |
| | More than 20 years | 21 | 50.00 |
| How often do you travel for recreation or pleasure? | Daily | 2 | 4.76 |
| | 2-3 Times a Week | 7 | 16.67 |
| | Once a Week | 5 | 11.90 |
| | 2-3 Times a Month | 10 | 23.81 |
| | Once a Month | 11 | 26.19 |
| | Less than Once a Month | 7 | 16.67 |
| | Never | 0 | 0.00 |
| How many miles did you drive in the last year? | 0 - 5,000 miles | 3 | 7.14 |
| | 5,000 - 10,000 miles | 11 | 26.19 |
| | 10,000 - 15,000 miles | 15 | 35.71 |
| | 15,000 - 20,000 miles | 7 | 16.67 |
| | More than 20,000 miles | 6 | 14.29 |
| What is your primary language? | English | 40 | 95.24 |
| | Other | 2 | 4.76 |
| What is your home state? | Oregon | 40 | 95.24 |
| | Other | 2 | 4.76 |
| Gender | Male | 28 | 66.67 |
| | Female | 14 | 33.33 |
| Age | *Minimum* | *Average* | *Maximum* |
| | 21 | 38.7 | 72 |

As seen in Table 20, a reasonably wide range of ages were collected. Fewer females were enrolled than males, but both genders were represented by a diverse group of age ranges. It can be seen that a wide variety of other demographics were represented in the driving simulator test.

*4.2.2 Driver Simulator Results*

The driving simulator test provided 42 useable responses for each sign alternative and 34 useable responses for the eye tracking. The responses were scored as 1 if correct, 0.5 if partially correct, and 0 if incorrect. In addition to the comprehension score, critical confusions were considered. The data was initially observed by comparing descriptive statistics of each alternative (Table 21).

**Table 21:** Driving simulator test descriptive statistics

| Sign Alternative: | Mean: | Critical Confusions: | Median: | Range: | Standard Deviation: |
|---|---|---|---|---|---|
| “i” Sign | 0.73 | 2.38% | 1.00 | 0.0 – 1.0 | 0.44 |
| “i” Sign with circle | 0.76 | 4.76% | 1.00 | 0.0 – 1.0 | 0.43 |
| “INFO” Sign | 0.95 | 0.00% | 1.00 | 0.0 – 1.0 | 0.22 |
| “?” Sign with circle | 0.53 | 4.76% | 0.50 | 0.0 – 1.0 | 0.40 |

There were multiple recurring wrong answers. The most common incorrect interpretations were that the “i” symbols indicated that a gas station was nearby and that the blue background indicated it was a hospital sign. All of the critical confusions were due to subjects interpreting the signs as indicating a hospital nearby. These were considered critical confusions because the subject would be misguided if they were looking for a hospital. A complete list of the incorrect answers and their frequency is shown in Table 22. This table does not include subject responses that did not include a specific guess.

**Table 22:** Incorrect Tourist Information sign comprehension

| **Answer:** | **"i" Sign:** | **"i" Sign with circle:** | **"INFO" Sign:** | **"?" Sign with circle:** |
|---|---|---|---|---|
| Hospital | 1 | 2 | | 2 |
| Gas Station | 1 | 3 | | |
| Intersection | 1 | 2 | | |
| Interstate | 1 | 1 | | |
| Bus Stop | | | | 1 |
| Exclamation Mark | 1 | | | |
| International Airport | 1 | | | |
| Pedestrian | 1 | 1 | | |
| Total | 7 (16.7%) | 9 (21.4%) | 0 (0%) | 3 (7.1%) |

The incorrect Tourist Information sign interpretations were further examined for similarities. Table 23 includes images of the signs identified as being critical confusions.

**Table 23:** Sign confusions

| | | |
|---|---|---|
|  Hospital |  Gas Station |   Interstate Shield |
|  Bus Stop |  Airport |  Pedestrian Crossing |

Three commonalities exist between 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 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 was created by including all factors as additive variables. A reduced model was found by comparing the full model with reduced models until only 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 on the sign alternatives to determine the comprehension differences between the sign alternatives (Table 24).

**Table 24:** 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 presented in Table 24 show that in the driving simulator test, the "INFO" Sign alternative performs better than all other alternatives. The two "i" Sign alternatives do not perform differently at a significant level. The "?" Sign performed worse than all other alternatives at a statistically significant level. These results, as well as 95 percent confidence intervals, are shown graphically in Figure 13.

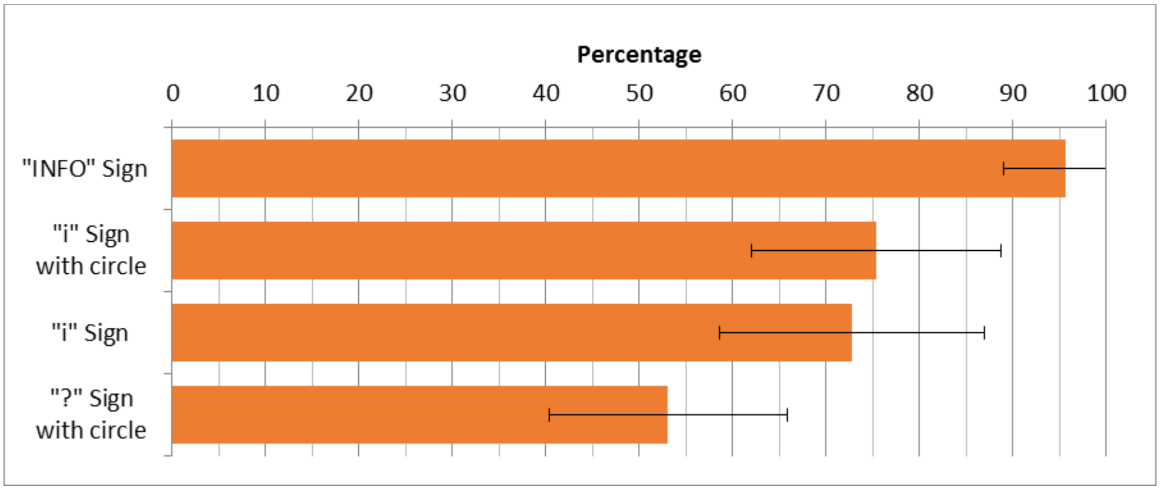



**Figure 13:** Driving simulator task averages with confidence intervals

These two-tail t-tests and confidence intervals provide evidence of the differences between driver comprehension rates of the sign alternatives.

While no difference existed in glance between sign alternatives, differences may exist between correct and incorrect responses. Descriptive statistics of the differences in glance patterns for correct and incorrect answers are shown in Table 25.

**Table 25:** Total dwell time descriptive statistics

| Subject Response: | Mean (s): | Median (s): | Range (s): | Standard Deviation (s): |
|---|---|---|---|---|
| Correct | 3.96 | 4.08 | 0.14 – 7.58 | 1.74 |
| Partially Correct | 3.85 | 4.00 | 1.71 – 5.91 | 1.30 |
| Incorrect | 4.28 | 4.18 | 0.70 – 7.75 | 1.88 |

A panel linear model was developed to describe the differences between total dwell durations. The model was developed by treating the total dwell duration as the dependent variable and the comprehension score, the sign alternative, and the driver demographics as the independent variables. The model was developed from a full additive model to a reduced model by removing the least significant variables and testing the full model against the reduced model. 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.

### *4.2.3 Post Drive Survey Rating Task*

The rating task data was generated when subjects were asked to rate each sign (from 0 to 100 percent) with the percentage of the United States population that would correctly understand each of five information sign alternatives. One outlier was found and removed in the analysis. Descriptive statistics were calculated for each information sign alternative (Table 26).

**Table 26:** Rating task statistics

| Sign Alternative: | Mean: | Median: | Range: | Standard Deviation: |
|---|---|---|---|---|
| “i” Sign | 53.7 | 56 | 4 – 95 | 27.9 |
| “i” Sign with circle | 62.3 | 60 | 20 – 100 | 26.0 |
| “INFO” Sign | 87.9 | 93 | 50 – 100 | 14.2 |
| “?” Sign with circle | 47.8 | 50 | 5 – 100 | 29.4 |

As Table 26 shows, the “INFO” sign performed best followed by the “i” Sign alternatives and then the “?” Sign with a circular border. Box and whisker plots were created for each of the signs in the rating task and are shown in Figure 14.

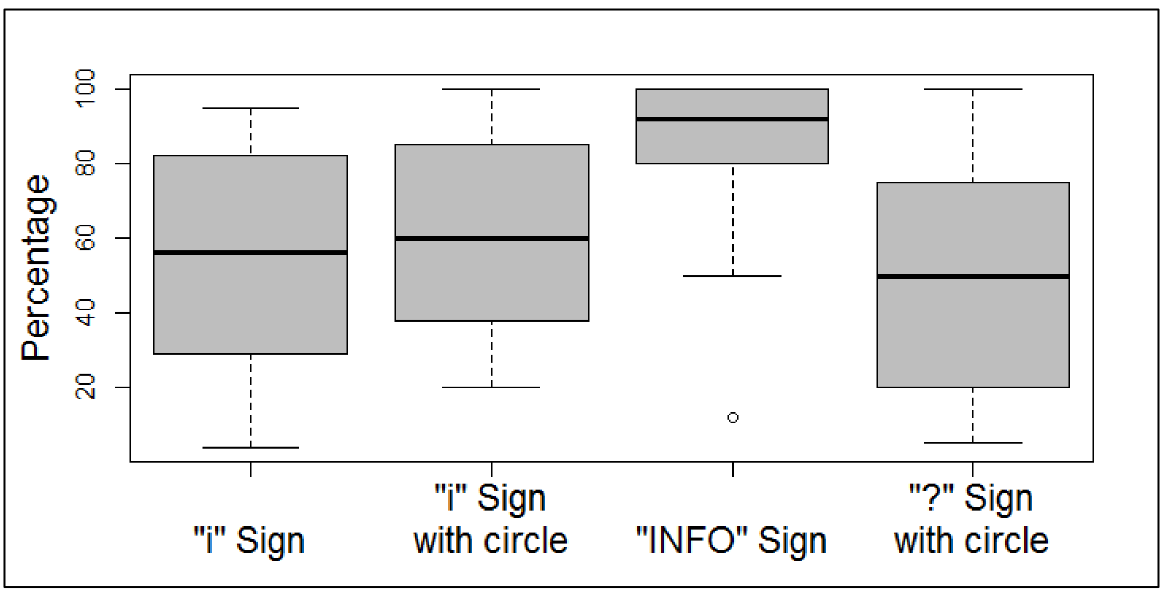



**Figure 14:** Sign comprehension scores from the rating task

Figure 14 illustrates the basic comparison between each sign alternative. The "INFO" sign alternative was consistently predicted as having the best comprehension rates as compared to the other tested sign alternatives. Both random and fixed effects models were considered to fit the post drive 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 demographics. The model was reduced by removing the least significant terms until the model was found to be significantly different from the previous model. The final reduced model included the sign alternative, the miles driven in the previous year, and age. Table 27 shows the estimates of these variables in comparison with a base value for each variable.

**Table 27:** 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 ($p < 0.05$).

As seen from Table 27, the "INFO" sign was rated higher than all other alternatives and the "i" Sign, with and without the circular border, was rated as second highest. The "?" Sign with circle was rated worst for comprehension. 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. Figure 15 shows the mean rating with the 95 percent confidence intervals for each sign alternative.

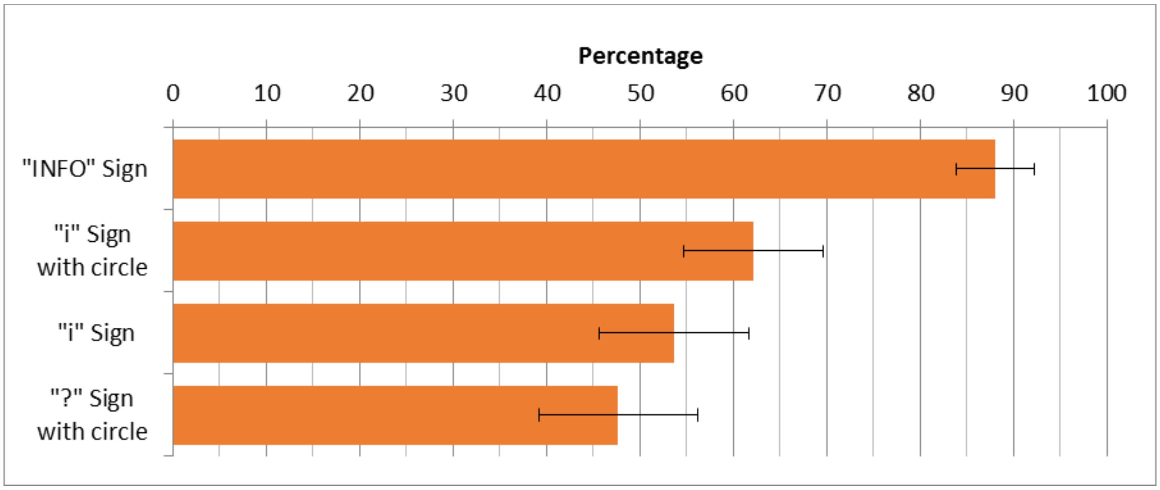



**Figure 15:** Rating task averages with confidence intervals

Figure 15 illustrates the differences in sign alternatives from the ranking task. Based on these results, the “INFO” Sign was predicted to be the most readily comprehended. As can also be seen from Figure 15 and Figure 13, there was no significant differences in the “i” Sign with or without the circular border.

## 4.3 Test Methods Comparison

There is always a need to establish and advance best practice research methodologies. Using the research results from the study of alternative information signs in Oregon each testing method (online survey and driving simulator study) for traffic sign comprehension was compared. The driving simulator comprehension was considered the baseline for results because it is the most representative of the actual driving task. The graphical comparison between testing method results is shown below in Figure 16 and the numerical results and model estimates are shown in Table 28.

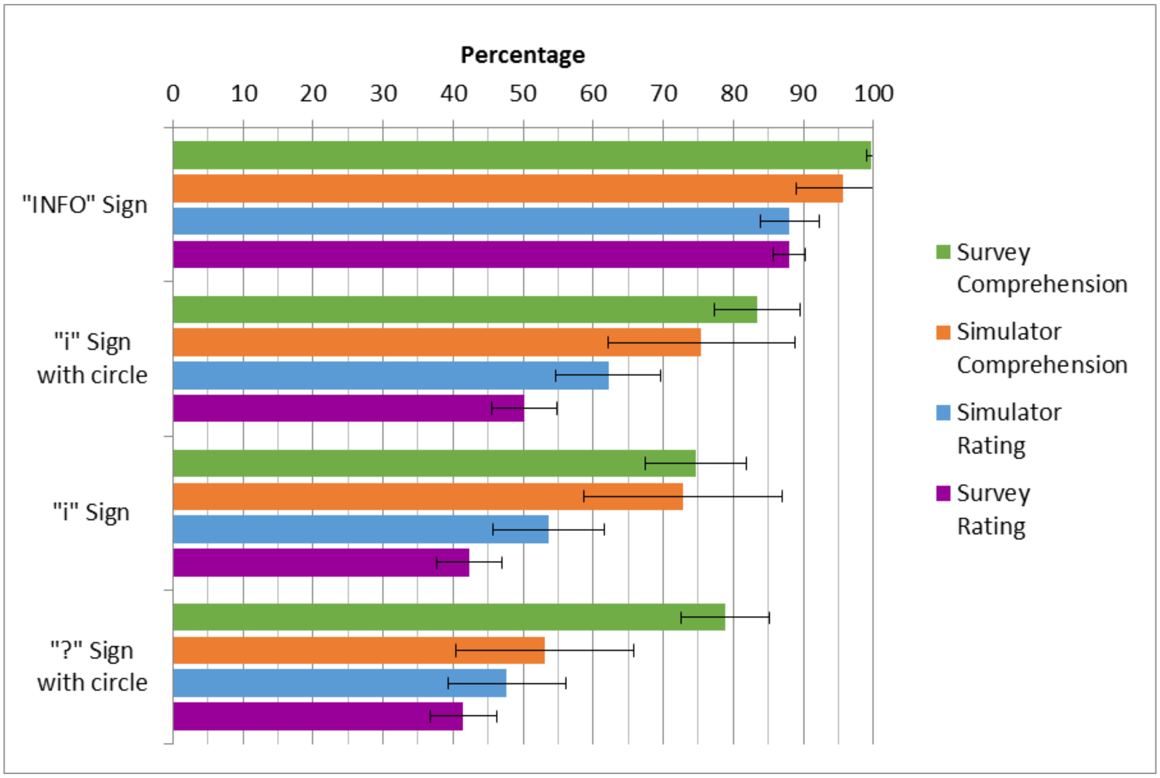



**Figure 16:** Testing method results comparison

**Table 28:** P-values between testing method numerical results

| Sign: | Open Ended Comprehension: | Rating Task: |
|---|---|---|
| "INFO" Sign | 0.384 | 0.910 |
| "i" Sign with circle | 0.384 | **0.028** |
| "i" Sign | 0.852 | **0.032** |
| "?" Sign with circle | **< 0.001** | 0.263 |

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

As seen from the results above in Figure 16 and Table 28, the results from each testing method follow the same general ranking of sign alternatives, but with varying magnitudes for each sign alternative. There were statistical differences between the test methods. The "i" Signs results were significantly different in the rating task and the "?" Sign with circle results were significantly different between the open ended comprehension methods. 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 ideal method to test sign comprehension. The next ideal test is the open ended comprehension test. The method of the open ended test most closely matches the comprehending task while driving.

# 5. CONCLUSIONS AND RECOMMENDATIONS

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 studies have suggested a minimum threshold of 85% for acceptable sign comprehension. Much research has been done to find the comprehension rates and other performance measures of traffic signs using a variety of techniques. This thesis specifically used three methodologies to test the comprehension rates of alternative Tourist Information signs. Multiple methodologies were used to ensure that an accurate measure of comprehension for the alternative Tourist Information signs was determined and for the purpose of identifying a preferred methodology for accurately determining comprehension rates.

## 5.1 Final Recommendations

The first goal of this research was to determine the comprehension rates of alternative Tourist Information sign. The first null hypothesis which states, there is no difference in driver's comprehension between each sign alternative, is rejected. Through each of the test methodologies, the "INFO" Sign alternative out performed all other alternatives in terms of comprehension at a statistically significant level. Additionally, No statistical difference was found in the total dwell times, or the circular boarders on comprehension rates between sign alternatives. The order the signs were presented to subjects was randomized in the survey tasks and counterbalanced in the driving simulator study. The order the signs were displayed in was taken into account when creating the panel linear models for the rating tasks and was tested for significance in the open ended comprehension task and the driving simulator task.

When considering the performance of signs it is also crucial to ensure they meet standards. The “INFO” Sign was the only sign to meet the ANSI standards of comprehension greater than 85% and critical confusions less than 5%.

### *5.1.1 Influence of 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 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 more understand the new Tourist Information alternative signs better.

In the online survey rating task, age and highest level of education completed tested as significant variables. Older subjects tended to rate the comprehension of the general US driving population lower than younger subjects. This could indicate that the older subjects were less confident of their answers and that feeling is being reflected as they rated the understanding of the population or that older drivers were less confident in the in the ability of the rest of the population. However, measurements of self-efficacy were not recorded to substantiate this. The highest level of education completed was also significant in the panel linear model developed for the online survey rating task. The only differences in the ratings due to education were between the group of subjects with an Associate's Degree and those with a PhD degree. Subjects with an Associate's Degree tended to rate the general comprehension higher than the rest of the education levels and subjects with a PhD Degree tended to rate the general comprehension lower than all of the other education levels. The results of an effect of the highest level of education completed are inconclusive because the levels that tested as significant do not follow a trend (i.e., an increase in education leads to an increase in rating).

Another consideration was the subject's dwell times on sign alternatives. The total dwell time was compared in two instances; first, between the sign alternatives; and second, between correct, partially correct, and incorrect responses. The second null hypothesis which states, there is no difference in the driver's glance patterns or fixation points between each sign alternative, is not rejected. The third hypothesis which states, there is no difference in the driver's glance patterns or fixation points between correct, partially correct, and incorrect responses, is also not rejected. 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 do 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 recognize the symbol or word message.

### *5.1.2 Common Confusions*

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 are reduced rates of comprehension errors, whereas symbols can be more easily misunderstood. 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.

## 5.2 Results Comparison

Previous work has been performed on a wide variety of other traffic signs and specifically on the Tourist Information sign. These results corroborate the results of this research study in several ways, including the comprehension rates of the alternatives and the difference in glance patterns between symbol and word signs.

### *5.2.1 Comprehension Results*

The Tourist Information sign has been studied before 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%, 72.9%, and 99.7% of drivers comprehending the “i” Sign, the “?” Sign, and the “INFO” Sign, respectively, as found in this research. The results for the “?” symbol and the “INFO” message were slightly higher in this research than in the 2008 report by Katz et al. 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 been increasing, which has led to an increased rate of comprehension. These results may also suggest regional differences in sign comprehension.

The results of this study can also be compared between test methods. The fourth null hypothesis which states, there is no difference in driver’s comprehension between each sign alternative in the online survey and in the driving simulator, is not rejected. There were significant differences in the results of the rating tasks for both “i” Sign alternatives and significant differences in the open ended comprehension tasks for the “?” Sign with the circular border.

*5.2.2 Glance Patterns*

As the results from the driving simulator ANCOVA test revealed (section 4.2.2), there was no significant difference in the glance patterns between sign alternatives. These results imply 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, where they found there was not a significant difference in reaction time between symbolic signs and word signs with simple messages, like “HILL” or “BUMP”.

### 5.3 Future Work

There are multiple aspects of this project that have identified the potential for future work. The most authentic comprehension response would be one collected in the field with subjects using their personal vehicles, however naturalistic studies of this type are inherently risky and expensive. The results of this research could be compared to comprehension rates collected in the field, which would add to the power of the argument of which test method represents best practice. Considering the driving simulator as the ground truth for comprehension rates, the experiment that performed second best, as compared to the driving simulator experiment, was the open ended test from the online survey. As drivers encounter signs, they must use the context of the roadway, along with their personal experience and knowledge, to discover the meaning of the sign. The driving simulator very closely matches this experience and the open ended test replicates the comprehending task fairly well except that it excludes the driving task requirement of control, guidance, and navigation.

More research in the field of dwell times on varying traffic signs would benefit future sign message development. Ells and Dewar (1979) found that the reaction times for symbolic signs and message signs with simple, one-word messages were similar, which corroborates the glance patterns identified in this research. However, Ells and Dewar found that the reaction time for message signs with complex word messages was significantly longer than for symbolic signs. Eye tracking could be used to find the dwell times for more complex word signs to discover if the reaction time for the sign is directly related to the amount of time required by the subject to observe the sign message.

Lastly, this research could also benefit from an expanded population with particular emphasis on either non-English speaking or English as a second language as a requirement. These results would benefit the research by adding the population that tourism-focused signage is often targeting.

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**APPENDIX A 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?

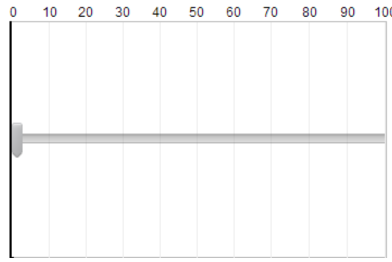
16. What does this sign mean to you?


17. What does this sign mean to you?

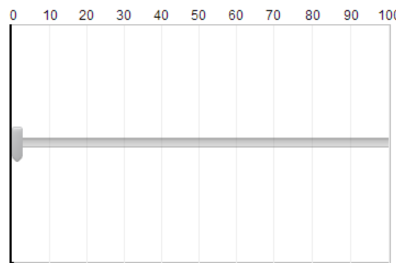
18. What does this sign mean to you?


19. What does this sign mean to you?

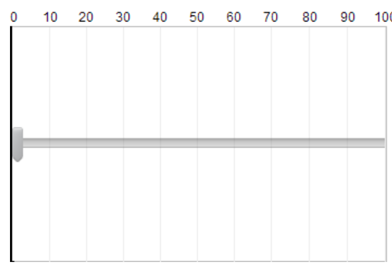
20. Select the percentage of the population you think will understand the following signs to represent a Tourist Information center.
Tourist Information Centers provide brochures, directions, and information about the surrounding area. This information includes local and regional activities and tourist attractions, as well as information about local restaurants and lodging.

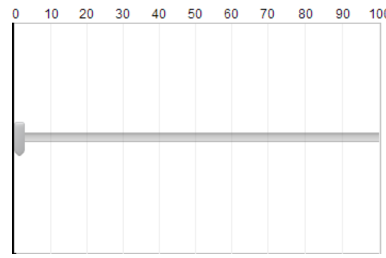









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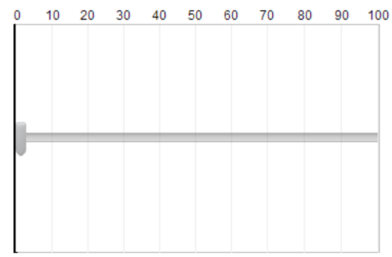
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