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INVESTIGATION AND MITIGATION OF DRIVER CONFUSION AT MODERN ROUNDABOUTS

Aemal Khattak, Ph.D.
Associate Professor
Department of Civil Engineering
University of Nebraska-Lincoln

Ram Bishu, Ph.D., Professor
Karen Schurr, Lecturer
Gregroy McKnight, Masters Student

Nebraska Transportation Center
262 WHIT
2200 Vine Street
Lincoln, NE 68583-0851
(402) 472-1975

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Dr. Aemal Khattak
Associate Professor
Department of Civil Engineering
University of Nebraska-Lincoln

Karen Schurr
Lecturer
Department of Civil Engineering
University of Nebraska-Lincoln

Dr. Ram Bishu
Professor
Department of Civil Engineering
University of Nebraska-Lincoln

Gregory McKnight
Masters Student
Department of Civil Engineering
University of Nebraska-Lincoln

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Nebraska Transportation Center
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16. Abstract

This research deals with two related issues: investigation and mitigation of roundabout elements that lead to driver confusion, and development of a flexible criteria matrix by which the Nebraska Department of Roads (NDOR) can evaluate arterial intersections to identify good candidates for conversion to roundabouts. The use of modern roundabouts along arterial roadways is relatively new in Nebraska. The first urban arterial roundabout was opened to traffic in June of 2002 at the intersection of 33rd and Sheridan Blvd in the City of Lincoln. Citizens and some professionals were somewhat skeptical of the capability of this roundabout to improve traffic delay and safety. However, after the construction of this roundabout the City of Lincoln has reported reduced traffic delays and the Nebraska Department of Roads (NDOR) has reported a reduction in traffic accidents. The objectives of the research include: (1) identification of user issues and confusing elements of roundabouts via surveys and development of mitigation measures for safer usage of arterial roundabouts in Nebraska; and (2) development of a criteria matrix for arterial intersections that NDOR can use to check the candidacy of intersections for conversion to single-or multi-lane roundabouts.

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Table of Contents

List of Figures

List of Tables

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Abstract

This research deals with two related issues: investigation and mitigation of roundabout elements that lead to driver confusion, and development of a flexible criteria matrix by which the Nebraska Department of Roads (NDOR) can evaluate arterial intersections to identify good candidates for conversion to roundabouts. The use of modern roundabouts along arterial roadways is relatively new in Nebraska. The first urban arterial roundabout was opened to traffic in June of 2002 at the intersection of 33rd and Sheridan Blvd in the City of Lincoln. Citizens and some professionals were somewhat skeptical of the capability of this roundabout to improve traffic delay and safety. However, after the construction of this roundabout the City of Lincoln has reported reduced traffic delays and the Nebraska Department of Roads (NDOR) has reported a reduction in traffic accidents. The objectives of the research include: (1) identification of user issues and confusing elements of roundabouts via surveys and development of mitigation measures for safer usage of arterial roundabouts in Nebraska; and (2) development of a criteria matrix for arterial intersections that NDOR can use to check the candidacy of intersections for conversion to single-or multi-lane roundabouts.

Executive Summary

Construction of modern roundabouts in place of traditional four-legged intersections is becoming common in the United States. Roundabout negotiation can be confusing for drivers who are not familiar with their use. This research was carried out to identify roundabout elements that play a role in incorrect roundabout negotiation, ascertain driver characteristics prominent in incorrect roundabout negotiation, assess the relative potential for incorrect negotiation amongst different groups of drivers, and suggest measures for improving drivers' abilities to negotiate roundabouts.

Potential for incorrect roundabout negotiation was measured by asking questions in a survey questionnaire related to rules of roundabout negotiation and the purpose of different roundabout elements. Incorrectly answered questions from the survey identified roundabout design elements that can potentially lead to incorrect roundabout use. Analyses tested seven hypotheses regarding driver characteristics leading to incorrect roundabout negotiation. Results showed six driver groups that had greater potential for incorrect roundabout negotiation:

- Unfamiliar roundabout users compared to familiar users (those drivers using roundabouts more than once per month).
- Passenger vehicle drivers compared to specialty vehicle drivers (police, bus, etc.).
- Drivers in cities without roundabouts compared to drivers in cities with roundabouts.
- Older drivers compared to younger drivers (ages less than 60 years).
- Drivers who dislike roundabouts compared to drivers that like roundabouts.
- Drivers that are not confident they can drive through a roundabout compared to drivers that are confident they can drive through a roundabout.

- Drivers that do not generally wear their seat belt when driving have a greater potential for incorrect roundabout negotiation compared to drivers that generally wear a seat belt.
- Drivers that generally do not avoid certain roadways and intersections because of traffic congestion have a greater potential for incorrect roundabout negotiation compared to drivers that generally avoid certain roadways and intersections because of traffic congestion.

Results also showed that drivers were concerned about the behavior of other drivers, emergency vehicle procedures, and wanted to receive information on roundabouts via driver's manual, brochures and on-site signage. Recommendations include provision of information on a priority basis to non-specialty vehicle drivers concerning roundabout elements, including truck apron purpose and use, turn signal use, and emergency vehicle procedures. The research team also recommends updating information on roundabouts contained in the Nebraska Driver's Manual.

Chapter 1 Introduction

1.1 Report Organization

This report consists of five chapters; this introductory chapter is followed by a chapter that provides a review of relevant literature on roundabouts. The third chapter presents details of a roundabout survey questionnaire developed as part of this research project and collected data, while the fourth chapter describes analysis of the collected data including testing of research hypotheses. The last chapter of this report presents research conclusions, recommendations, and identifies roundabout issues for future research.

1.2 Background

Consideration and construction of modern roundabouts in place of traditional four-legged intersections is increasing in the United States. Modern roundabouts in the United States have been adopted from Europe and Australia, where roundabout usage is more common. The modern roundabout is a circular intersection that requires entering drivers to yield to traffic in the circle and allows for continuous traffic flow through the intersection at speeds less than 30 mph (1). Roundabouts provide operational and safety benefits and their common use in transportation roadway design is recommended (2, 3, 4). Many drivers confuse modern roundabouts with rotaries and neighborhood traffic circles. While these three roadway design elements do have similarities, they have different operational and design characteristics as described below.

A rotary intersection is a precursor of the modern roundabout, as it is a circular intersection designed to move traffic more efficiently (more continuous flow of traffic) through an intersection than a more typical stop-controlled or signalized intersection. A rotary, much like a modern roundabout, has continuous traffic flow, creating little delay from stoppage. Rotary applications were limited due to the large diameter requirement, as large as 1,000 ft for design

speeds of 40 mph; and a limited capacity of no more than 3,000 vehicles per hour (vph) entering from all intersection legs (5). Rotaries operated according to the traditional "yield-to-the-right" rule where circulating traffic yielded to entering traffic. Rotaries were common in the United States prior to the 1960's but they did not operate effectively and had high crash rates so they fell out of use (1). Design guidelines for rotary intersections were removed from the American Association of State Highway and Transportation Officials (AASHTO) design guidebook in 1984 (6, 7).

Roadway designers use neighborhood traffic circles on local streets for traffic calming purposes. The diameters of these circles are typically smaller than modern roundabout diameters. The typical neighborhood traffic circle diameter is less than 25 ft, while a modern roundabout typically has a diameter of at least 45 ft and it can be as large as 200 ft (1). The approaches of a neighborhood traffic circle may be uncontrolled or stop-controlled and are usually unchannelized. Some neighborhood traffic circles allow direct left turn movements similar to an uncontrolled intersection (1).

Modern roundabouts differ from rotaries and neighborhood traffic circles in several design and operational features. In a roundabout, all traffic must yield on entry, approaches are channelized, and geometric curvature is designed for travel speeds that are typically less than 30 mph (1).

Figure 1.1 shows the general geometric layout of a modern roundabout (hereafter referred to simply as a roundabout). Splitter islands separate entering and exiting traffic and also deflect traffic to reduce entrance speeds. The splitter islands also provide a refuge point for pedestrians. Roundabouts have a central island with a truck apron (for small diameter roundabouts) to accommodate large vehicles negotiating the horizontal curvature of the roadway. A roundabout

can be designed at varying diameters (45 – 200 ft) to accommodate many individual project requirements, such as right-of-way (ROW) restraints, roadway widths, and roadway entry angles, among others. Roundabouts can accommodate any number of legs as long as all approach centerlines pass through the center of the inscribed circle and the angles between the legs are equally spaced (1). Pedestrian and bicycle traffic can be accommodated at roundabouts when necessary.

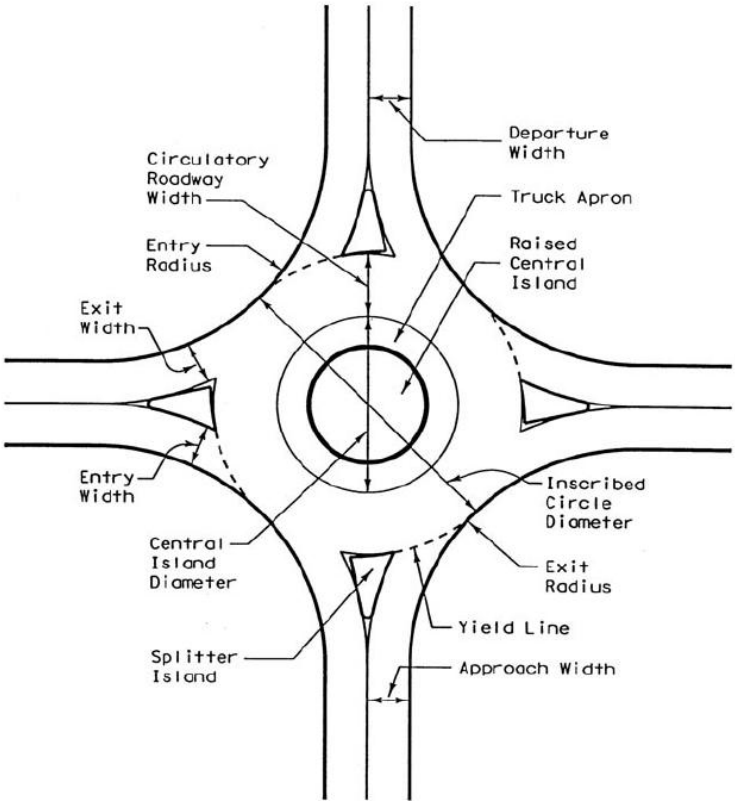


Figure 1.1 Key Roundabout Features (8)

The use of roundabouts in the United States is relatively new, beginning in the 1990s. Much research has documented the operation and safety aspects of their implementation. Further, research has shown that drivers are initially opposed to roundabout construction and frequently cite confusion of roundabout negotiation as a cause for this opposition. However, driver opposition and their confusion decrease after the construction of a roundabout (3, 4, 9).

Roundabouts have been constructed on Nebraska roadways starting with the first construction of a roundabout along a major urban arterial in 2002 at the intersection of 33rd Street and Sheridan Boulevard in Lincoln. A study conducted by Kirkham Michael (funded by the City of Lincoln) analyzed operational and safety characteristics at this roundabout (10) showing that crash rate and average intersection delay decreased when the intersection was converted to a roundabout from a traditional four-legged signalized intersection. Although delay and safety were improved, the Nebraska Department of Roads (NDOR) remains concerned about drivers' potential for incorrect roundabout negotiation.

1.3 Research Statement and Objectives

This research hypothesized that drivers' potential for incorrect roundabout negotiation depends on roundabout design elements and drivers' characteristics. Roundabout design elements that contribute to incorrect driver negotiation and driver characteristics influencing the potential for incorrect roundabout negotiation are unidentified in the literature. While it is reasonable to expect that different groups of drivers (e.g. drivers of specialty vehicles, passenger car drivers, etc.) will have different potentials for incorrect roundabout negotiation, such differences are unknown.

The main objective of this research was the identification of user issues and confusing elements of roundabouts via survey questionnaires and development of mitigation measures for

safer usage of arterial roundabouts in Nebraska. Specifically, the research was to identify roundabout elements that play a role in incorrect roundabout negotiation, ascertain driver characteristics prominent in incorrect roundabout negotiation, assess the relative potential for incorrect negotiation amongst different groups of drivers, and suggest measures for improving drivers' abilities to properly negotiate roundabouts. For this research, potential for incorrect roundabout negotiation was measured by asking drivers to illustrate their knowledge of proper roundabout negotiation procedures. Drivers who correctly answered more questions related to proper roundabout negotiation procedures were deemed to have less potential for incorrect negotiation.

1.4 Research Hypotheses

This research tested the following hypotheses to determine driver characteristics prominent in correct negotiation of roundabouts.

Hypothesis 1

Unfamiliar roundabout users have a greater potential for incorrect roundabout negotiation compared to drivers familiar with roundabouts. Roundabout users were deemed familiar if they used a roundabout at least once per month.

Hypothesis 2

Passenger vehicle drivers have a greater potential for incorrect roundabout negotiation compared to specialty vehicle drivers. For this research, specialty vehicles were defined as: ambulance, police vehicle, snowplow, municipal bus, school bus, large (semi) truck, fire ladder truck, and garbage/delivery vehicle.

Hypothesis 3

Drivers in Nebraska cities without roundabouts have a greater potential for incorrect roundabout negotiation compared to drivers in Nebraska cities with roundabouts.

Hypothesis 4

Older drivers (≥ 60 years) have a greater potential for incorrect roundabout negotiation compared to younger drivers.

Hypothesis 5

Drivers who make fewer daily trips have a greater potential for incorrect roundabout negotiation compared to drivers who make five or more daily trips.

Hypothesis 6

Drivers who dislike roundabouts have a greater potential for incorrect roundabout negotiation compared to those that approve of roundabout use.

Hypothesis 7

Drivers that do not feel confident they can drive through a roundabout in the correct manner have a greater potential for incorrect roundabout negotiation compared to those that feel confident they can drive through a roundabout in the correct manner.

Chapter 2 Literature Review

Topics covered in the literature review were: roundabout safety and operations, modeling of roundabouts, public opinions, public information, and driver confusion. In addition, a review of archived video of the opening of a roundabout at 33rd Street and Sheridan Boulevard in Lincoln, Nebraska was performed.

2.1 Roundabout Safety and Operations

Persaud et al. and Waddell and Albertson have analyzed the safety of roundabouts constructed throughout the country using before-and-after studies (2, 11). This research has shown safety improvements when converting two-way stop, four-way stop, and signalized controlled intersections to roundabouts. Crash rates have decreased, especially fatal crashes, at converted roundabout intersections. Persaud et al. showed a 40 % reduction in total crash rates, 80 % reduction in injury crash rates, and 90 % reduction in fatal crash rates for converted roundabout intersections (2). Most crashes on roundabouts are not usually associated with serious injuries (e.g. they are rear-end or sideswipe crashes).

Retting et al. analyzed operational aspects of roundabouts constructed throughout the country and showed that roundabouts reduce delay for converted intersections (3, 4). Roundabouts improve operations at problem intersections where other traffic control has failed (11, 12, 13). Transportation agencies are turning to roundabouts more often to solve delay problems that could not easily be solved by other traffic control measures.

Roundabouts improve corridor operations as well as single intersection operations (14). Use of roundabouts along a corridor can improve safety and operations by eliminating conflict points from left-turning movements at intersections and mid-block two-way left-turn lanes. Delay and travel time through a corridor can be improved by eliminating all left-turning

movements and having right-in, right-out operation at mid-block driveways. Drivers wishing to turn left mid-block can perform a U-turn at a roundabout intersection to get to their final destination (14). A summary of literature documenting the safety and operations research in roundabouts discussed in this literature review is shown in table 2.1.

Table 2.1 Roundabout Safety and Operations Literature Summary

Research Objective	Author	Methodology	Major Findings/Results
Determine crash rate changes after roundabout conversion	Persaud et al., 2001	Empirical Bayes crash data analysis	40% reduction for all crash severities 80% reduction for injury crashes 90% reduction for fatal injury crashes
Determine crash rate changes after 4 roundabout conversions along a business corridor	Ariniello et al., 2005	Before/after crash data analysis	Even with an increase in traffic, an 88% reduction in crashes (93% reduction in injury crashes) was experienced on the corridor
Evaluate impact of roundabout construction on traffic flow at three sites	Retting et al., 2002	Before/after traffic flow video data analysis using SIDRA	Vehicle stops reduced by 14, 34, and 37 % Traffic saturation reduced by 56, 62, and 59 %
Evaluate impact of roundabout construction on traffic flow at three sites	Retting et al., 2006	Before/after traffic flow video data analysis using SIDRA	Average intersection delays reduced by 83-93 % Congestion (v/c ratio used) reduced by 58-84 %
Evaluate delay of mini-roundabout vs. AWSC	Waddell et al., 2005	HCM delay models using RODEL-1	Delay reduced by 63% (measured in delay hours)
Determine travel time changes after 4 roundabout conversions along a business corridor	Ariniello et al., 2005	Before/after data analysis	Corridor travel time was reduced from 103 to 68 seconds Access point delay reduced from 28 to 13 seconds

2.2 Roundabout Modeling

Researchers have developed different modeling techniques for roundabout analysis since their use has become common in the US (13, 15, 16, 17, 18). For example, Kittelson &

Associates, Inc. have developed computer modeling software and regression models to predict crash rates and operational characteristics of roundabouts (13). Analysts can apply these models to evaluate proposed conversions to roundabouts. In addition to models, Chapman and Benekohal developed a set of four roundabout warrants (16). These warrants work much like the warrants for implementing a traffic signal and transportation officials can use them to justify roundabout construction. The four warrants include pedestrian volume, horizontal alignment, vertical alignment, and unbalanced flow. Table 2.2 presents a summary of literature documenting roundabout modeling techniques.

Table 2.2 Roundabout Model Development Literature Summary

Research Objective	Author	Analysis Tool	Major Findings/Results
Develop roundabout safety prediction models	Kittelson & Associates, Inc., 2006	Empirical Bayes method, regression analysis used to create a working table	Percent reduction in accidents for different conversion situations
Develop performance index for comparing delay at differing intersection types	Kennedy et al., 2005	Conflict opportunity software	The model accurately predicts crash rates for intersection conversion
Develop roundabout installation warrants	Chapman et al., 2002	Research review	Four warrants were identified: pedestrian volume, horizontal alignment, vertical alignment, and unbalanced flow
Develop roundabout operation prediction models	Kittelson & Associates, Inc., 2006	Calibrated regression analysis used to create a critical lane flow equation	Capacity models for analyzing roundabout operations and proposed LOS critical lane flow values
Investigate relationship between geometric design and speeds	Asma et al., 2006	Correlation analysis of multiple variables	85th percentile speed prediction models at approach, entry, circulating and exiting

2.3 Public Opinion, Involvement and Impact

Researchers have conducted studies on public opinion of roundabouts in the US (3, 4, 9, 19, 20). Many transportation agencies have experienced public resistance when implementing roundabouts. Public opinion polls of drivers in Hutchinson, Kansas; Harford County, Maryland; and Reno, Nevada (communities where roundabout construction was planned) show that more

than half of surveyed drivers (55%) were opposed to roundabout construction and were not aware of their operational characteristics (3). Drivers surveyed stated safety, confusion, or that they would rather have a traffic signal as the main reasons for opposing roundabouts both before and after construction (3). The reasons given for opposing roundabouts were the same before and after roundabout construction, but the overall proportion of drivers opposed to roundabouts decreased by 27% after roundabout construction (3). Other research has achieved similar results in driver opinion of roundabouts; table 2.3 summarizes these results.

Table 2.3 Public Opinion, Involvement, and Impact Literature Summary

Research Objective	Author	Methodology	Major Findings/Results
Identify if drivers are confused at roundabouts	Doucet, 2006	Paper survey	Alternate signage recommended, favorable public opinion of operations and safety
Measure public opinion before and after roundabout construction	Retting et al., 2002	Before/after telephone survey	– Before: 31% favor, 55% oppose – After: 63% favor, 28% oppose
Measure public opinion before and after roundabout construction	Retting et al., 2006	Before/after telephone survey	– Before: 36% support roundabout – After: 50% support roundabout
Measure long term public opinion in communities with roundabouts	Retting et al., 2007	Telephone survey	– Favor: before: 17%, 6-weeks after: 57%, 1-5 years after: 69% – Oppose: before: 54%, 6-weeks after: 32%, 1-5 years after: 24%
To gather input from residents regarding roundabout perceptions	ETC Institute, 2006	Mail Out/ Telephone Survey	62% of residents were satisfied while 15% were dissatisfied. Residents believe travel time is reduced and prefer roundabouts to other intersection types
Show improved roadway operations lead to economic growth for area business	Ariniello et al., 2005	Before/after economic data analysis	Economic growth was shown for the corridor that had roundabouts constructed and all area businesses supported their construction because of this growth
Review roundabout design process used in different local projects	Kliska et al., 2005	Project review	High public involvement and education in advance of roundabout construction leads to less opposition

Many of the studies conducted on roundabout opinion were in communities where roundabout construction was new. Therefore, many drivers were not familiar with roundabout operations, and the result that drivers opposed roundabouts before construction and supported them after was reasonable. Drivers surveyed in communities that had more exposure to roundabouts, for longer periods, were much more accepting of roundabouts and had favorable opinions of their construction (20). Public opinion improved over time as higher proportions of drivers were in favor of roundabouts one to five years after construction (9).

Roundabouts are effective in improving the economic vitality of a region by decreasing overall delay to allow customers better access to businesses (14). Businesses and community members may oppose roundabout construction because they feel that roundabouts will cause more congestion and safety problems affecting the economy of the region. Ariniello showed roundabouts constructed along a corridor of businesses decreased delay and travel times, which led to more economic growth for those businesses (14).

Roundabout projects with high levels of public involvement and education have led to successful roundabout construction. Involving the public reduces driver misconceptions and promotes joint gain for all parties, meaning that all parties can be satisfied with the outcome of the decisions made. Explaining the benefits of roundabouts to drivers will help them know why a roundabout is proposed (12). A summary of literature documenting public opinion, involvement and impact in roundabout construction discussed in this literature review is shown in table 2.3.

2.4 Roundabout Information Dissemination to the Public

Transportation agencies have employed different roundabout information dissemination techniques such as brochures and websites. Informing drivers on safety aspects of roundabouts, as well as proper driving techniques, help drivers understand the proposed construction of a

roundabout in their community and how they should drive when negotiating the roundabout. Other information distribution methods include public meetings and demonstrations. Researchers have shown that providing information to the public is vital to the acceptance of a roundabout project. More information given to drivers in as many ways as possible has resulted in better roundabout operations and greater acceptance by communities (12, 21, 22, 23). The proper information technique used for a certain project should be determined individually to best serve the needs of a community. For example, a special demonstration may be the best method for a retirement community that will be directly affected by roundabout construction (12).

The State of Nebraska has produced a brochure detailing the benefits and operational characteristics of roundabouts to use when opening roundabouts throughout the state (24). In addition, at the opening of the first arterial roundabout in the City of Lincoln, NE, officials used variable message signs on a temporary basis to help better inform drivers approaching the roundabout of the proper operating procedure.

2.5 Driver Confusion and Error

As transportation agencies construct roundabouts, they can expect issues at these intersections. Research in roadway design elements such as roundabouts that confuse drivers is sparse. Roundabouts have design elements that go against common rules-of-the-road operation that can lead to confusion and error for unfamiliar drivers. Traffic circulates in a counterclockwise direction, and drivers must yield to a vehicle to the left when at the approach waiting to enter the circular roadway. This activity goes against the common rule-of-the-road expectancy to yield to vehicles on the right when at an intersection. Figure 1.1 shows the geometric layout of a typical roundabout with the locations of the approaches and the circular roadway. In addition, drivers wanting to make a left turn will not take the most direct route to

attain their desired change of direction. Both of these elements go against common driver practice at intersecting roadways, and can lead to driver confusion or error. An unfamiliar driver approaching a roundabout can cause operational as well as safety problems.

Geometric features of roundabouts vary with the different applications of roundabouts. Research has recommended geometric features of roundabouts to fall within certain parameters, such as having four legs. However, agencies can design roundabouts to fit a particular application (1, 8, 25). Differences in the geometric design of roundabouts can lead to driver confusion and erroneous negotiation.

Retting et al. conducted three before-and-after telephone driver opinion studies reporting on driver confusion at roundabouts (3, 4, 9). Drivers cited confusion as a reason for opposing roundabouts more frequently after the construction of a roundabout in their community. Results of these studies showed increases of 6% (3) and 1% (4) directly after the construction of a roundabout, and a 7% (9) long-term increase in drivers that cited confusion for opposing roundabouts. The authors did not define driver confusion and only reported it as a response to why participants opposed roundabouts. A summary of this literature documenting how other researchers have described driver confusion at roundabouts discussed in this literature review is shown in table 2.4.

Table 2.4 Driver Confusion Literature Summary

Research Objective	Author	Driver Confusion Survey Results
Measure public opinion before and after roundabout construction	Retting et al., 2002	21% before and 27% after construction opposed roundabouts because of confusion
Measure public opinion before and after roundabout construction	Retting et al., 2006	20% before and 21% after construction opposed roundabouts because of confusion
Measure long term public opinion after roundabout construction at previously studied sites	Retting et al., 2007	28% of respondents cited confusion as reason for opposition 1 to 5 years after construction

2.6 Review of Roundabout Operations Video

In addition to the literature review, the research team conducted a review of operations at the 33rd Street and Sheridan Boulevard roundabout in Lincoln. A previous NDOR-funded study performed by the Mid-America Transportation Center (MATC) included video surveillance after opening of the roundabout to document operations, safety and driver conflicts (26). Video surveillance data used in that project was used in this review to document driver conflicts. Table 2.5 shows a summary of documented driver conflicts.

Table 2.5 Video Review Conflict Summary

Right-of-way conflicts	Vehicle on circular roadway yields to vehicle on approach
	Approaching vehicle does not yield to vehicle within the circular roadway
Vehicle-pedestrian conflicts	Pedestrian walks in the circular roadway instead of using the crosswalks
	Vehicle stops on the circular roadway instead of at the crosswalk stop bar to wait for pedestrians
Driver error conflicts	One vehicle turns wide to exit the roundabout while the next vehicle turns tightly causing the two vehicles to be side by side at the exit
	Vehicle stops on the circular roadway and backs up to turn onto the proper exit
	Tractor-trailer drives onto the central island past the truck apron since unprepared to drive the tight turns of the roundabout
Emergency vehicle procedure conflicts	Vehicle stops on the circular roadway to wait for an emergency vehicle approaching the roundabout instead of exiting the roundabout

Driver behaviors shown in table 2.5 represent the range of driver conflicts experienced at the 33rd Street and Sheridan Boulevard roundabout. Conflicts documented included right-of-way issues such as drivers within the circular roadway yielding to entering traffic and drivers on the approaches not yielding to those in the circular intersection. The video review showed vehicle-pedestrian conflicts as well, such as vehicles waiting for pedestrians on the roundabout instead of at the stop-bar locations. The conflicts documented do not represent every possible conflict but represent easily identifiable conflicts that can be related to incorrect roundabout negotiation as defined in this research. The research team performed a review of all driver conflict types of the time period from 5 to 6 PM on opening day compared with the same time period three months

later. Both dates were weekdays, with a nearby school not in session during the first date and in session during the second. Again, video from the previous MATC study was used for this analysis. The total number of driver conflicts was documented for each time period. There were six more driver conflicts on the opening date (seven over one hour) than approximately three months later (one over one hour). Table 2.6 presents a list of the observed conflicts. Although the cause of each conflict is not known, these conflicts represent incorrect roundabout negotiation as previously defined.

Table 2.6 Conflict Comparison

Date	Time	Conflict
6/2/2002	5:06	Approaching vehicle does not yield to vehicle within the circular roadway
	5:07	Vehicle on circular roadway yields to vehicle on approach
	5:11	Vehicle on circular roadway yields to vehicle on approach
	5:20	Vehicle on circular roadway yields to vehicle on approach
	5:31	Vehicle on circular roadway yields to vehicle on approach
	5:32	Vehicle on circular roadway yields to vehicle on approach
	5:48	Vehicle on circular roadway yields to vehicle on approach
8/28/2002	5:22	Vehicle on circular roadway yields to vehicle on approach

The research team also performed a review of crash data from this intersection. As stated earlier, the construction of a roundabout at the intersection of 33rd Street and Sheridan Boulevard has decreased crash frequencies (9). In a before-and-after study of the intersection,

police-reported crash frequency decreased from 33 to 6 (both 2.5-year periods). Of those six crashes reported in the time after the construction of the roundabout, two were reported in the first six months, three the following year, and one during the last year of the study. Figure 2.1 shows the general trend of the crashes reported at the 33rd Street and Sheridan Boulevard roundabout in Lincoln over the study period. In observing this trend, traffic volume changes and the impacts of other factors (e.g. weather, etc.) were not taken into account. Crashes reduced over the observed period even though traffic volume would be expected to increase, which would have resulted in a greater number of crashes, all else being equal. This is a simple comparison of frequencies with no statistical validity so it only serves as background information for this study.

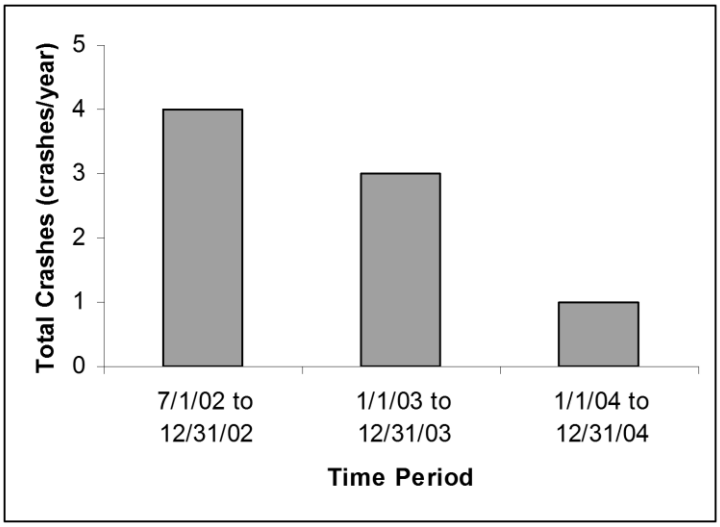


Figure 2.1 Total Crashes after the Construction of the 33rd and Sheridan Roundabout

2.7 Literature Review Summary

Researchers have analyzed many aspects of roundabouts. The appropriate construction of a roundabout intersection can improve the safety and operational characteristics of the intersection. For application to this research specifically, researchers have analyzed driver perception and opinion of roundabouts. While no literature documented in this review directly measured driver confusion or incorrect negotiation at roundabouts, researchers have found that drivers cite confusion as a reason for opposing roundabouts both before and after a roundabout is constructed in their community. Retting et al. showed that the percentage of drivers opposed to roundabouts due to confusion increased after roundabout construction. A review of operations at a Nebraska roundabout showed how driver conflicts can be attributed to incorrect roundabout negotiation as defined by this research.

Chapter 3 Survey Design

A comprehensive survey was designed to solicit information on drivers' knowledge of roundabout negotiation along with their characteristics. Survey design criteria included clarity, appropriateness of content, and proper length. Input from NDOR on the survey questionnaire was incorporated and a pilot survey was conducted to ensure the survey was appropriate. The University of Nebraska-Lincoln Institutional Review Board (IRB) reviewed and approved the final survey questionnaire for distribution to human subjects after the survey questionnaire met University policy. A discussion of the designed survey follows.

3.1Survey Questionnaire

The survey questionnaire is shown in appendix A. There were four sections of the survey questionnaire: roundabout information, attitude and opinion, roundabout operations, and general information. In addition to the four sections, there was a one-page consent form to inform survey participants about the research and their part in the study. This consent form was one of the requirements of the IRB process and serves as part of the introduction to the survey for the respondents. There is also background information about the study on the first page with directions on completing the questionnaire.

The first section of the survey questionnaire (section A) is a roundabout information section. This section asks for information on drivers' experience with roundabouts. The first two questions ask respondents how frequently they drive through a roundabout. The next several questions ask respondents how they get information about roundabouts and what information technique would be the best way to inform drivers. This section also includes a question to determine if the respondent drives a specialty vehicle (ambulance, police vehicle, snowplow, etc.). This section concludes with several questions about the drivers' experience with variable

message signs at roundabouts and if they feel that variable message signs would be a valuable information technique at newly constructed roundabouts.

The second section of the survey questionnaire is an attitude and opinion section (section B). Respondents provide a level of agreement or disagreement with a series of statements. This section is included to determine the opinion of respondents toward different aspects of roundabouts, such as safety and delay. There are also several questions just for specialty vehicle drivers about specific design elements of roundabouts, such as turning needs of specialty vehicles.

The third section of the survey questionnaire is about roundabout operations (section C). This section asks questions regarding the act of negotiating a roundabout. Questions in this section assess the survey participants' knowledge of correctly negotiating a roundabout. Many of the questions of this section have correct and incorrect answers. The content covered in this section includes proper negotiation techniques, such as right-of-way, turn signal use, and emergency vehicle procedures.

The last section of the survey questionnaire is a general information section (section D). This section solicits driver characteristics from survey participants, such as age, gender, and city of residence. In addition, questions seeking information, such as number of daily trips, commute time, and typical driving speed, are included in this section.

3.2 Survey Questionnaire Data Analysis Use

Questions from section A (Roundabout Information) were intended to define the four survey respondent types: familiar and unfamiliar roundabout users, as well as specialty vehicle and passenger vehicle drivers. Familiar users were defined as respondents that indicated driving through a roundabout once or more per month (questions A1 or A2). All other respondents were

considered unfamiliar users of roundabouts. Response to Question A5 was used to classify drivers as specialty vehicle drivers or passenger vehicle drivers.

Responses to section B provided data for analysis of drivers' opinion toward roundabouts. The research used nine questions from section C to assess the survey respondent's knowledge of correctly negotiating a roundabout. More correct responses to these questions were deemed to indicate a higher level of roundabout knowledge. These questions are shown in table 3.1 and can be seen in full, along with the correct answers, within the survey questionnaire shown in appendix A.

Table 3.1 Questions that Assess Knowledge of Roundabout Negotiation

C2	If vehicles A and B arrive at their current positions at the same time, which vehicle should yield?
C4	If you are trying to get from point A to point B through a roundabout intersection, which image represents the appropriate behavior?
C5	While driving through a roundabout, if you miss the exit you wanted, what should you do?
C6	Should you use your turn signal while waiting at the yield line of a roundabout?
C7	Should you use your right turn signal when exiting the roundabout?
C8	If you are waiting at the yield line of a roundabout and an emergency vehicle arrives at one of the other approaches, what should you do?
C9	If you are driving in a roundabout when an emergency vehicle approaches, what should you do?
C10	Where should vehicles wait for pedestrian and bicycle traffic when encountered?
C11	What is the purpose of the ring-shaped paved area of a roundabout which is shown in the figure and image?

The analysis used driver characteristics that can define different driver groups, such as age or community, to test the hypotheses of this research. Responses to section D provided information on driver characteristics.

3.3 Survey Distribution Sites

Five cities with different population and roadway characteristics were selected for distribution of the survey questionnaire. Selection criteria included assurance of capturing the four driver populations (familiar and unfamiliar drivers, as well as specialty and passenger vehicle drivers), presence and absence of roundabouts, and proximity to the City of Lincoln, from where the research was being conducted.

The selected five cities were Lincoln, Omaha, Blair, Norfolk, and Plattsmouth. Lincoln, Omaha, Blair, and Norfolk currently have roundabouts while Plattsmouth does not. Using four cities that have roundabouts ensured the survey will solicit enough familiar drivers. Most survey participants in Plattsmouth probably would be unfamiliar drivers since there is no roundabout in that city. However, drivers in cities that do have roundabouts are not necessarily familiar drivers since some drivers may not be using roundabouts more than once per month (the definition of familiar drivers in this research was those using a roundabout more than once per month). Therefore, these drivers, although in cities with roundabouts, would still be unfamiliar roundabout users.

Chapter 4 Data Collection

4.1 Survey Distribution Methodology

Surveys were distributed at major activity centers in the five selected cities. Printed survey questionnaires were given to a person at the activity center who then distributed them to respondents. The same person received completed questionnaires from respondents and returned them to the research team. For example, the research team coordinated with the principal of Skutt Catholic High School in Omaha to have the surveys distributed to students at the school. The team left surveys with the principal and returned several weeks later to collect the completed survey questionnaires.

A total of 2,500 surveys were distributed in the five cities. Of the 500 surveys designated for each city, 100 targeted specialty vehicle drivers while the remainder targeted passenger vehicle drivers. Surveys for specialty vehicle drivers were distributed at police stations, firehouses, school transportation services, city transportation offices, trucking agencies, and other activity centers to ensure drivers of specialty vehicles would respond to the survey. Surveys for passenger vehicle drivers were distributed at different public activity centers. Bias in survey distribution cannot be completely eliminated, but distribution at public activity centers such as banks, doctors' offices, hair salons, local businesses, community centers, and retail stores helped to minimize it.

4.2 Survey Distribution

The survey distribution and collection effort occurred over a two-month period starting with distribution in the City of Plattsmouth. The research team distributed the first set of surveys on March 12th, 2007. Table 4.1 shows activity centers where surveys were distributed, as well as the number of surveys distributed and collected at each activity center.

Table 4.1 Plattsmouth Survey Distribution Activity Centers

Name	Location	Distributed		Collected	
		#	Date 2007	#	Date 2007
Specialty Vehicle Drivers					
Plattsmouth Police Department	4th & Main	30	12-Mar	6	6-Apr
Plattsmouth Volunteer Fire Dept.	5th & Ave A	15	Unable to Participate		
Plattsmouth Street Dept.	444 N 13th St	15	12-Mar	6	20-Mar
Schmidt Transportation	108 E Bay Rd	15	12-Mar	0	6-Apr
Kerns Excavating Co.	2507 Smith Av	10	12-Mar	9	23-Mar
Plattsmouth School Admin.	1912 E Hwy 34	15	12-Mar	7	20-Mar
Other Drivers					
McKnight Family Dental	Hwy 34 & 8th Ave	70	12-Mar	48	6-Apr
Plattsmouth High School	1916 Hwy 34	80	13-Mar	24	23-Mar
Plattsmouth State Bank	5th & Main	50	12-Mar	16	20-Mar
Community Rehab	Hwy 34 & 8th Ave	70	12-Mar	16	20-Mar
Headquarters for Hair	3rd & Main	70	12-Mar	24	20-Mar
Shear Design	Hwy 34 & 8th Ave	50	12-Mar	2	23-Mar
Plattsmouth Animal Hospital	Hwy 34 & 8th Ave	10	20-Mar	9	23-Mar

The large number of uncollected surveys in Plattsmouth led the research team to diversify survey distribution centers in other cities. For example, surveys were distributed over several days in Lincoln. Table 4.2 shows a list of the activity centers where surveys were distributed, as well as the number of surveys collected in Lincoln. Activity centers used for survey distribution in Omaha, Blair, and Norfolk are shown in tables 4.3, 4.4, and 4.5, respectively.

Table 4.2 Lincoln Survey Distribution Activity Centers

Name	Location	Distributed		Collected	
		#	Date 2007	#	Date 2007
Specialty Vehicle Drivers					
Lincoln Fire & Rescue	18th & Q	25	29-Mar	24	5-Apr
Lincoln Police Department	10th & J	20	2-Apr	16	9-Apr
StarTran	7th & J	20	30-Mar	11	9-Apr
Street Operations	901 N 6th	15	2-Apr	15	13-Apr
LPS - Transportation Services	52nd & O	15	3-May	0	
Crete Carrier Corporation	NW 56th & O	15	2-Apr	5	13-Apr
Other Drivers					
Lincoln Southeast High school	2930 South 37th	85	3-May	65	16-May
Rousseau Elementary School	3701 S 33rd St	25	3-May	14	14-May
Lincoln Council on Alcohol	9th & L	30	2-Apr	24	19-Apr
Encompass Architects	7th & O	10	2-Apr	5	19-Apr
University Health Center	15th & U	20	2-Apr	15	17-Apr
Clark Enersen Partners	11th & J	20	2-Apr	5	14-May
Catholic Family Life	37th & Sheridan	30	30-Mar	11	13-Apr
Calvert Street Professional Center	36th & Calvert	37	30-Mar	6	13-Apr
Calvert Senior Center	4500 Stockwell St	25	30-Mar	1	19-Apr
Cathedral of Risen Christ School	37th & Sheridan	25	30-Mar	8	13-Apr
33rd & Sheridan Center	33rd & Sheridan	25	30-Mar	12	13-Apr
33rd & Pioneers Center	33rd & Pioneers	28	30-Mar	5	13-Apr
Gauntlet Games	13th & High	30	30-Mar	4	13-Apr

Table 4.3 Omaha Survey Distribution Activity Centers

Name	Location	Distributed		Collected	
		#	Date 2007	#	Date 2007
Specialty Vehicle Drivers					
Omaha Police Department	505 S 15th St	25	Unable to Participate		
Omaha Fire Headquarters	1516 Jackson St	20	9-Apr	19	30-Apr
Omaha Street Maintenance	5225 Dayton St.	20	9-Apr	19	30-Apr
Metro Area Transit	2222 Cuming Street	15	9-Apr	15	30-Apr
Laidlaw Transit Inc.	14001 L St	20	30-Apr	5	14-May
Other Drivers					
Gordmans Retail Store	120th & Center	100	6-Apr	95	7-May
Fiserv Financial Services	132nd & Q	30	8-Apr	19	30-Apr
Dr. Elvira Rios' Office	1 Lakeside Hills Bldg	10	9-Apr	3	30-Apr
Alegent Physical Therapy	1 Lakeside Hills Bldg	10	9-Apr	0	30-Apr
NP Dodge Realtors	Lakeside Drive	30	9-Apr	15	30-Apr
Bangs Hair Salon	Lakeside Hills Plz	30	9-Apr	0	30-Apr
Hair By Tami	Lakeside Hills Plz	30	9-Apr	1	30-Apr
Avant Salon & Day Spa	Lakeside Hills Plz	30	9-Apr	6	30-Apr
Immanuel Lakeside Village	Lakeside Hills	50	9-Apr	8	30-Apr
Skutt Catholic High School	156th & Center	80	30-Apr	49	14-May

Table 4.4 Blair Survey Distribution Activity Centers

Name	Location	Distributed		Collected	
		#	Date 2007	#	Date 2007
Specialty Vehicle Drivers					
Blair Community Schools	440 N 10th	15	25-Apr	4	22-May
Blair Police Department	17th & Lincoln	25	20-Apr	12	8-May
Blair Volunteer Fire Department	16th & Lincoln	25	20-Apr	17	17-May
Street Department	3rd & Grant	10	20-Apr	6	8-May
STS Trucking	270 E Grant	40	20-Apr	15	8-May
Other Drivers					
Washington County Bank	16th & Lincoln	25	20-Apr	8	8-May
City Hall	16th & Lincoln	5	20-Apr	4	8-May
Blair High School Students	440 N 10th St	60	25-Apr	54	8-May
Blair High School Teachers	440 N 10th St	25	25-Apr	24	17-May
Heartland Family Dentistry	261 S 19th St	25	20-Apr	4	8-May
Hair Designs Unlimited	662 S 19th St	30	20-Apr	0	8-May
Alegent Health Immanuel Clinic	718 S 19th St	25	20-Apr	4	8-May
Blair Dental Clinic	17th & Lincoln	25	20-Apr	8	8-May
Jim & Connie's Blair Bakery	17th & Lincoln	25	20-Apr	0	8-May
Woodhouse Ford	At Roundabout	35	20-Apr	1	8-May
Washington County Courthouse	15th & Colfax	30	20-Apr	25	8-May
Enterprise Publishing	16th & Front	25	20-Apr	7	8-May
DL Blair Corporation	16th & Front	25	20-Apr	14	8-May
Post Office	16th & Front	25	20-Apr	4	8-May

Table 4.5 Norfolk Survey Distribution Activity Centers

Name	**Location**	**Distributed**		**Collected**	
		#	**Date 2007**	**#**	**Date 2007**
Specialty Vehicle Drivers					
Affiliated Foods	13th & Omaha	20	7-May	4	17-May
Norfolk Fire Division	7th & Koenigstein	25	7-May	3	17-May
Norfolk Police	7th & Koenigstein	20	7-May	15	17-May
Norfolk Street Division	10th & Michigan	15	7-May	14	17-May
Norfolk Schools Transportation	Blaine & Nwestern	20	7-May	**7**	17-May
Other Drivers					
St. Joseph Rehabilitation Center	18th & Prospect	25	7-May	6	17-May
Crafts Incorporated	2602 S 13th St	15	7-May	**7**	17-May
Family Dental/Floral Expressions	13th & Taylor	15	7-May	4	17-May
Charles Sintek DDS	13th & Nebraska	10	7-May	3	17-May
Square Turn Professional Plaza	1502 N 13th	17	7-May	3	17-May
Northstar Services	7th & Nebraska	25	7-May	16	17-May
Norfolk HHS	6th & Koenigstein	25	7-May	23	17-May
Orthodontists	5th & Nebraska	25	7-May	5	17-May
JEO Engineering	8th & Norfolk	25	7-May	10	17-May
The Daily News	6th & Norfolk	30	7-May	10	17-May
Workforce Development	1st & Norfolk	15	7-May	8	17-May
Norfolk Senior Center	3rd & Prospect	30	7-May	27	17-May
Norfolk Public Library	3rd & Prospect	25	7-May	17	17-May
VFW	3rd& Braasch	25	7-May	0	17-May
Norfolk Senior High	801 Riverside Blvd	85	23-Apr	78	17-May
State Farm Insurance	902 Riverside Blvd	8	7-May	5	17-May

Activity centers in each city provided a diverse group of respondents for the survey. With any self-completion survey, return rates vary with the type of application. Self-completion surveys are expected to have return rates between five and twenty percent when participants are asked to return surveys by mail (27). By delivering and collecting surveys by hand to the activity centers, the research team hoped to achieve a 20% return rate. However, an overall return rate of

45.7% was achieved, which exceeded the team's expectations. Table 4.6 details the return rate for different driver groups within each survey city as well as the overall return rate.

As can be seen in the table, the first distribution city, Plattsmouth, had a lower return rate than the other cities. The return rate of 33.4% for the Plattsmouth site was still higher than the expected return rate of 20%. Norfolk, the final distribution site, achieved the highest return rate with an overall return rate of 53.0%. The research team attributes the increased return rate at the later distribution cities to the diversification of activity centers solicited after the high number of unreturned surveys during the Plattsmouth distribution.

Table 4.6 Return Rate for Survey Distribution Cities

Site	**All Driver Types**			**Specialty Vehicle Drivers**			**Passenger Vehicle Drivers**		
	Distributed	Collected	Return Rate %	Distributed	Collected	Return Rate %	Distributed	Collected	Return Rate %
Plattsmouth	500	167	33.4	100	28	28.0	400	139	34.8
Lincoln	500	246	49.2	110	71	64.5	390	175	44.9
Omaha	500	254	50.8	100	58	58.0	400	196	49.0
Blair	500	211	42.2	115	54	47.0	385	157	40.8
Norfolk	500	265	53.0	100	43	43.0	400	222	55.5
Total	**2500**	**1143**	**45.7**	**525**	**250**	**47.6**	**1975**	**889**	**45.0**

4.3 Data Reduction

Data from collected surveys was recorded in Microsoft Excel software using the coding scheme shown in appendix B. As can be expected with any self-completion survey, some respondents returned the survey incomplete or filled out incorrectly. Survey respondents were allowed to skip any question they were not comfortable answering. The research team recorded surveys that had unanswered questions or incorrectly filled out questions, but marked them for further review. Upon review of the full data set, twenty surveys were judged to be severely erroneous or incomplete and were subsequently discarded. Appendix B provides details of the discarded surveys and the reasons for discarding them. The final sample size was 1,116.

Chapter 5 Data Analysis

5.1 Data Analysis Methodology

The research team used cross tabulation analyses to individually test the seven hypotheses, t-tests to test the total correct answers against the seven hypotheses, and estimated an ordinal regression model to determine driver characteristics prominent in incorrect roundabout negotiation. Additionally, the research team looked at roundabout elements that were of concern to drivers and informational techniques that would help with negotiating roundabouts. Table 5.1 summarizes the variables used in this analysis while appendix B provides more detailed definitions.

Table 5.1 Variables Used in Analyses

Variable	Variable Name	Definition	Coding Definition
familiar	Driver familiarity	Defines if respondent is a familiar or unfamiliar roundabout user	0 if unfamiliar roundabout user, 1 if familiar
site	Respondent site response	Defines what community respondent marked	1 if Lincoln, 2 if Omaha, 3 if Norfolk, 4 if Plattsmouth, 5 if Blair, 6 if Other
drvr.type	Driver type	Defines if respondent is a specialty vehicle or passenger vehicle driver	0 if passenger vehicle driver, 1 if specialty vehicle driver
dislike	Driver opinion	Defines if respondent likes roundabouts or not	0 if strongly like, like, or are indifferent to roundabouts, 1 if strongly dislike or dislike roundabouts
high.trips	Number of daily trips	Defines if respondent makes a high number of daily trips	0 if respondent makes fewer than 5 daily trips, 1 if 5 or more daily trips
older	Older driver	Defines if respondent is an older driver	0 if respondent is under 60, 1 if 60 or older

Table 5.1 Variables Used in Analyses (cont.)

Variable	Variable Name	Definition	Coding Definition
can.drv	Confidence in negotiation	Defines if respondent is confident they can negotiate a roundabout	0 if not confident, 1 if confident
tot.ans	Total correct answers	The sum of the 9 roundabout knowledge assessment question responses	Represents the total number of correct responses to questions C2, C4, C5, C6, C7, C8, C9, C10, C11
platts	City with roundabout or not	Defines if respondent is from a city with a roundabout or not	0 if from a city with roundabouts, 1 if not
grpd.ans	Grouping of correct answers	Groups total correct answers of respondents into four categories	0 if 0-3, 1 if 4-5, 2 if 6-7, 3 if 8-9 correct answers
gender	Gender	Defines respondent gender	0 if female, 1 if male
commute	Commute time	The time in minutes of respondents commute time	Scale values
drv.spd	Typical driving speed	Respondents typical driving speed	1 if more than 5 mph below posted, 2 if 5 mph below to posted, 3 if at posted, 4 if posted to 5 mph above, 5 if more than 5 mph above posted
hv.pssngr	Driver has passengers	Defines if respondent typically has passengers	0 if does not typically have passengers, 1 if does
seat.belt	Driver wears seatbelt	Defines if respondent typically wears seatbelt	0 if does not typically wear seatbelt, 1 if does
avd.sfty	Avoids due to safety	Defines if respondent avoids roadways because of safety	0 if does not avoid due to safety, 1 if does
avd.cong	Avoids due to congestion	Defines if respondent avoids roadways because of congestion	0 if does not avoid due to congestion, 1 if does

Cross tabulation compares two variables that have a limited number of distinct values (e.g. the integers 0 through 5), and produces a table that divides the distribution of one of the variable's outcomes according to the distribution of the other variable's outcomes. Each cell in

this table represents the frequency of the combination of those outcomes. In addition, cross tabulation analysis can measure the relationship between the variables. A chi-square test can measure the discrepancy between the observed cell counts and what would be expected if the rows and columns of the cross tabulation were unrelated. The chi-squared test compares two attributes in a sample of data to determine if there is any relationship between them. The test shows the level of difference between the observed distributions of outcomes and the expected equally distributed outcomes. The test assumes the samples to be independent, have the same distribution, and have mutually exclusive event outcomes.

The chi-squared test statistic is calculated by finding the difference between each observed and theoretical frequency for each outcome, squaring them, dividing each by the theoretical frequency, and taking the sum of the results (28):

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \qquad 5.1$$

where,

O_i = observed frequency;

E_i = expected frequency (all outcomes equally distributed).

The output of the chi-squared test reports the significance value of the chi-squared statistic compared with the expected chi-squared test value from the chi-squared distribution. If this significance value is below a threshold of acceptable statistical significance, the test proves that the rows and columns (variable outcomes) of the cross tabulation table are related.

For this research, a significance threshold of 0.05 was used, meaning that a 95% confidence level was used for the statistical analysis. A 95% level of confidence implies that if independent samples are taken repeatedly from the same population, then 95% of the intervals

will include the unknown population parameter. Higher confidence levels give more confidence that the results are correct (28).

The researchers used t-tests to test the total correct answers against the seven hypotheses. A t-test was used to examine a hypothesis such as two means being equal, or a mean being statistically equal to some value (typically zero). This test assumes observations are independent and a random sample without outliers from a normal distribution. The data collected in this research met these assumptions. The equation used to calculate the test statistic for a t-test is (28):

$$t' = \frac{(\bar{x}-\bar{y})}{\sqrt{\left(s_1^2/m\right)-\left(s_2^2/n\right)}} \qquad 5.2$$

where,

$\bar{x}$ and $\bar{y}$ are the means being tested,

s_1^2 and s_2^2 represent the variances, and

m and n represent the sample sizes pertaining to the two means.

The test statistic is compared to a standard value based on a user-defined confidence level (a confidence level of 95% was used). The test statistic is used to determine if a null hypothesis regarding equality of two sample means should be rejected. If the test rejects the null hypothesis, it implies that the two sample means are statistically different from one another. For a 95% confidence level, the absolute value of the test statistic must be greater than 1.96.

An ordinal regression model was estimated to identify driver characteristics prominent in incorrect roundabout negotiation. Typical linear regression does not work when the dependent variable is measured on the ordinal scale. A variable measured on the ordinal scale has values that are ordered (e.g. levels of patient discomfort during a hospital stay or student grades). The

only information available is that one category is greater than another; the real difference between the categories is unknown. The ordinal regression model works by grouping results into an order with cutoff points (thresholds) that can be defined by an estimated or user-inputted distribution, with no regard to the results fitting any predefined distribution such as the normal distribution. The regression model is (29):

$$link(y_{ij}) = \theta_j - [\beta_1 x_{i1} + \beta_2 x_{i2} + \cdots + \beta_p x_{iJ}] \quad 5.3$$

where,

$link(y_{ij})$ is the link function that is user defined,

θ_j is the threshold constant,

β_j are the prediction coefficients, and

x_{ij} are parameters (independent variable).

The distribution of outcomes that are being predicted dictate what function should be used for the link function. When modeling, multiple link functions can be analyzed to determine the most appropriate function. The appropriateness of the model and goodness of fit is measured using a chi-squared test as defined previously in the methodology section. The assumption of this model is that the relationship between the ordinal outcome (dependent variable) and the explanatory variables (independent variables) is independent of the categories (cutoff points). This assumption implies that the corresponding regression coefficients are equal for each cut-off point.

5.2 Results of Questions Assessing Knowledge of Roundabout Negotiation

The overall results for the nine questions that assess knowledge of correct roundabout negotiation are shown in table 5.2 and figure 5.1. The full question, choices, and correct answers

(marked) for each of these nine questions are shown in appendix A (the survey questionnaire). Less than 10% of respondents incorrectly answered questions C2, C4, and C5, while more than 85% of respondents incorrectly answered questions C6 and C11. Many respondents understood the basic ideas of the direction of travel around a roundabout and right-of-way at entry points. Many respondents did not know the purpose of the center truck apron as well as proper turn-signal use. The following sections will discuss driver characteristics prominent in incorrectly answering these questions.

Table 5.2 Responses to Questions Assessing Knowledge of Correct Negotiation

Question	Incorrect Responses	Correct Responses	Percent Incorrect (%)
C2: Which vehicle should yield?	97	1019	8.7
C4. Which is the correct left turn?	47	1069	4.2
C5. What to do if missed exit?	76	1040	6.8
C6. Use turn signal when entering?	958	158	85.8
C7. Use turn signal when exiting?	353	763	31.6
C8. What to do if emergency vehicle (at yield line)?	155	961	13.9
C9. What to do if emergency vehicle (in roundabout)?	572	544	51.3
C10. Where to wait for pedestrians?	334	782	29.9
C11. What is the truck apron?	980	136	87.8

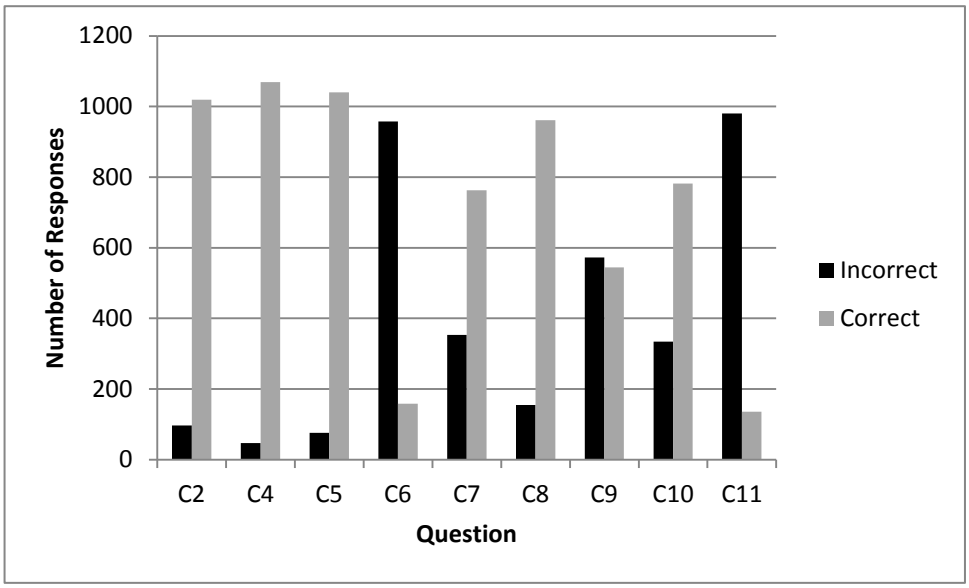


Figure 5.1 Responses to Questions Assessing Knowledge of Roundabout Negotiation

5.3 Cross Tabulation of Individual Questions Results

The research team conducted a cross tabulation analysis for questions that assessed knowledge of correct roundabout negotiation resulting in a total of 63 cross tabulations (nine questions for seven hypotheses). The variables used in this analysis are defined in table 5.3 and are detailed in appendix B. Appendix C provides the cross tabulation table, as well as the chi-squared test results for each of these analyses. Table 5.3 summarizes the results of these tests including the chi-squared test value significance. The table highlights those values that are below 0.05 since they are significant chi-squared values. The following sections will discuss each significant value from this table.

Table 5.3 Chi-Squared Significance Values from Cross Tabulation Analyses

	Chi-Squared Statistic Significance for Each Question								
	C2	C4	C5	C6	C7	C8	C9	C10	C11
Hypothesis 1	0.000	0.048	0.198	0.442	0.000	0.090	0.000	0.000	0.000
Hypothesis 2	0.473	0.793	0.341	0.228	0.000	0.052	0.070	0.147	0.000
Hypothesis 3	0.000	0.017	0.194	0.030	0.000	0.101	0.000	0.000	0.000
Hypothesis 4	0.000	0.000	0.064	0.464	0.190	0.619	0.204	0.008	0.556
Hypothesis 5	0.570	0.210	0.654	0.363	0.085	0.205	0.319	0.419	0.118
Hypothesis 6	0.003	0.271	0.001	0.028	0.001	0.986	0.507	0.004	0.008
Hypothesis 7	0.000	0.000	0.000	0.292	0.003	0.000	0.000	0.000	0.011

Hypothesis 1: Unfamiliar roundabout users have a greater potential for incorrect roundabout negotiation compared to drivers familiar with roundabouts.

The research team tested this hypothesis for each of the nine questions assessing knowledge of correct roundabout negotiation. Each cross tabulation analysis involved the variable “familiar” as defined in table 5.1. Table 5.3 summarizes the results of the cross tabulations and appendix C shows the full analyses. These analyses resulted in six significant cross tabulation chi-squared values. Question C2, C4, C7, C9, C10, and C11 had significant chi-square test statistic values. Table 5.4 summarizes the frequency of incorrect and correct answers for each of these questions based on driver familiarity. As can be seen in this table, frequencies of incorrect answers by unfamiliar drivers are higher (compared to familiar drivers) for questions C2, C4, C9, C10 and C11. The frequency of incorrect answers by familiar drivers is higher

(compared to unfamiliar drivers) only for question C7. Appendix D presents a graphical representation of the results shown in table 5.4.

Table 5.4 Frequency of Responses for Hypothesis 1

	Incorrect	**Correct**	**Total**	**% Incorrect**
Question C2. Which vehicle should yield?				
Unfamiliar	50	302	352	14.2%
Familiar	47	717	764	6.2%
Question C4. Which is the correct left turn?				
Unfamiliar	21	331	352	6.0%
Familiar	26	738	764	3.4%
Question C7. Use turn signal when exiting?				
Unfamiliar	81	271	352	23.0%
Familiar	272	492	764	35.6%
Question C9. What to do if emergency vehicle (in roundabout)?				
Unfamiliar	262	90	352	74.4%
Familiar	310	454	764	40.6%
Question C10. Where to wait for pedestrians?				
Unfamiliar	142	210	352	40.3%
Familiar	192	572	764	25.1%
Question C11. What is the truck apron?				
Unfamiliar	327	25	352	92.9%
Familiar	653	111	764	85.5%

Hypothesis 2: Passenger vehicle drivers have a greater potential for incorrect roundabout negotiation compared to specialty vehicle drivers.

The research team tested this hypothesis for each of the nine questions assessing knowledge of correct roundabout negotiation. Each cross tabulation analysis involved the variable “drvr.type” as defined in table 5.1. Table 5.3 summarizes the results of the cross tabulations and appendix C shows the full analyses. These analyses resulted in two significant

cross tabulation chi-squared values. Question C7 and C11 had significant chi-square test statistic values. Table 5.5 summarizes the frequency of incorrect and correct answers for each of these questions based on driver familiarity. The frequencies of incorrect answers by passenger vehicle drivers are higher for questions C7 and C11. Appendix D presents a graphical representation of the results shown in table 5.5.

Table 5.5 Frequency of Responses for Hypothesis 2

	Incorrect	**Correct**	**Total**	**% Incorrect**
Question C7. Use turn signal when exiting?				
Passenger Vehicle Driver	302	559	861	35.1%
Specialty Vehicle Driver	51	204	255	20.0%
Question C11. What is the truck apron?				
Passenger Vehicle Driver	774	87	861	89.9%
Specialty Vehicle Driver	206	49	255	80.8%

Hypothesis 3: Drivers in Nebraska cities without roundabouts have a greater potential for incorrect roundabout negotiation compared to drivers in Nebraska cities with roundabouts.

The research team tested this hypothesis for each of the nine questions assessing knowledge of correct roundabout negotiation. Each cross tabulation analysis involved the variable "site" as defined in table 5.1. Table 5.3 summarizes the results of the cross tabulations and appendix C shows the full analyses. These analyses resulted in seven significant cross tabulation chi-squared values. Question C2, C4, C6, C7, C9, C10 and C11 had significant chi-square test statistic values. Table 5.6 summarizes the frequency of incorrect and correct answers

for each of these questions based on community. Appendix D presents a graphical representation of the results shown in table 5.6.

Table 5.6 Frequency of Responses for Hypothesis 3

	Incorrect	Correct	Total	% Incorrect
Question C2. Which vehicle should yield?				
Lincoln	12	220	232	5.2%
Omaha	23	214	237	9.7%
Norfolk	15	229	244	6.1%
Plattsmouth	25	108	133	18.8%
Blair	10	162	172	5.8%
Other	10	81	91	11.0%
Question C6. Use turn signal when entering?				
Lincoln	210	22	232	90.5%
Omaha	208	29	237	87.8%
Norfolk	198	46	244	81.1%
Plattsmouth	109	24	133	82.0%
Blair	152	20	172	88.4%
Other	76	15	91	83.5%
Question C9. What to do - emergency vehicle (in roundabout)?				
Lincoln	85	147	232	36.6%
Omaha	147	90	237	62.0%
Norfolk	68	176	244	27.9%
Plattsmouth	108	25	133	81.2%
Blair	103	69	172	59.9%
Other	56	35	91	61.5%
Question C11. What is the truck apron?				
Lincoln	191	41	232	82.3%
Omaha	225	12	237	94.9%
Norfolk	203	41	244	83.2%
Plattsmouth	128	5	133	96.2%
Blair	149	23	172	86.6%
Other	77	14	91	84.6%

	Incorrect	Correct	Total	% Incorrect
Question C4. Which is the correct left turn?				
Lincoln	8	224	232	3.4%
Omaha	6	231	237	2.5%
Norfolk	8	236	244	3.3%
Plattsmouth	12	121	133	9.0%
Blair	5	167	172	2.9%
Other	7	84	91	7.7%
Question C7. Use turn signal when exiting?				
Lincoln	69	163	232	29.7%
Omaha	60	177	237	25.3%
Norfolk	93	151	244	38.1%
Plattsmouth	30	103	133	22.6%
Blair	78	94	172	45.3%
Other	19	72	91	20.9%
Question C10. Where to wait for pedestrians?				
Lincoln	37	195	232	15.9%
Omaha	86	151	237	36.3%
Norfolk	50	194	244	20.5%
Plattsmouth	60	73	133	45.1%
Blair	70	102	172	40.7%
Other	29	62	91	31.9%

Hypothesis 4: Older drivers have a greater potential for incorrect roundabout negotiation compared to younger drivers.

The research team tested this hypothesis for each of the nine questions assessing knowledge of correct roundabout negotiation. Each cross tabulation analysis involved the variable "older" as defined in table 5.1. Table 5.3 summarizes the results of the cross tabulations and appendix C shows the full analyses. These analyses resulted in three significant cross tabulation chi-squared values. Questions C2, C4, and C10 had significant chi-square test statistic values. Table 5.7 summarizes the frequency of incorrect and correct answers for each of these questions based on respondents being older or younger drivers. Older drivers more frequently incorrectly answered the three questions found significant. Appendix D presents a graphical representation of the results shown in table 5.7.

Table 5.7 Frequency of Responses for Hypothesis 4

	Incorrect	**Correct**	**Total**	**% Incorrect**
Question C2. Which vehicle should yield?				
Drivers under 60	70	913	983	7.1%
Drivers over 60	26	96	122	21.3%
Question C4. Which is the correct left turn?				
Drivers under 60	32	951	983	3.3%
Drivers over 60	14	108	122	11.5%
Question C10. Where to wait for pedestrians?				
Drivers under 60	280	703	983	28.5%
Drivers over 60	49	73	122	40.2%

Hypothesis 5: Drivers who make fewer daily trips have a greater potential for incorrect roundabout negotiation compared to drivers who make five or more daily trips.

The research team tested this hypothesis for each of the nine questions assessing knowledge of correct roundabout negotiation. Each cross tabulation analysis involved the variable "high.trips" as defined in table 5.1. Table 5.3 summarizes the results of the cross tabulations and appendix C shows the full analyses. These analyses resulted in no significant cross tabulation chi-squared values. Since none of the cross tabulation calculations resulted in significant chi-squared test statistics, none of the questions had a significant difference between those respondents that make high numbers of trips per day and those that make fewer trips.

Hypothesis 6: Drivers who dislike roundabouts have a greater potential for incorrect roundabout negotiation compared with those that approve of roundabouts.

The research team tested this hypothesis for each of the nine questions assessing knowledge of correct roundabout negotiation. Each cross tabulation analysis involved the variable "dislike" as defined in table 5.1. Table 5.3 summarizes the results of the cross tabulations and appendix C shows the full analyses. These analyses resulted in six significant cross tabulation chi-squared values. Question C2, C5, C6, C7, C10, and C11 had significant chi-square test statistic values. Table 5.8 summarizes the frequency of incorrect and correct answers for each of these questions based on respondents liking roundabouts or not. As can be seen in table 5.8, drivers that like or are neutral to roundabouts more frequently incorrectly answered question C6 but more frequently answered the other questions correctly. Appendix D presents a graphical representation of the results shown in table 5.8.

Table 5.8 Frequency of Responses for Hypothesis 6

	Incorrect	**Correct**	**Total**	**% Incorrect**
Question C2. Which vehicle should yield?				
Neutral or Like	65	814	879	7.4%
Dislike	32	205	237	13.5%
Question C5. What to do if missed exit?				
Neutral or Like	48	831	879	5.5%
Dislike	28	209	237	11.8%
Question C6. Use turn signal when entering?				
Neutral or Like	765	114	879	87.0%
Dislike	193	44	237	81.4%
Question C7. Use turn signal when exiting?				
Neutral or Like	257	622	879	29.2%
Dislike	96	141	237	40.5%
Question C10. Where to wait for pedestrians?				
Neutral or Like	245	634	879	27.9%
Dislike	89	148	237	37.6%
Question C11. What is the truck apron?				
Neutral or Like	760	119	879	86.5%
Dislike	220	17	237	92.8%

Hypothesis 7: Drivers that do not feel confident they can drive through a roundabout in the correct manner have a greater potential for incorrect roundabout negotiation compared with those that feel confident they can drive through a roundabout in the correct manner.

The research team tested this hypothesis for each of the nine questions assessing knowledge of correct roundabout negotiation. Table 5.3 summarizes the results of the cross tabulations and appendix C shows the full analyses. These analyses resulted in eight significant cross tabulation chi-squared values. Question C2, C4, C5, C7, C8, C9, C10, and C11 had significant chi-square test statistic values. Only question C6 resulted in a non-significant chi-squared value. Table 5.9 summarizes the frequency of incorrect and correct answers for those

questions found to have a significant difference between those that said they know how to drive through a roundabout and those that said they do not. As can be seen in table 5.9, drivers that said they can confidently drive through a roundabout more frequently answered questions correctly. Appendix D presents a graphical representation of the results shown in table 5.9.

Table 5.9 Frequency of Responses for Hypothesis 7

	Incorrect	**Correct**	**Total**	**% Incorrect**
Question C2. Which vehicle yields?				
Not Confident Could Drive	30	99	129	23.3%
Confident Could Drive	63	906	969	6.5%
Question C4. Which is the correct left turn?				
Not Confident Could Drive	22	107	129	17.1%
Confident Could Drive	22	947	969	2.3%
Question C5. What to do if missed exit?				
Not Confident Could Drive	29	100	129	22.5%
Confident Could Drive	44	925	969	4.5%
Question C7. Use turn signal when exiting?				
Not Confident Could Drive	55	74	129	42.6%
Confident Could Drive	289	680	969	29.8%
Question C8. What to do if emergency vehicle (at yield line)?				
Not Confident Could Drive	43	86	129	33.3%
Confident Could Drive	107	862	969	11.0%
Question C9. What to do if emergency vehicle (in roundabout)?				
Not Confident Could Drive	93	36	129	72.1%
Confident Could Drive	469	500	969	48.4%
Question C10. Where to wait for pedestrians?				
Not Confident Could Drive	70	59	129	54.3%
Confident Could Drive	257	712	969	26.5%
Question C11. What is the truck apron?				
Not Confident Could Drive	122	7	129	94.6%
Confident Could Drive	841	128	969	86.8%

Summary of Cross Tabulation Analysis

Table 5.10 summarizes the results of the significant hypotheses tested using cross tabulations.

Table 5.10 Hypotheses Significant Cross Tabulation Results

Question	Potential for incorrect roundabout negotiation
C2. Which vehicle should yield?	Unfamiliar drivers have a greater potential compared to familiar drivers
	Plattsmouth drivers have a greater potential compared to other cities
	Older drivers have a greater potential compared to younger drivers
	Drivers that dislike roundabout have a greater potential compared to drivers that like roundabouts
	Drivers who are not confident they can drive through a roundabout have a greater potential compared to drivers that are confident they can drive through a roundabout
C4. Which is the correct left turn?	Unfamiliar drivers have a greater potential compared to familiar drivers
	Plattsmouth drivers have a greater potential compared to other cities
	Older drivers have a greater potential compared to younger drivers
	Drivers who are not confident they can drive through a roundabout have a greater potential compared to drivers that are confident they can drive through a roundabout
C5. What to do if missed exit?	Drivers that dislike roundabout have a greater potential compared to drivers that like roundabouts
	Drivers who are not confident they can drive through a roundabout have a greater potential compared to drivers that are confident they can drive through a roundabout
C6. Use turn signal when entering?	Lincoln drivers have a greater potential compared to other cities
	Drivers that like roundabout have a greater potential compared to drivers that dislike roundabouts
C7. Use turn signal when exiting?	Familiar drivers have a greater potential compared to unfamiliar drivers
	Passenger vehicle drivers have a greater potential compared to specialty vehicle drivers
	Blair drivers have a greater potential compared to other cities
	Drivers that dislike roundabout have a greater potential compared to drivers that like roundabouts
	Drivers who are not confident they can drive through a roundabout have a greater potential compared to drivers that are confident they can drive through a roundabout

Table 5.10 Hypotheses Significant Cross Tabulation Results (cont.)

Question	Potential for incorrect roundabout negotiation
C8. What to do if emergency vehicle (at yield line)?	Drivers who are not confident they can drive through a roundabout have a greater potential compared to drivers that are confident they can drive through a roundabout
C9. What to do if emergency vehicle (in roundabout)?	Unfamiliar drivers have a greater potential compared to familiar drivers
	Plattsmouth drivers have a greater potential compared to other cities
	Drivers who are not confident they can drive through a roundabout have a greater potential compared to drivers that are confident they can drive through a roundabout
C10. Where to wait for pedestrians?	Unfamiliar drivers have a greater potential compared to familiar drivers
	Plattsmouth drivers have a greater potential compared to other cities
	Older drivers have a greater potential compared to younger drivers
	Drivers that dislike roundabout have a greater potential compared to drivers that like roundabouts
	Drivers who are not confident they can drive through a roundabout have a greater potential compared to drivers that are confident they can drive through a roundabout
C11. What is the truck apron?	Unfamiliar drivers have a greater potential compared to familiar drivers
	Passenger vehicle drivers have a greater potential compared to specialty vehicle drivers
	Plattsmouth drivers have a greater potential compared to other cities
	Drivers that dislike roundabout have a greater potential compared to drivers that like roundabouts
	Drivers who are not confident they can drive through a roundabout have a greater potential compared to drivers that are confident they can drive through a roundabout

Although the research team conducted each cross tabulation independently, many of the results of table 5.10 are comparable. Many drivers of Plattsmouth are unfamiliar roundabout users, so it is only fitting that many of the significant test results between Hypothesis 1 and Hypothesis 3 are similar. The frequencies of incorrect answers from unfamiliar drivers and Plattsmouth respondents were often higher for the same questions.

5.4 Analysis of Roundabout Knowledge

Two analyses were conducted to assess roundabout knowledge, a t-test and ordinal regression estimation. The t-tests were conducted to test the variable "tot.ans" as defined in table 5.1 (the total number of correct answers for the nine questions assessing knowledge of roundabout negotiation) for each of the seven hypotheses. The ordinal regression model was estimated to determine which driver characteristics are prominent in incorrect roundabout negotiation. The model used the variables representing each of the hypotheses as independent variables, and the total number of correct answers as the dependent variable. Additional independent variables (not included in the defined hypotheses) that could influence the total correct responses from survey participants were included in model development. The following sections discuss these two analyses.

5.5 T-test Analysis Results

T-tests were conducted for each hypothesis; the results of the tests are shown in table 5.11. They tested if the mean number of correct answers for the questions assessing knowledge of correct roundabout negotiation were statistically different from each other when grouped by the defined driver populations for each hypothesis. As shown in the table, six of the seven hypotheses were found to have statistically different mean total correct answers. The t-value for Hypothesis 5 (number of daily trips) was below 1.96 so was not significant at a 95% confidence level. The results of the t-tests confirmed the initial expectations of each hypothesis.

Table 5.11 T-test Results for Hypotheses

Hypothesis		Number of Responses	Mean	Std. Dev.	t-value	Significance
1	Unfamiliar User	352	5.40	1.607	-6.100	0.000
	Familiar User	764	5.98	1.437		
2	Passenger Vehicle Driver	861	5.70	1.489	-4.079	0.000
	Specialty Vehicle Driver	255	6.14	1.563		
3	Have Roundabout in City	885	5.91	1.416	5.600	0.000
	Do not have Roundabouts in City	133	5.14	1.841		
4	Respondent under 60	983	5.86	1.467	3.342	0.001
	Respondent over 60	122	5.38	1.774		
5	Fewer than 5 daily trips	633	5.76	1.440	-1.247	0.213
	5 or more daily trips	457	5.88	1.568		
6	Respondent likes roundabouts	879	5.88	1.449	3.464	0.001
	Respondent dislikes roundabouts	237	5.50	1.714		
7	Not confident can drive through roundabout	129	4.57	2.168	-10.400	0.000
	Confident can drive through roundabout	969	5.98	1.314		

5.6 Ordinal Regression Model Estimation Results

To run the ordinal regression model, the total answers variable ("tot.ans" used in the t-test analysis) was redefined to include only four ordinal categories instead of the 10 initially used. The ordinal variable used for the analysis had four categories: 0 to 3 correct responses, 4 or 5 correct responses, 6 or 7 correct responses, and 8 or 9 responses. The variables tested in this model were shown in table 5.1 (page 33). To complete the analysis, the various link function options were tested and the model with the best chi-squared test statistic was used for analysis. For this analysis, the logit link function was found to be the most significant from this comparison. When using the logit link function, the ordinal regression model performs as an

ordered logit model. By including all variables in the model, all factors are tested simultaneously. After the initial model was estimated with all variables, those found not to be significant were removed for the final model for parsimony. This model is shown in table 5.12. Appendix C shows the initial estimated model. The parameters found significant in the final model are discussed in table 5.12.

Table 5.12 Ordinal Regression Model Results

Model Fitting Information				
Chi-Square	145.096			
Degrees of Freedom	7			
Significance	0.000			
Parameter	**Variable Coding**	**Estimate**	**Std. Error**	**t-value**
familiar	0 – Unfamiliar 1 - Familiar	0.474	0.134	3.549
drvr.type	0 - Passenger vehicle drivers 1 - Specialty vehicle drivers	0.499	0.163	3.063
older	0 - Under 60 1 - Over 60	-0.446	0.194	-2.301
can.drv	0 –Said cannot negotiate roundabout 1 – Said can negotiate roundabout	1.318	0.191	6.906
gender	0 – Female 1 - Male	0.600	0.134	4.472
seat.belt	0 - Does not wear seatbelt 1 - Wears seatbelt	0.798	0.177	4.510
avd.cong	0 - Doesn't avoid roadways because of congestion 1 – Avoids roadways because of congestion	0.294	0.124	2.378

Table 5.13 Significant Parameters from Regression Analysis

Parameter	Estimate	Variable Coding	Result
familiar	0.474	0 – Unfamiliar 1 - Familiar	Familiar drivers displayed greater knowledge of roundabout negotiation
drvr.type	0.499	0 - Passenger vehicle drivers 1 - Specialty vehicle drivers	Specialty vehicle drivers showed greater knowledge of roundabout negotiation
older	-0.446	0 - Under 60 1 - Over 60	Younger drivers exhibited greater knowledge of roundabout negotiation
can.drv	1.318	0 –Said cannot negotiate roundabout 1 – Said can negotiate roundabout	Drivers that said they can negotiate roundabouts displayed greater knowledge of roundabout negotiation
gender	0.600	0 – Female 1 - Male	Male respondents showed greater knowledge of roundabout negotiation
seat.belt	0.798	0 - Does not wear seatbelt 1 - Wears seatbelt	Drivers that wore a seatbelt indicated greater knowledge of roundabout negotiation
avd.cong	0.294	0 - Doesn't avoid roadways because of congestion 1 – Avoids roadways because of congestion	Drivers that avoid roadways because of congestion have greater knowledge of roundabout negotiation

The variables found significant in the model that correspond with any of the seven hypotheses had similar significant results as the initial cross tabulation results as well as the t-tests. The results of the analyses presented above were used in the following chapter to make conclusions regarding the characteristics of drivers that lead to incorrect roundabout negotiation as well as commenting on what elements of roundabouts are most commonly incorrectly negotiated by drivers.

5.7 Roundabout Elements of Concern to Drivers

The survey asked drivers to indicate what elements of roundabouts were of concern to them (Question C1). Figure 5.2 tabulates the responses received (respondents could indicate multiple elements of concern to them). Results show that respondents were most concerned about other drivers, waiting or not waiting for other vehicles entering the roundabout, and the procedure when an emergency vehicle is approaching the roundabout.

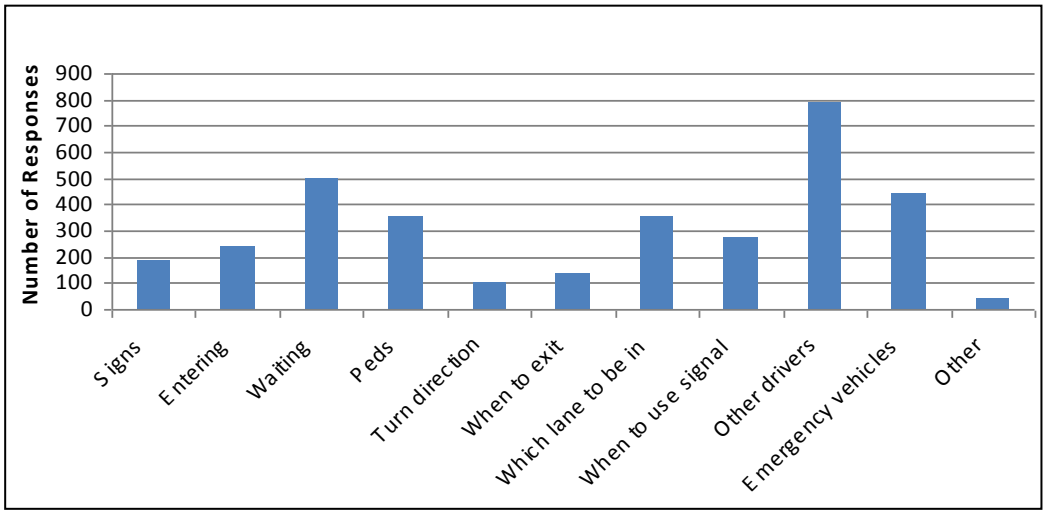


Figure 5.2 Elements of Concern to Drivers

5.8 Helpful Informational Techniques

Survey respondents were asked what type of informational techniques would help them understand how to drive through a roundabout (Question A4). Respondents could choose multiple informational techniques when answering Question A4. Figure 5.3 presents the results of Question A4. Most of the respondents chose the driver's manual followed by on-site signage

and brochures as the preferred technique that would help them understand how to drive through a roundabout.

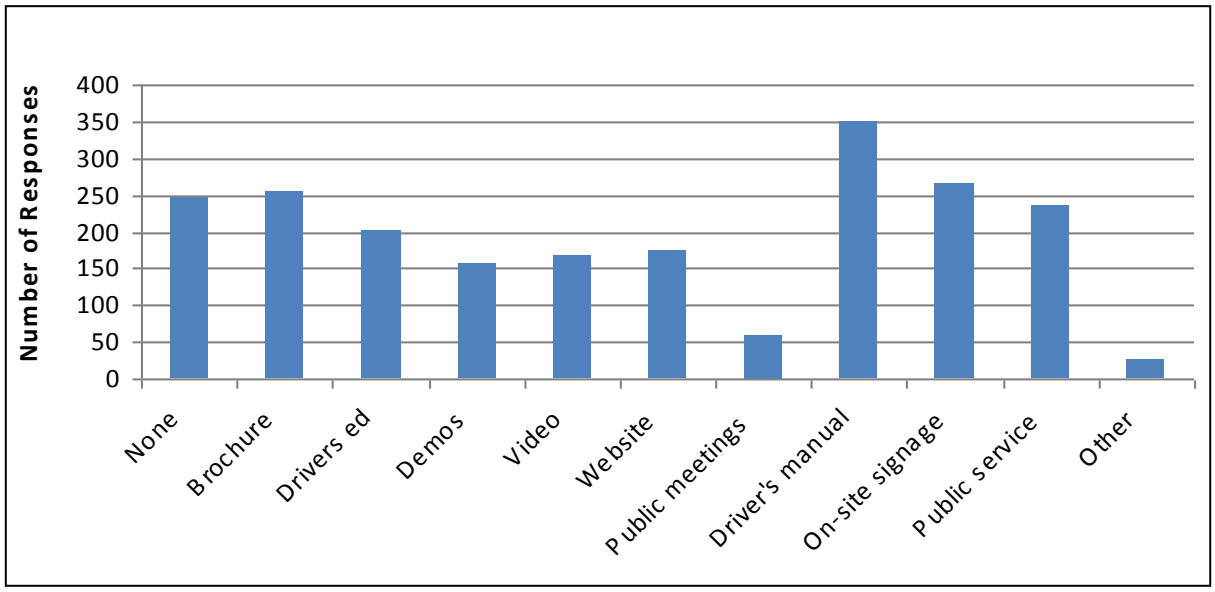


Figure 5.3 Preferred Helpful Informational Techniques

Chapter 6 Conclusions and Recommendations

The objectives of this research were to identify roundabout elements that play a role in incorrect roundabout negotiation, ascertain driver characteristics prominent in incorrect roundabout negotiation, assess the relative potential for incorrect negotiation amongst different groups of drivers, and suggest measures for improving drivers' abilities to properly negotiate roundabouts. The following conclusions are drawn based on the findings.

6.1 Conclusions

In summary, to achieve the stated objectives, a survey was designed and administered to drivers in five different Nebraska cities. Collected surveys were analyzed to achieve the objectives of this research. Nine questions assessed knowledge of correct roundabout negotiation. Drivers incorrectly answered questions regarding the purpose of the truck apron, turn signal use, and emergency vehicle procedures at roundabouts. These elements play a role in incorrect roundabout negotiation. The analysis of survey responses confirmed six of the seven hypotheses regarding driver characteristics prominent in incorrect roundabout negotiation. These are the conclusions from the hypothesis testing:

- Unfamiliar roundabout users have a greater potential for incorrect roundabout negotiation compared to familiar roundabout users.
- Passenger vehicle drivers have a greater potential for incorrect roundabout negotiation compared to specialty vehicle drivers.
- Drivers in different cities in Nebraska have different potential for incorrect roundabout negotiation. Drivers in Plattsmouth, a community without a roundabout, have a greater potential for incorrect roundabout negotiation.

- Older drivers have a greater potential for incorrect roundabout negotiation compared to younger drivers.
- Drivers that disfavor roundabouts have a greater potential for incorrect roundabout negotiation compared to drivers who favor roundabouts.
- Drivers that are not confident they can drive through a roundabout in the correct way have a greater potential for incorrect roundabout negotiation compared to drivers who are confident they can drive through a roundabout in the correct way.

No significant conclusions could be made for hypothesis 5 regarding drivers that make a higher number of daily trips. The ordinal regression analysis showed that factors not included in the initial hypotheses influence the level of roundabout knowledge. The following are the conclusions based on these factors:

- Drivers that do not generally wear their seat belt when driving have a greater potential for incorrect roundabout negotiation compared to drivers that generally wear a seat belt.
- Drivers that generally do not avoid certain roadways and intersections because of traffic congestion have a greater potential for incorrect roundabout negotiation compared to drivers that generally avoid certain roadways and intersections because of traffic congestion.

Drivers were concerned about the behavior of other drivers, emergency vehicle procedures, and wanted to receive information on roundabouts via driver's manual, brochures and on-site signage. The researchers reviewed information on roundabouts in the Nebraska Driver's Manual (details in appendix E) and suggest updates to the roundabout section.

6.2 Recommendations

This research shows that driver knowledge of roundabout negotiation in Nebraska has room for improvement. However, the potential for improvement varies across different types of drivers. Given that non-specialty vehicle drivers exhibited greater potential for incorrect negotiation of roundabouts, it may be prudent to first focus on improving their knowledge of roundabouts. In addition, this research showed that several roundabout elements (truck apron purpose, turn signal use, emergency vehicle procedures) have low levels of driver knowledge. Knowledge of these elements will help toward reducing incorrect roundabout negotiation and therefore should be a priority for transportation agencies.

The research team recommends updating information on roundabouts contained in the Nebraska Driver's Manual. The updated information pertains to both single- and multi-lane roundabouts, as shown in figures 6.1 and 6.2.

RULES FOR DRIVING ROUNDABOUTS

General Information for all roundabouts

Roundabouts are becoming more common in the US because they provide safer and more efficient traffic flow than standard intersections in some cases. By keeping traffic flow moving one-way in a counterclockwise direction, there are fewer conflict points and traffic flows smoothly.
Crash statistics show that roundabouts reduce fatal crashes about 90%, reduce injury crashes about 75%, and reduce overall crashes about 35%, when compared to other types of intersection control.

When driving a roundabout, the same general rules apply for maneuvering through any other type of intersection.

Truck Apron

Large vehicles need more space when driving in a roundabout. A truck apron is a paved area along the inside circle or outside edges of the roundabout for the rear wheels of large trucks to use when turning. Truck aprons are not to be used by cars, SUVs, pickup trucks, pedestrians, or bicyclists.

Steps for driving a roundabout

1. Slow down. Obey traffic signs.
2. Yield to pedestrians and bicyclists as you approach the roundabout.
3. Yield to traffic approaching on your left already in the roundabout.
4. Enter the roundabout when there is a safe gap in traffic.
5. Keep your speed low within the roundabout.
6. As you approach your exit, turn on your right turn signal.
7. Yield to pedestrians and bicycles as you exit.

Emergency vehicles in the roundabout

- ✓ Always yield to emergency vehicles.
- ✓ If you have not entered the roundabout, pull over and allow emergency vehicles to pass.
- ✓ If you have entered the roundabout, continue to your exit, then once beyond the splitter island, pull over and allow emergency vehicles to pass.
- ✓ Avoid stopping in the roundabout.

Driving a one-lane roundabout

This example shows the traffic movement patterns through a one-lane roundabout.
The one-lane roundabout is known as one of the safest and most efficient types of intersections.

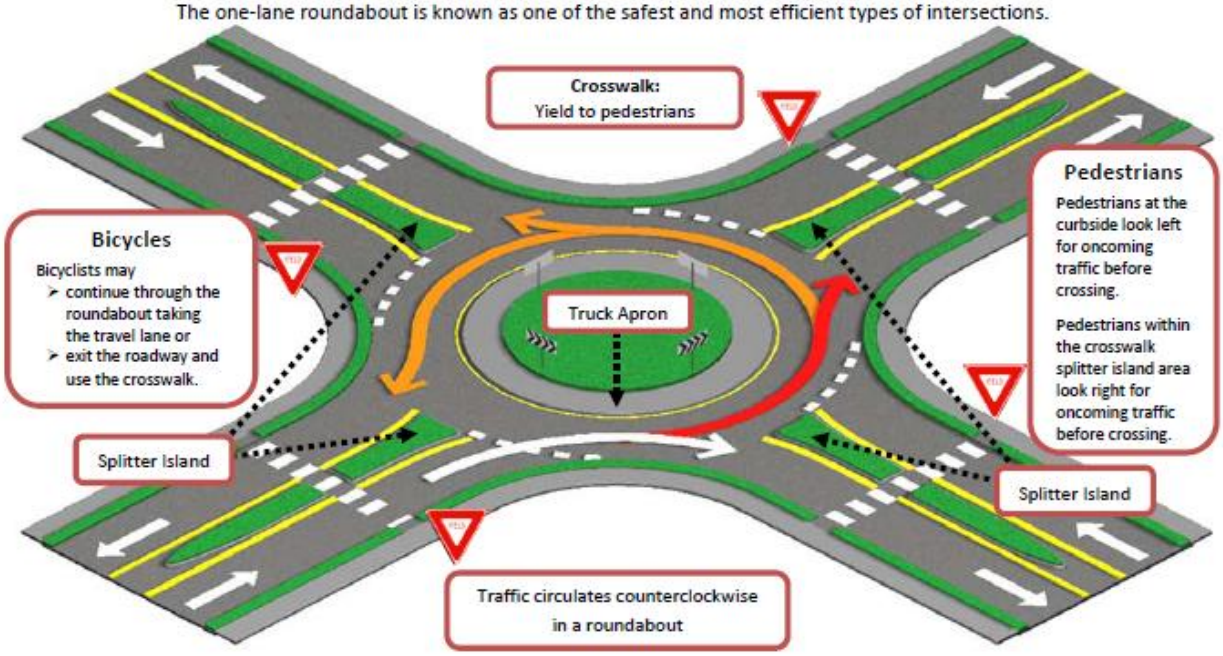


Figure 6.1 Suggested Update to NE Driver's Manual on Driving Single-Lane Roundabouts

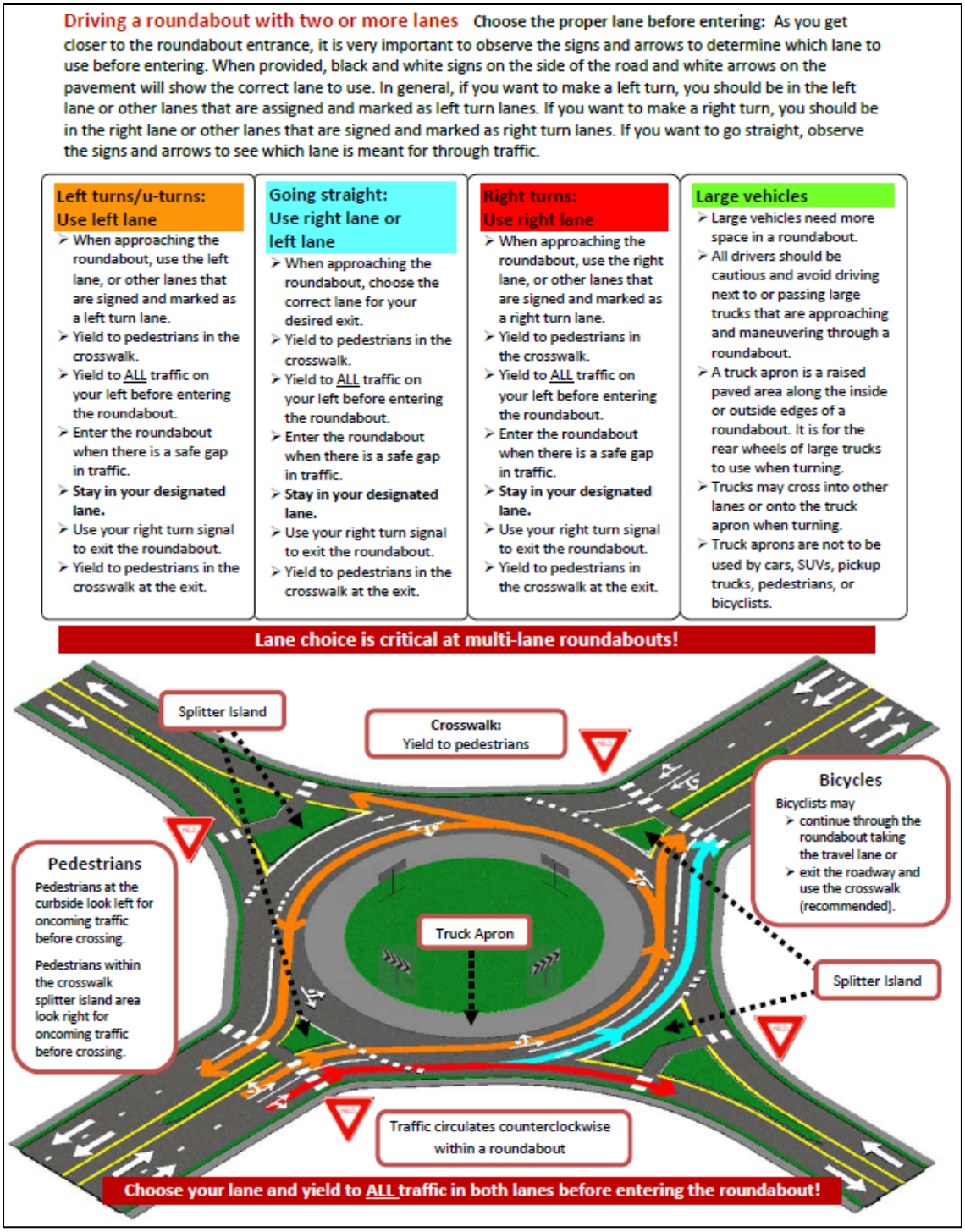


Figure 6.2 Suggested Update to NE Driver's Manual on Driving Multi-Lane Roundabouts

6.3 Future Work

While this research identified roundabout elements prominent in incorrect roundabout negotiation, driver groups with greater potential for incorrect roundabout negotiation, and improvement measures, research into the effectiveness of different methods for providing roundabout information is needed. For example, some education techniques may be more effective for certain driver populations, such as older drivers responding better to educational demonstrations than a website.

Since the Plattsmouth site was a city without a roundabout during this analysis, future research can measure changes in incorrect roundabout negotiation or opinion of roundabouts after a planned roundabout in that community opens. A comparison of responses from Plattsmouth drivers before and after roundabout construction may reveal changes in driver knowledge, attitudes, and opinions regarding roundabouts.

There is need to monitor drivers' behavior in roundabouts on a relatively long-term basis to observe safety issues faced by drivers. This is especially true for multi-lane roundabouts, which require knowing correct lanes to use in addition to knowledge of other roundabout pertinent rules.

References

1. Robinson, B. W. 2000. *Roundabouts: An informational Guide*. Publication FHWA-RD-00-067. FHWA, U.S. Department of Transportation.

2. Persaud, B. N., R. A. Retting, P. E. Garder, and D. Lord. 2001. Safety Effect of Roundabout Conversions in the United States: Empirical Bayes Observational Before-After Study. *Transportation Research Record: Geometric Design and the Effects on Traffic Operations*, no. 1751:1-8.

3. Retting, R. A., G. Luttrell, and E. R. Russell. 2002. Public Opinion and Traffic Flow Impacts of Newly Installed Modern Roundabouts in the United States. *TRB 2002 Annual Meeting CD-ROM*. Transportation Research Board, Washington, D.C.

4. Retting, R. A., S. Mandavilli, E. R. Russell, and A. T. McCartt. 2006. Traffic Flow and Public Opinion: Newly Installed Roundabouts in New Hampshire, New York, and Washington. *TRB 2006 Annual Meeting CD-ROM.* Transportation Research Board, Washington, D.C.

5. AASHO. 1954. *A Policy on Geometric Design of Rural Highways*, Washington, D.C.

6. AASHO. 1965. *A Policy on Geometric Design of Rural Highways*, Washington, D.C.

7. AASHTO. 1984. *A Policy on the Geometric Design of Highways and Streets*, Washington, D.C.

8. AASHTO. 2004. *A Policy on Geometric Design of Highways and Streets*, Washington, D.C.

9. Retting, R. A., S. Y. Kyrychenko, and A. T. McCartt. 2007. Long-Term Trends in Public Opinion Following Construction of Roundabouts. *TRB 2007 Annual Meeting CD-ROM.* CD-ROM. Transportation Research Board, Washington, D.C.

10. Kirkham Michael. 2006. *2003-2004 Crash Study City of Lincoln, Nebraska*. City of Lincoln, Lincoln, NE.

11. Waddell, E., and J. Albertson. 2005. The Dimondale Mini: America's First Mini-Roundabout. Paper presented at the National Roundabout Conference 2005, Vail, CO.

12. Kliska, J., and K. Winn. 2005. The 'Sock Puppet' and other Lessons Learned in Grand Junction, CO. Paper presented at the National Roundabout Conference 2005, Vail, CO.

13. Kittelson & Associates, Inc. 2006. *Applying Roundabouts in the United States.* NCHRP Project No. 3-65, Transportation Research Board, Washington, D.C.

14. Ariniello, A. J. 2005. Are Roundabouts Good for Business? Paper presented at the National Roundabout Conference 2005, Vail, CO.

15. Kennedy, D. R., and K. M. Taylor. 2005. Estimating Roundabout Performance using Delay and Conflict Opportunity Crash Prediction. Paper presented at the National Roundabout Conference 2005, Vail, CO.

16. Chapman, J. R., and R. F. Benekohal. 2002. Roundabout Warrants: A Proposed Framework for Future Development. *TRB 2002 Annual Meeting CD-ROM.* Transportation Research Board, Washing, D.C.

17. Asma, T. A., and A. Flannery. 2006. Modeling Driver Selected Speeds at Single Lane Roundabouts. Paper presented at the ITE 2006 Annual Meeting and Exhibit, Milwaukee, WI.

18. Transportation Research Board. 2000. *Highway Capacity Manual*. National Research Council. Washington, D.C.

19. Doucet, J. 2006. Holistic Design of Roundabout Intersections. Special Project at University of Nebraska-Lincoln, Lincoln, NE.

20. ETC Institute. 2006. *2006 Roundabout Survey*. Prepared for the City of Olathe, KS.

21. Sarkar, S., D. Burden, and M. Wallwork. 1999. Are Drivers well informed about Non-conventional Traffic Controls at Intersections? *TRB 1999 Annual Meeting CD-ROM*. Transportation Research Board, Washing, D.C.

22. Rusell, E. R., M. Rys, and G. Luttrell. 2002. Kansas Roundabout Reluctance. *TRB 2002 Annual Meeting CD-ROM.* Transportation Research Board, Washington, D.C.

23. Inman, V. W. and B. J. Katz. 2005. Navigation Signing for Roundabouts. Paper presented at the National Roundabout Conference 2005, Vail, CO.

24. Nebraska Department of Roads. 2005. *Roundabouts*. Lincoln NE.

25. FHWA. 2003. Manual on Uniform Traffic Control Devices for Highways and Streets. U.S. Department of Transportation

26. Schurr, K. S., and J. Abos-Sanchez. 2005. Effects of Central Island Landscape Treatments at Single-Lane Roundabouts. NDOR Research Project Number SPR-P1 (03) P550, Lincoln, NE.

27. Richardson, A. J., E. S. Ampt, and A. H. Meyburg. 2005. *Survey Methods for Transport Planning*. 2nd ed. Melbourne, Australia: Eucalyptus Press.

28. Devore, J. 1991. *Probability & Statistics for Engineering and Sciences.* 3rd ed. Pacific Grove, CA: Brooks/Cole Publishing.

29. Noonan, J. 2006. SPSS 14.0 [Computer software]. Chicago: SPSS Inc.

30. Social Security Online. 2006. *Normal Retirement Age*. July. http://www.ssa.gov/OACT/ProgData/nra.html.

31. Nebraska Department of Motor Vehicles. 2008. Nebraska Driver's Manual (English).

Appendices

Appendix A Survey Questionnaire

The following pages show the complete survey questionnaire. The consent form had a perforated edge so that respondents could keep the page for their records if they chose. Correct answers for the nine questions assessing knowledge of correct roundabout use are marked in the survey questionnaire.

IRB#2007-01-179 EP
Date Approved: 2/21/07
Valid Until: 02/20/08

UNIVERSITY OF NEBRASKA – LINCOLN

Investigation and Mitigation of Driver Confusion at Modern Roundabouts

The University of Nebraska-Lincoln is conducting research in driver confusion at modern roundabouts. As part of this research project, the research team is conducting a survey of Nebraska drivers. This survey will be used to help the research team develop mitigation techniques for confusing elements at roundabouts. You are being invited to participate because you are a community member of an area that either currently has roundabouts or will have a roundabout installed in the near future. You must be an of-age, licensed driver to complete this 10-minute survey.

You are being asked to complete the attached questionnaire and return it to the investigator. You are not being asked to complete additional activities as part of the research and it will require no additional time on your part nor will you be compensated for your participation. You are being asked to allow us to include data from your participation with the activities of this research. The purpose of this analysis is to determine those roundabout elements that drivers find confusing. Your participation in this study will benefit the research program and improve roundabout design procedures to help eliminate confusion for drivers at Nebraska roundabouts. There are no known risks or discomforts associated with this survey.

Any information obtained during this study that could identify you will be kept strictly confidential. Access to this information will be restricted to the research team. The results of the summary and analysis may be presented at professional meetings and in the professional literature. Results of the data collection will not be reported in a way that individual participants can be identified. Data will be reported by group summary only with no reference to individual responses.

You may ask any questions concerning this research and have those questions answered before agreeing to participate in the study. Questions about the research can be directed to Greg McKnight at (402) 472-1974 or Dr. Ram Bishu at (402) 472-2393. Sometimes study participants have questions or concerns abut their rights. In that case, you should call the University of Nebraska-Lincoln Institutional Review Board at (402) 472-6965.

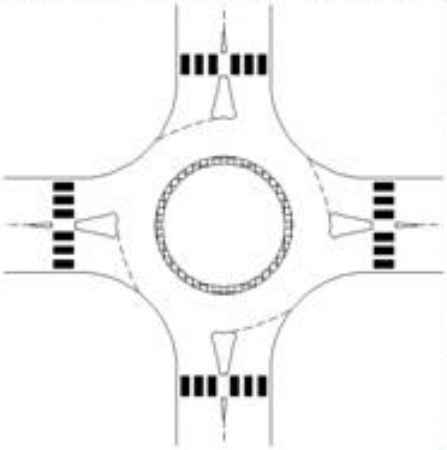
You are voluntarily making a decision whether or not to participate in this research study. You are free to decide not to participate in this study. You can skip any question you are not comfortable answering if you so choose. You can also withdraw at any time without harming your relationship with the researchers or the University of Nebraska-Lincoln. Completing and returning this questionnaire certifies that you are a licensed driver and have decided to participate having read and understood the information presented. You should keep this letter for your records.

Investigation of Driver Behavior at Roundabouts

Background Information about this study

The University of Nebraska-Lincoln and the Nebraska Department of Roads (NDOR) are conducting this survey to determine what elements of roundabouts affect Nebraska drivers. The NDOR is funding this study to better serve Nebraska drivers. The results of this survey will be used by the NDOR to help improve roundabout design and information techniques to help Nebraska drivers better negotiate roundabouts.

The images below show a typical single-lane roundabout intersection:



You must be a licensed driver to complete this survey. If you are not a licensed driver, please stop and return the survey.

Please place an X in the appropriate box indicating your response to the questions.

Drivers that frequently use roundabouts as well as drivers that rarely or never use roundabouts are encouraged to participate in this survey, as all driver issues are of concern for this research.

SECTION A. Roundabout Information

A1. How often have you driven through a single-lane roundabout?

- ☐ I have never driven through a roundabout
- ☐ A few times when visiting another place
- ☐ About once per month
- ☐ Several times per month
- ☐ Several times per week
- ☐ At least once per day
- ☐ I don't know

Please continue the survey on the next page

There are also multiple-lane roundabouts. These roundabouts operate similar to a single-lane roundabout but have more than one lane of circulating traffic at all points around the roundabout. This type of roundabout is not common in Nebraska but has been used in other areas of the United States.

A2. How often have you driven through a multiple-lane roundabout?

- ☐ I have never driven through a multi-lane roundabout
- ☐ A few times when visiting another place
- ☐ About once per month
- ☐ Several times per month
- ☐ Several times per week
- ☐ At least once per day
- ☐ I don't know

A3. Have you received any information about how to drive through a roundabout?

- ☐ No
- ☐ Yes, if so, what source(s)? (**Check all that apply**)
  - ☐ Brochure/Book/Article
  - ☐ Demonstration
  - ☐ Website
  - ☐ Driver's education course
  - ☐ Video/Film
  - ☐ Public meeting/presentation
  - ☐ I have driven through a roundabout in another place
  - ☐ I was a passenger with another driver as we drove through a roundabout
  - ☐ I don't remember
  - ☐ Other: _____

A4. What type of informational techniques would help you understand how to drive through a roundabout? (**Check those you feel are most appropriate**)

- ☐ No driver information is needed
- ☐ Brochure
- ☐ Demonstration
- ☐ Website
- ☐ Driver's education course
- ☐ Video/Film
- ☐ Public meetings/presentations
- ☐ Driver's Manual
- ☐ On-site additional temporary signage, message systems
- ☐ Demonstrations during public service announcements on local TV stations
- ☐ Other: _____
- ☐ I don't know

If you drive a specialty vehicle (fire truck, bus, police vehicle, etc.), please answer questions A5 & A6, if not, please turn to question A7

A5. What type of vehicle do you drive?

- ☐ Ambulance
- ☐ Municipal Bus
- ☐ Fire Ladder Truck
- ☐ Police vehicle
- ☐ School Bus
- ☐ Garbage/Delivery
- ☐ Snowplow/Maintenance
- ☐ Large (Semi) Truck
- ☐ Other: _____

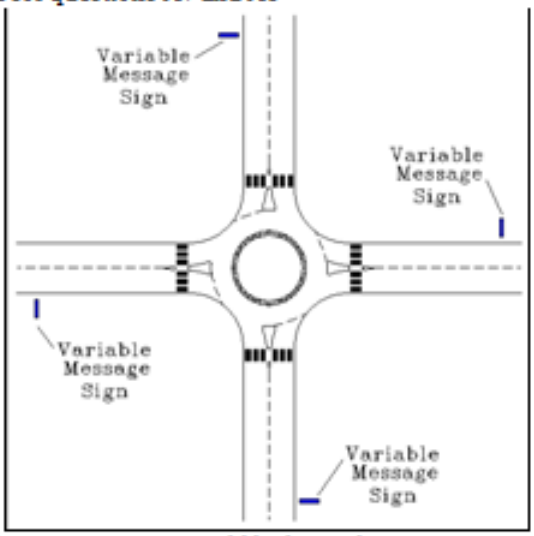
Please continue the survey on the next page

A6. What types of informational techniques would help *specialty vehicle drivers* in particular understand how to drive through a roundabout? (**Check those you feel are most appropriate**)

- ☐ No driver information is needed
- ☐ Demonstrations/Training
- ☐ Brochures
- ☐ I don't know
- ☐ Websites
- ☐ Educational videos
- ☐ Other: _____

Questions A7 through A9 refer to the use of Variable Message Signs. The image shows a typical variable message sign. These signs are used along roadways temporarily to inform drivers of different roadway conditions ahead such as construction zones, traffic accidents, special events, road closings, and many other temporary applications. These types of signs have been used at the opening of roundabout intersections to further help guide drivers in driving through the intersection.

Please refer to the figure for questions A7 and A8



A7. If used, the variable message signs would be located as you approach a roundabout at the four locations shown in the figure. What was your reaction to the use of a dynamic message sign when a roundabout in your community was first opened to traffic?

- ☐ I have not driven through a roundabout before
- ☐ I have not driven through a roundabout that had a variable message sign used at it
- ☐ The sign provided me the guidance to drive through the roundabout
- ☐ I didn't need the extra help, but I think it was helpful for other drivers
- ☐ The sign was too distracting; it caused more confusion than it helped people

Please continue the survey on the next page

A8. If a Variable Message Sign were used at the location shown in the figure, what message would be the most beneficial to help you?

Message 1 Message2

- ☐ Message 1
- ☐ Message 2
- ☐ Both messages would be equally beneficial
- ☐ Neither message would benefit drivers
- ☐ I don't know

A9. Do you think that variable message signs would benefit drivers if used for the first few weeks after a roundabout is opened to traffic?

- ☐ Yes
- ☐ No
- ☐ I am indifferent to their use
- ☐ I don't know

Please continue the survey on the next page

SECTION B: Attitude and Opinion

Please indicate your opinion of the following statements using the provided scale. There is room for comments on any of these statements at the bottom of this page.

		1 Strongly Agree	2 Agree	3 Neutral	4 Disagree	5 Strongly
B1	I like roundabouts	☐	☐	☐	☐	☐
B2	I favor the installation of roundabouts in my community	☐	☐	☐	☐	☐
B3	A roundabout intersection is safer than other intersections	☐	☐	☐	☐	☐
B4	A roundabout intersection reduces delay compared to other intersections	☐	☐	☐	☐	☐
B5	Roundabout intersections are safer for pedestrians than other intersections	☐	☐	☐	☐	☐
B6	Roundabout intersections are safer for bicyclists than other intersections	☐	☐	☐	☐	☐
B7	I feel confident that I can drive through a roundabout in the correct way	☐	☐	☐	☐	☐
B8	If you are a specialty vehicle driver (fire truck, bus, etc.), please indicate your views on the following statements about roundabouts, if not, please skip to the next section.					
B8.1	All design elements of a roundabout are adequate	☐	☐	☐	☐	☐
B8.2	There is enough space to turn in a roundabout intersection	☐	☐	☐	☐	☐
B8.3	Other drivers know how to act when an emergency vehicle is present	☐	☐	☐	☐	☐
B8.4	Curb locations are satisfactory for negotiating a roundabout	☐	☐	☐	☐	☐
B8.5	The paved area around the central island is useful for turning	☐	☐	☐	☐	☐
B8.6	Driving through a roundabout intersection does not increase my travel/response time compared to a conventional type of intersection	☐	☐	☐	☐	☐

Additional comments from these statements:

_____

_____

_____

_____

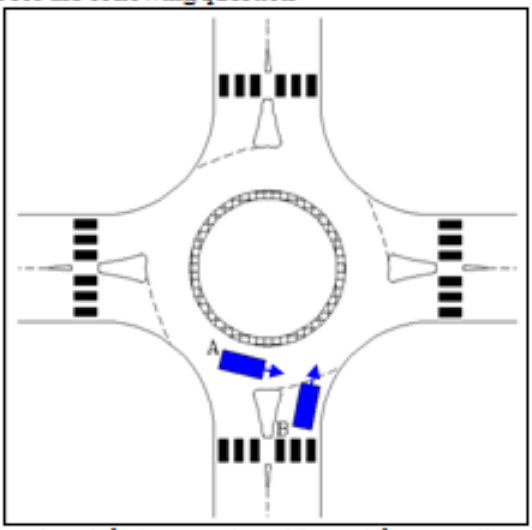
Please continue the survey on the next page

SECTION C. Roundabout Operations

C1. What elements of roundabouts are of concern to you? (**Check all that apply**)

- ☐ Traffic signs
- ☐ Entering the circular roadway
- ☐ Waiting, or not waiting for other vehicles entering the roundabout when driving on the circular roadway
- ☐ Waiting for pedestrians and/or bicyclists
- ☐ The direction to turn onto the circular roadway
- ☐ When to exit the circular roadway
- ☐ Which lane to be in when on a multiple lane roundabout
- ☐ When to use a turn signal while driving on a roundabout
- ☐ Other drivers knowing how to drive though the roundabout
- ☐ The procedure when an emergency vehicle is approaching the roundabout
- ☐ Other:_____
- ☐ Other:_____

Please refer to the figure for the following question



C2. If vehicles A and B arrive at their current positions at the same time, which vehicle should yield?

- ☐ Vehicle A should yield to vehicle B
- ■ Vehicle B should yield to vehicle A
- ☐ Either vehicle can yield
- ☐ I don't know

C3. Are the signs leading up to a roundabout easy to follow?

- ☐ I have not driven through a roundabout
- ☐ Yes
- ☐ No
- ☐ I don't know

Please continue the survey on the next page

Please refer to the figures for the following question

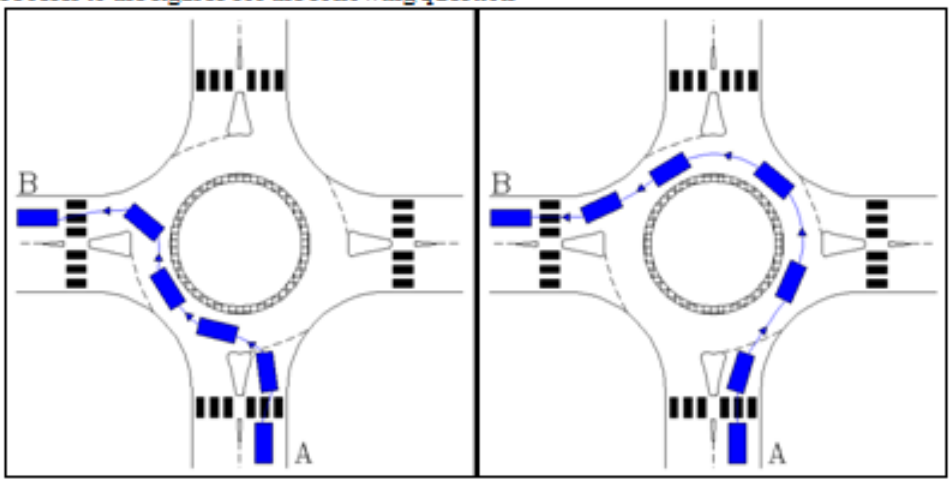


Figure 1 Figure 2

C4. If you are trying to get from point A to point B through a roundabout intersection, which image represents the appropriate behavior?

- ☐ Figure 1 is the correct method
- ■ Figure 2 is the correct method
- ☐ Both figures represent an acceptable route
- ☐ I don't know

C5. While driving through a roundabout, if you miss the exit you wanted, what should you do?

- ☐ Back up on the roundabout to the correct exit
- ■ Continue around the circle until you get back to the correct exit
- ☐ Take the next exit and use other roadways to get to your destination
- ☐ I don't know

C6. Should you use your turn signal while waiting at the yield line of a roundabout?

- ■ Yes, you should use your turn signals to indicate a desired right, straight or left direction change
- ☐ Yes, you should use your right turn signal to indicate you are turning on to the roundabout
- ☐ A turn signal is not necessary
- ☐ I don't know

C7. Should you use your right turn signal when exiting the roundabout?

- ■ Yes
- ☐ No
- ☐ I don't know

Please continue the survey on the next page

C8. If you are waiting at the yield line of a roundabout and an emergency vehicle arrives at one of the other approaches, what should you do?

- ☐ Proceed onto the roundabout as normal
- ☐ Proceed onto the roundabout as normal and if needed, pull over to the side of the circulating roadway if the emergency vehicle needs to pass
- ■ Wait where you are until the emergency vehicle clears the roundabout
- ☐ I don't know

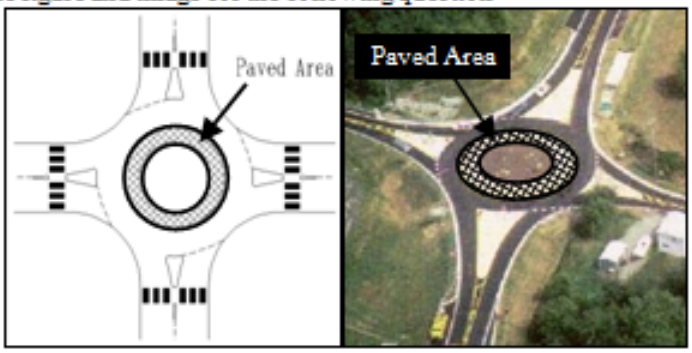
C9. If you are driving in a roundabout when an emergency vehicle approaches, what should you do?

- ☐ Proceed through the roundabout as normal until your exit
- ☐ Pull over close to the curb while still in the roundabout until the emergency vehicle clears the roundabout
- ■ Exit at the next available exit and pull over once away from the roundabout
- ☐ I don't know

C10. Where should vehicles wait for pedestrian and bicycle traffic when encountered?

- ■ At the stop lines in front of crosswalk locations
- ☐ Vehicles do not yield to pedestrians and bicyclists at roundabouts
- ☐ I don't know

Please refer to the figure and image for the following question



C11. What is the purpose of the ring-shaped paved area of a roundabout which is shown in the figure and image? (**Check all that apply**)

- ☐ For pedestrian traffic
- ☐ For bicycle traffic
- ■ Large vehicles can drive over it when making turns
- ■ Emergency vehicles can drive over it when making turns
- ☐ Only to make the roundabout look nice
- ☐ There is no specific purpose
- ☐ I don't know

Please continue the survey on the next page

The final section deals with general information about you and your driving behaviors. We remind you that you are not obligated to answer every question if you so choose.

SECTION D: General Information

D1. Check the appropriate box
- ☐ Female
- ☐ Male

D2. Within what age range do you belong?
- ☐ Under 20
- ☐ 20-24
- ☐ 25-29
- ☐ 30-34
- ☐ 35-39
- ☐ 40-44
- ☐ 45-49
- ☐ 50-54
- ☐ 55-59
- ☐ 60-64
- ☐ 65-69
- ☐ 70 or over

D3. Of what community are you a resident?
- ☐ Lincoln
- ☐ Omaha
- ☐ Norfolk
- ☐ Plattsmouth
- ☐ Blair
- ☐ Other: _____

D4. How long have you lived in your current community? _____ years

D5. How many trips do you make on an average weekday? _____ trips per weekday
A trip is defined as any time you drive a vehicle. An example of a person making three trips in one day could be one trip from home to work, one trip from work to the grocery store, and one trip from the grocery store to home.

D6. What percentage of your total trips are routine trips? _____%
Routine trips would be those trips you make on a regular basis, like to work or school.

D7. How long is your usual commute (if applicable)? _____ minutes

D8. What best describes your primary occupation?
- ☐ Management/Financial
- ☐ Education/Student
- ☐ Construction/Farming/Technical
- ☐ Transportation/Production
- ☐ Community/Social/Family
- ☐ Computers/Architecture/Engineering/Science
- ☐ Retired
- ☐ Government/Military
- ☐ Leisure/Hospitality/Sales/Arts
- ☐ Healthcare/Legal/Protective Services
- ☐ Office/Administration
- ☐ Unemployed/Laid off
- ☐ Other_____

D9. What best describes your driving speed?
- ☐ More than 5 miles below the posted speed
- ☐ Between 5 miles below and the posted speed
- ☐ At the posted speed
- ☐ Between the posted speed and 5 miles above
- ☐ More than 5 miles above the posted speed

Please continue the survey on the next page

D10. Which characteristics best describe your general driving behavior: (**check all that apply**)

- ☐ I usually have at least one passenger on most trips
- ☐ I wear my seat belt when driving
- ☐ I avoid certain roadways and intersections because of traffic safety concerns
- ☐ I avoid certain roadways and intersections because of traffic congestion
- ☐ None of these apply to me

Please indicate your opinion of the following statements using the given scale.		1 Strongly Agree	2 Agree	3 Neutral	4 Disagree	5 Strongly Disagree
D11	I favor the installation of roundabouts in my community	☐	☐	☐	☐	☐
D12	I think my community will benefit from the installation of roundabouts	☐	☐	☐	☐	☐
D13	I would like additional information about how to drive through a roundabout	☐	☐	☐	☐	☐

This concludes the survey; we thank you for your participation in this University of Nebraska-Lincoln and Nebraska Department of Roads transportation research project. Please use the bottom of this page to add any additional comments about roundabouts, their operations or this research.

Appendix B Data Coding & Reduction

To ease data analysis, the research team numerically coded survey responses. This appendix details the assignment of coding values for the survey questionnaire. In addition to defining how survey responses were coded, this appendix details how invalid survey responses were identified and treated.

The research team brought collected surveys back to the University of Nebraska-Lincoln campus for analysis. Microsoft Excel software was used for data entry and reduction. A numeric coding system was used to enter the data of each survey. The variables coded for use in analysis for this research are shown in table B.1. This table defines how the research team coded each variable used in analysis.

Table B.1 Variable Coding for Analysis

Var.	Variable Name	Definition	Coding
familiar	Familiar Driver Dummy	Defines if respondent is a familiar or unfamiliar roundabout user	0 if unfamiliar roundabout user, 1 if familiar (more than once per month)
site	Respondent Site Response	Defines what community respondent marked	1 if Lincoln, 2 if Omaha, 3 if Norfolk, 4 if Plattsmouth, 5 if Blair, 6 if Other
drvr. type	Driver Type Dummy	Defines if respondent is a specialty vehicle or passenger vehicle driver	0 if passenger vehicle driver, 1 if specialty vehicle driver
dislike	Driver Opinion Dummy	Defines if respondent favors roundabouts or not	0 if strongly favor, favor, or are neutral to roundabouts, 1 if strongly dislike or dislike roundabouts
high. trips	Number of Trips Dummy	Defines if respondent makes a high number of daily trips	0 if respondent makes fewer than 5 daily trips, 1 if 5 or more daily trips
older	Older Driver Dummy	Defines if respondent is an older driver	0 if respondent is under 60, 1 if 60 or older
can.drv	Said Can Drive Dummy	Defines if respondent said they can drive through a roundabout	0 if strongly disagree, disagree or are neutral, 1 if strongly agree or agree
platts	Respondent city does not have roundabouts	Defines if a respondent is from a community without a roundabout	0 if from a city with a roundabout, 1 if from city with roundabouts
tot.ans	Total Correct Answers	Sum of the total number of correct responses to the 9 questions used for analysis	Integers 0 through 9
C2.ans	Question C2 Answer	Defines if respondent correctly answered question C2	0 if incorrect, 1 if correct
C4.ans	Question C4 Answer	Defines if respondent correctly answered question C4	0 if incorrect, 1 if correct
C5.ans	Question C5 Answer	Defines if respondent correctly answered question C5	0 if incorrect, 1 if correct

Table B.1 Variable Coding for Analysis (cont.)

Var.	Variable Name	Definition	Coding
C7.ans	Question C7 Answer	Defines if respondent correctly answered question C7	0 if incorrect, 1 if correct
C8.ans	Question C8 Answer	Defines if respondent correctly answered question C8	0 if incorrect, 1 if correct
C9.ans	Question C9 Answer	Defines if respondent correctly answered question C9	0 if incorrect, 1 if correct
C10.ans	Question C10 Answer	Defines if respondent correctly answered question C10	0 if incorrect, 1 if correct
C11.ans	Question C11 Answer	Defines if respondent correctly answered question C11	0 if incorrect, 1 if correct
grpd.ans	Grouping of correct answers	Groups total correct answers of respondents into four categories	0 if 0-3, 1 if 4-5, 2 if 6-7, 3 if 8-9 correct answers
gender	Gender	Defines respondent gender	0 if female, 1 if male
commute	Commute time	The time in minutes of respondents commute time	Scale values
drv.spd	Typical driving speed	Respondents typical driving speed	1 if 5 below posted, 2 if 5 below to posted, 3 if at posted, 4 if posted to 5 above, 5 if 5 above posted
hv.pssngr	Driver has passengers	Defines if respondent typically has passengers	0 if does not typically have passengers, 1 if does
seat.belt	Driver wears seatbelt	Defines if respondent typically wears seatbelt	0 if does not typically wear seatbelt, 1 if does
avd.sfty	Avoids due to safety	Defines if respondent avoids roadways because of safety	0 if does not avoid due to safety, 1 if does
avd.cong	Avoids due to congestion	Defines if respondent avoids roadways because of congestion	0 if does not avoid due to congestion, 1 if does

The variables in table B.1 were used throughout the analysis. The first seven variables of the table represent the variables used for each of the six hypotheses and the driver perception analysis. For example, the variable "familiar" was used in conjunction with each of the nine questions assessing knowledge of correct roundabout negotiation to test hypothesis 1: familiar roundabout users will have less potential for incorrect roundabout negotiation. The research team coded these seven variables to categorize the respondents into different groups according to the goals of the research.

The research team defined the variable "familiar" for hypothesis 1 using question A1 and A2 from the survey questionnaire. Respondents had a choice of responses representing the number of times they drive through a single-lane (A1) or multi-lane (A2) roundabout. The research team categorized those respondents that marked "I have never driven through a roundabout;" "A few times when visiting another place;" "About once per month;" or "I don't know" as unfamiliar roundabout users. The research team categorized those that responded with "Several times per month;" "Several times per week;" or "At least once per day" as familiar roundabout users. If a respondent was categorized as a familiar driver from either question A1 or A2, a one value was assigned to the variable "familiar." If the respondent was categorized as an unfamiliar driver in both questions, a zero value was assigned.

The research team defined the variable "drv.typ" for hypothesis 2 using question A5 from the survey questionnaire. The survey asked for specialty vehicle drivers to mark the type of specialty vehicle they drive. If a survey respondent marked down any of the specialty vehicle types, the research team assigned a one value to the variable "drv.typ." If the respondent left the question blank, the research team categorized those respondents as passenger vehicle drivers and assigned a zero value to the variable "drv.typ."

The research team defined the variable "site" for hypothesis 3 using question D3 from the survey questionnaire. The survey asked respondents to mark the community that they are of a resident of. Each of the five survey cities were included along with a sixth choice of "other" for those respondents that did not live in the community they were responding to the survey in. This variable represents the community the respondent marked down as a resident of, regardless of the city where the survey was distributed. The research team coded the variable "site" to assign an integer value from 1 to 6 for each of the choices, as can be seen in table B.1.

The research team defined the variable "older" for hypothesis 4 using question D2 from the survey questionnaire. The survey asked respondents to mark their age range in 5-year increments. The research team defined an older driver as being over 60 years old, as many Americans are preparing to retire between the ages of 60 and 65 (30). The variable "older" assigned a one value to those respondents that marked age ranges 60 or over and a zero value to respondents that marked age ranges below 60.

The research team defined the variable "high.trip" for hypothesis 5 using question D5 from the survey questionnaire. The survey asked respondents how many daily trips they make, where a trip is any time a vehicle is driven between two points. The variable "high.trip" assigned a one value to those respondents that make five or more trips per day and a zero value to those respondents that make less than five trips per day. The research team defined a respondent making five or more trips as making a high number of daily trips. The median response to this question was 4 trips, so a respondent making 5 or more trips is a more frequent driver.

The research team defined the variable "dislike" for hypothesis 6 using question B1 from the survey questionnaire. The survey asked respondents if they like roundabouts on a five-point scale (Strongly agree, agree, neutral, disagree, and strongly disagree). The variable

"dislike" assigned a one value to those respondents that marked "Disagree" or "Strongly Disagree," and a zero value to those respondents that marked "Strongly Agree," "Agree," or "Neutral."

The research team defined the variable "can.drv" for hypothesis 7 using question B7 from the survey questionnaire. The survey asked respondents if they felt confident that they could drive through a roundabout in the correct way using a five-point scale (Strongly agree, agree, neutral, disagree, and strongly disagree). The variable "can.drv" assigned a one value to those respondents that marked "Strongly Agree" or "Agree" and a zero value to those respondents that marked "Strongly Disagree," "Disagree," or "Neutral."

The research team defined the variable "platts" for the regression analysis using question D3 from the survey questionnaire. Similar to the "site" variable used in the cross tabulation analyses, this variable simply defines the respondent as either being from a community with roundabouts or not, as all communities other than Plattsmouth have roundabouts. If a survey respondent marked down they were from Plattsmouth, the research team assigned a one value to the variable "platts" otherwise a zero was assigned.

The research team defined the variable "tot.ans" for the final analysis combining the hypotheses. This variable represents the total number of correct answers to the nine questions assessing knowledge of correct roundabout negotiation. For example, if a respondent correctly answers six of these nine questions, the "tot.ans" variable will be a six.

The rest of the variables defined in table B.1 represent the responses to each of the questions assessing knowledge of correct roundabout negotiation and the extra variables used for the ordinal regression model analysis. The research team coded each of the nine variables representing the nine questions assessing knowledge of correct roundabout negotiation to

produce a zero if the respondent incorrectly answered the question and a one if the respondent correctly answered the question. Responses of "I don't know" or if the question was left blank were coded as zeros also. The research team will use these variables in conjunction with the seven variables discussed above to conduct the analyses of this research.

This initial data entry included every survey returned to the research team. Some survey respondents incorrectly responded to the survey or did not complete the entire survey. The research team reviewed the full data set and eliminated the data from several returned surveys. An example of an eliminated survey due to incompleteness and one due to incorrect response is discussed below.

The research team eliminated survey response number 84 from the final data set due to incompleteness. Of the total 39 questions of the survey, this respondent only completed 28. Of those 11 questions unanswered, seven of them were questions assessing knowledge of correct roundabout negotiation. Since the respondent's intent could not be determined, the research team did not use the results of this survey for analysis.

The research team eliminated survey response number 71 from the final data set due to inaccuracy. This respondent marked that they drove every type of specialty vehicle in question A5.

Of the total 1,136 surveys entered, the research team removed a total of 20 survey responses from the final data set because they were not useable. The 20 deleted survey responses and the reasons for deletion are shown in table B.2. The final data set used for analysis had 1,116 survey responses.

Table B.2 Deleted Survey Responses

Response number	Reason for deletion
38	No response to Section A
68	No response to Section C
69	No response to Section C
71	Responded as every type of specialty vehicle driver
157	No response to Section D
160	Did not complete the survey after question C7
179	No response to Section C
298	No response to Section C
357	No response to Section C
456	No response to Section C
521	No response to Section C
547	Multiple Responses to Section B
549	No response to Section C
608	No response to Section C
683	No response to Section C
687	Did not complete the survey after question C7
771	Did not complete the survey after question C1
807	Did not complete the survey after question C7
819	Did not complete the survey after question C7
877	Did not complete the survey after Section A

Appendix C Cross Tabulation Results

Hypothesis 1

The following cross tabulation results determine if unfamiliar roundabout users have greater potential for incorrect roundabout negotiation than familiar roundabout users.

Table C.1 Hypothesis 1 Cross Tabulation Results for Question C2

Question C2. Which vehicle should yield?			
	Incorrect	Correct	Total
Unfamiliar User	50	302	352
Familiar User	47	717	764
Total	97	1019	1116
Chi-Squared Value	19.690		
Significance	0.000		

Table C.2 Hypothesis 1 Cross Tabulation Results for Question C4

Question C4. Which is the correct left turn?			
	Incorrect	Correct	Total
Unfamiliar User	21	331	352
Familiar User	26	738	764
Total	47	1069	1116
Chi-Squared Value	3.923		
Significance	0.048		

Table C.3 Hypothesis 1 Cross Tabulation Results for Question C5

Question C5. What to do if missed exit?			
	Incorrect	Correct	Total
Unfamiliar User	29	323	352
Familiar User	47	717	764
Total	76	1040	1116
Chi-Squared Value	1.654		
Significance	0.198		

Table C.4 Hypothesis 1 Cross Tabulation Results for Question C6

Question C6. Use turn signal when entering?			
	Incorrect	Correct	Total
Unfamiliar User	298	54	352
Familiar User	660	104	764
Total	958	158	1116
Chi-Squared Value	0.592		
Significance	0.442		

Table C.5 Hypothesis 1 Cross Tabulation Results for Question C7

Question C7. Use turn signal when exiting?			
	Incorrect	Correct	Total
Unfamiliar User	81	271	352
Familiar User	272	492	764
Total	353	763	1116
Chi-Squared Value	17.665		
Significance	0.000		

Table C.6 Hypothesis 1 Cross Tabulation Results for Question C8

Question C8. What to do if emergency vehicle (at yield)?			
	Incorrect	Correct	Total
Unfamiliar User	58	294	352
Familiar User	97	667	764
Total	155	961	1116
Chi-Squared Value	2.880		
Significance	0.090		

Table C.7 Hypothesis 1 Cross Tabulation Results for Question C9

Question C9. What to do if emergency vehicle (in circle)?			
	Incorrect	Correct	Total
Unfamiliar User	262	90	352
Familiar User	310	454	764
Total	572	544	1116
Chi-Squared Value	110.554		
Significance	0.000		

Table C.8 Hypothesis 1 Cross Tabulation Results for Question C10

Question C10. Where to wait for pedestrians?			
	Incorrect	Correct	Total
Unfamiliar User	142	210	352
Familiar User	192	572	764
Total	334	782	1116
Chi-Squared Value	26.583		
Significance	0.000		

Table C9 Hypothesis 1 Cross Tabulation Results for Question C11

Question C11. What is the truck apron?			
	Incorrect	Correct	Total
Unfamiliar User	327	25	352
Familiar User	653	111	764
Total	980	136	1116
Chi-Squared Value	12.420		
Significance	0.000		

Hypothesis 2

The following cross tabulation results determine if passenger vehicle drivers have greater potential for incorrect roundabout negotiation than specialty vehicle drivers.

Table C.10 Hypothesis 2 Cross Tabulation Results for Question C2

Question C2. Which vehicle should yield?			
	Incorrect	Correct	Total
Passenger Vehicle Driver	72	789	861
Specialty Vehicle Driver	25	230	255
Total	97	1019	1116
Chi-Squared Value	0.515		
Significance	0.473		

Table C.11 Hypothesis 2 Cross Tabulation Results for Question C4

Question C4. Which is the correct left turn?			
	Incorrect	Correct	Total
Passenger Vehicle Driver	37	824	861
Specialty Vehicle Driver	10	245	255
Total	47	1069	1116
Chi-Squared Value	0.069		
Significance	0.793		

Table C.12 Hypothesis 2 Cross Tabulation Results for Question C5

Question C5. What to do if missed exit?			
	Incorrect	Correct	Total
Passenger Vehicle Driver	62	799	861
Specialty Vehicle Driver	14	241	255
Total	76	1040	1116
Chi-Squared Value	0.907		
Significance	0.341		

Table C.13 Hypothesis 2 Cross Tabulation Results for Question C6

Question C6. Use turn signal when entering?			
	Incorrect	Correct	Total
Passenger Vehicle Driver	745	116	861
Specialty Vehicle Driver	213	42	255
Total	958	158	1116
Chi-Squared Value	1.455		
Significance	0.228		

Table C.14 Hypothesis 2 Cross Tabulation Results for Question C7

Question C7. Use turn signal when exiting?			
	Incorrect	Correct	Total
Passenger Vehicle Driver	302	559	861
Specialty Vehicle Driver	51	204	255
Total	353	763	1116
Chi-Squared Value	20.675		
Significance	0.000		

Table C.15 Hypothesis 2 Cross Tabulation Results for Question C8

Question C8. What to do if emergency vehicle (at yield)?			
	Incorrect	Correct	Total
Passenger Vehicle Driver	129	732	861
Specialty Vehicle Driver	26	229	255
Total	155	961	1116
Chi-Squared Value	3.769		
Significance	0.052		

Table C.16 Hypothesis 2 Cross Tabulation Results for Question C9

Question C9. What to do if emergency vehicle (in circle)?			
	Incorrect	Correct	Total
Passenger Vehicle Driver	454	407	861
Specialty Vehicle Driver	118	137	255
Total	572	544	1116
Chi-Squared Value	3.281		
Significance	0.070		

Table C.17 Hypothesis 2 Cross Tabulation Results for Question C10

Question C10. Where to wait for pedestrians?			
	Incorrect	Correct	Total
Passenger Vehicle Driver	267	594	861
Specialty Vehicle Driver	67	188	255
Total	334	782	1116
Chi-Squared Value	2.104		
Significance	0.147		

Table C.18 Hypothesis 2 Cross Tabulation Results for Question C11

Question C11. What is the truck apron?			
	Incorrect	Correct	Total
Passenger Vehicle Driver	774	87	861
Specialty Vehicle Driver	206	49	255
Total	980	136	1116
Chi-Squared Value	15.261		
Significance	0.000		

Hypothesis 3

The following cross tabulation results determine if drivers in communities that do not have roundabouts have greater potential for incorrect roundabout negotiation than drivers in communities that have roundabouts.

Table C.19 Hypothesis 3 Cross Tabulation Results for Question C2

Question C2. Which vehicle should yield?			
	Incorrect	Correct	Total
Lincoln	12	220	232
Omaha	23	214	237
Norfolk	15	229	244
Plattsmouth	25	108	133
Blair	10	162	172
Other	10	81	91
Total	95	1014	1109
Chi-Squared Value	25.745		
Significance	0.000		

Table C.20 Hypothesis 3 Cross Tabulation Results for Question C4

Question C4. Which is the correct left turn?			
	Incorrect	Correct	Total
Lincoln	8	224	232
Omaha	6	231	237
Norfolk	8	236	244
Plattsmouth	12	121	133
Blair	5	167	172
Other	7	84	91
Total	46	1063	1109
Chi-Squared Value	13.797		
Significance	0.017		

Table C.21 Hypothesis 3 Cross Tabulation Results for Question C5

Question C5. What to do if missed exit?			
	Incorrect	Correct	Total
Lincoln	10	222	232
Omaha	14	223	237
Norfolk	18	226	244
Plattsmouth	15	118	133
Blair	10	162	172
Other	7	84	91
Total	74	1035	1109
Chi-Squared Value	7.382		
Significance	0.194		

Table C.22 Hypothesis 3 Cross Tabulation Results for Question C6

Question C6. Use turn signal when entering?			
	Incorrect	Correct	Total
Lincoln	210	22	232
Omaha	208	29	237
Norfolk	198	46	244
Plattsmouth	109	24	133
Blair	152	20	172
Other	76	15	91
Total	953	156	1109
Chi-Squared Value	12.340		
Significance	0.030		

Table C.23 Hypothesis 3 Cross Tabulation Results for Question C7

Question C7. Use turn signal when exiting?			
	Incorrect	Correct	Total
Lincoln	69	163	232
Omaha	60	177	237
Norfolk	93	151	244
Plattsmouth	30	103	133
Blair	78	94	172
Other	19	72	91
Total	349	760	1109
Chi-Squared Value	34.473		
Significance	0.000		

Table C.24 Hypothesis 3 Cross Tabulation Results for Question C8

Question C8. What to do if emergency vehicle (at yield)?			
	Incorrect	Correct	Total
Lincoln	32	200	232
Omaha	33	204	237
Norfolk	26	218	244
Plattsmouth	27	106	133
Blair	27	145	172
Other	8	83	91
Total	153	956	1109
Chi-Squared Value	9.198		
Significance	0.101		

Table C.25 Hypothesis 3 Cross Tabulation Results for Question C9

Question C9. What to do if emergency vehicle (in circle)?			
	Incorrect	Correct	Total
Lincoln	85	147	232
Omaha	147	90	237
Norfolk	68	176	244
Plattsmouth	108	25	133
Blair	103	69	172
Other	56	35	91
Total	567	542	1109
Chi-Squared Value	140.953		
Significance	0.000		

Table C.26 Hypothesis 3 Cross Tabulation Results for Question C10

Question C10. Where to wait for pedestrians?			
	Incorrect	Correct	Total
Lincoln	37	195	232
Omaha	86	151	237
Norfolk	50	194	244
Plattsmouth	60	73	133
Blair	70	102	172
Other	29	62	91
Total	332	777	1109
Chi-Squared Value	60.839		
Significance	0.000		

Table C.27 Hypothesis 3 Cross Tabulation Results for Question C11

Question C11. What is the truck apron?			
	Incorrect	Correct	Total
Lincoln	191	41	232
Omaha	225	12	237
Norfolk	203	41	244
Plattsmouth	128	5	133
Blair	149	23	172
Other	77	14	91
Total	973	136	1109
Chi-Squared Value	32.362		
Significance	0.000		

Hypothesis 4

The following cross tabulation results determine if older drivers have a greater potential for incorrect roundabout negotiation compared with younger drivers.

Table C.28 Hypothesis 4 Cross Tabulation Results for Question C2

Question C2. Which vehicle should yield?			
	Incorrect	Correct	Total
Respondent under 60	70	913	983
Respondent over 60	26	96	122
Total	96	1009	1105
Chi-Squared Value	27.549		
Significance	0.000		

Table C.29 Hypothesis 4 Cross Tabulation Results for Question C4

Question C4. Which is the correct left turn?			
	Incorrect	Correct	Total
Respondent under 60	32	951	983
Respondent over 60	14	108	122
Total	46	1059	1105
Chi-Squared Value	18.381		
Significance	0.000		

Table C.30 Hypothesis 4 Cross Tabulation Results for Question C5

Question C5. What to do if missed exit?			
	Incorrect	Correct	Total
Respondent under 60	61	922	983
Respondent over 60	13	109	122
Total	74	1031	1105
Chi-Squared Value	3.440		
Significance	0.064		

Table C.31 Hypothesis 4 Cross Tabulation Results for Question C6

Question C6. Use turn signal when entering?			
	Incorrect	Correct	Total
Respondent under 60	846	137	983
Respondent over 60	102	20	122
Total	948	157	1105
Chi-Squared Value	0.537		
Significance	0.464		

Table C.32 Hypothesis 4 Cross Tabulation Results for Question C7

Question C7. Use turn signal when exiting?			
	Incorrect	Correct	Total
Respondent under 60	305	678	983
Respondent over 60	45	77	122
Total	350	755	1105
Chi-Squared Value	1.721		
Significance	0.190		

Table C.33 Hypothesis 4 Cross Tabulation Results for Question C8

Question C8. What to do if emergency vehicle (at yield)?			
	Incorrect	Correct	Total
Respondent under 60	137	846	983
Respondent over 60	15	107	122
Total	152	953	1105
Chi-Squared Value	0.247		
Significance	0.619		

Table C.34 Hypothesis 4 Cross Tabulation Results for Question C9

Question C9. What to do if emergency vehicle (in circle)?			
	Incorrect	Correct	Total
Respondent under 60	496	487	983
Respondent over 60	69	53	122
Total	565	540	1105
Chi-Squared Value	1.616		
Significance	0.204		

Table C.35 Hypothesis 4 Cross Tabulation Results for Question C10

Question C10. Where to wait for pedestrians?			
	Incorrect	Correct	Total
Respondent under 60	280	703	983
Respondent over 60	49	73	122
Total	329	776	1105
Chi-Squared Value	7.081		
Significance	0.008		

Table C.36 Hypothesis 4 Cross Tabulation Results for Question C11

Question C11. What is the truck apron?			
	Incorrect	Correct	Total
Respondent under 60	860	123	983
Respondent over 60	109	13	122
Total	969	136	1105
Chi-Squared Value	0.347		
Significance	0.556		

Hypothesis 5

The following cross tabulation results determine if drivers that make less than five daily trips have a greater potential for incorrect roundabout negotiation than drivers that make five or more daily trips.

Table C.37 Hypothesis 5 Cross Tabulation Results for Question C2

Question C2. Which vehicle should yield?			
	Incorrect	Correct	Total
Fewer than 5 daily trips	56	577	633
5 or more daily trips	36	421	457
Total	92	998	1090
Chi-Squared Value	0.323		
Significance	0.570		

Table C.38 Hypothesis 5 Cross Tabulation Results for Question C4

Question C4. Which is the correct left turn?			
	Incorrect	Correct	Total
Fewer than 5 daily trips	21	612	633
5 or more daily trips	22	435	457
Total	43	1047	1090
Chi-Squared Value	1.568		
Significance	0.210		

Table C.39 Hypothesis 5 Cross Tabulation Results for Question C5

Question C5. What to do if missed exit?			
	Incorrect	Correct	Total
Fewer than 5 daily trips	40	593	633
5 or more daily trips	32	425	457
Total	72	1018	1090
Chi-Squared Value	0.201		
Significance	0.654		

Table C.40 Hypothesis 5 Cross Tabulation Results for Question C6

Question C6. Use turn signal when entering?			
	Incorrect	Correct	Total
Fewer than 5 daily trips	551	82	633
5 or more daily trips	389	68	457
Total	940	150	1090
Chi-Squared Value	0.829		
Significance	0.363		

Table C.41 Hypothesis 5 Cross Tabulation Results for Question C7

Question C7. Use turn signal when exiting?			
	Incorrect	Correct	Total
Fewer than 5 daily trips	214	419	633
5 or more daily trips	132	325	457
Total	346	744	1090
Chi-Squared Value	2.969		
Significance	0.085		

Table C.42 Hypothesis 5 Cross Tabulation Results for Question C8

Question C8. What to do if emergency vehicle (at yield)?			
	Incorrect	Correct	Total
Fewer than 5 daily trips	80	553	633
5 or more daily trips	70	387	457
Total	150	940	1090
Chi-Squared Value	1.605		
Significance	0.205		

Table C.43 Hypothesis 5 Cross Tabulation Results for Question C9

Question C9. What to do if emergency vehicle (in circle)?			
	Incorrect	Correct	Total
Fewer than 5 daily trips	331	302	633
5 or more daily trips	225	232	457
Total	556	534	1090
Chi-Squared Value	0.992		
Significance	0.319		

Table C.44 Hypothesis 5 Cross Tabulation Results for Question C10

Question C10. Where to wait for pedestrians?			
	Incorrect	Correct	Total
Fewer than 5 daily trips	193	440	633
5 or more daily trips	129	328	457
Total	322	768	1090
Chi-Squared Value	0.652		
Significance	0.419		

Table C.45 Hypothesis 5 Cross Tabulation Results for Question C11

Question C11. What is the truck apron?			
	Incorrect	Correct	Total
Fewer than 5 daily trips	563	70	633
5 or more daily trips	392	65	457
Total	955	135	1090
Chi-Squared Value	2.450		
Significance	0.118		

Hypothesis 6

The following cross tabulation results determine if drivers that dislike roundabouts have a greater potential for incorrect roundabout negotiation compared to drivers that like roundabouts.

Table C.46 Hypothesis 6 Cross Tabulation Results for Question C2

Question C2. Which vehicle should yield?			
	Incorrect	Correct	Total
Favor roundabouts	65	814	879
Dislike roundabouts	32	205	237
Total	97	1019	1116
Chi-Squared Value	8.773		
Significance	0.003		

Table C.47 Hypothesis 6 Cross Tabulation Results for Question C4

Question C4. Which is the correct left turn?			
	Incorrect	Correct	Total
Favor roundabouts	34	845	879
Dislike roundabouts	13	224	237
Total	47	1069	1116
Chi-Squared Value	1.210		
Significance	0.271		

Table C.48 Hypothesis 6 Cross Tabulation Results for Question C5

Question C5. What to do if missed exit?			
	Incorrect	Correct	Total
Favor roundabouts	48	831	879
Dislike roundabouts	28	209	237
Total	76	1040	1116
Chi-Squared Value	11.874		
Significance	0.001		

Table C.49 Hypothesis 6 Cross Tabulation Results for Question C6

Question C6. Use turn signal when entering?			
	Incorrect	Correct	Total
Favor roundabouts	765	114	879
Dislike roundabouts	193	44	237
Total	958	158	1116
Chi-Squared Value	4.810		
Significance	0.028		

Table C.50 Hypothesis 6 Cross Tabulation Results for Question C7

Question C7. Use turn signal when exiting?			
	Incorrect	Correct	Total
Favor roundabouts	257	622	879
Dislike roundabouts	96	141	237
Total	353	763	1116
Chi-Squared Value	10.961		
Significance	0.001		

Table C.51 Hypothesis 6 Cross Tabulation Results for Question C8

Question C8. What to do if emergency vehicle (at yield)?			
	Incorrect	Correct	Total
Favor roundabouts	122	757	879
Dislike roundabouts	33	204	237
Total	155	961	1116
Chi-Squared Value	0.000		
Significance	0.986		

Table C.52 Hypothesis 6 Cross Tabulation Results for Question C9

Question C9. What to do if emergency vehicle (in circle)?			
	Incorrect	Correct	Total
Favor roundabouts	446	433	879
Dislike roundabouts	126	111	237
Total	572	544	1116
Chi-Squared Value	0.439		
Significance	0.507		

Table C.53 Hypothesis 6 Cross Tabulation Results for Question C10

Question C10. Where to wait for pedestrians?			
	Incorrect	Correct	Total
Favor roundabouts	245	634	879
Dislike roundabouts	89	148	237
Total	334	782	1116
Chi-Squared Value	8.341		
Significance	0.004		

Table C.54 Hypothesis 6 Cross Tabulation Results for Question C11

Question C11. What is the truck apron?			
	Incorrect	Correct	Total
Favor roundabouts	760	119	879
Dislike roundabouts	220	17	237
Total	980	136	1116
Chi-Squared Value	7.067		
Significance	0.008		

Hypothesis 7

The following cross tabulation results determine if drivers that are not confident that they can negotiate a roundabout in the correct way have a greater potential for incorrect roundabout negotiation compared to drivers that are confident that they can negotiate a roundabout in the correct way.

Table C.55 Hypothesis 7 Cross Tabulation Results for Question C2

Question C2. Which vehicle should yield?			
	Incorrect	Correct	Total
Not confident can drive through roundabout	30	99	129
Confident can drive through roundabout	63	906	969
Total	93	1005	1098
Chi-Squared Value	41.221		
Significance	0.000		

Table C.56 Hypothesis 7 Cross Tabulation Results for Question C4

Question C4. Which is the correct left turn?			
	Incorrect	Correct	Total
Not confident can drive through roundabout	22	107	129
Confident can drive through roundabout	22	947	969
Total	44	1054	1098
Chi-Squared Value	64.684		
Significance	0.000		

Table C.57 Hypothesis 7 Cross Tabulation Results for Question C5

Question C5. What to do if missed exit?			
	Incorrect	Correct	Total
Not confident can drive through roundabout	29	100	129
Confident can drive through roundabout	44	925	969
Total	73	1025	1098
Chi-Squared Value	59.035		
Significance	0.000		

Table C.58 Hypothesis 7 Cross Tabulation Results for Question C6

Question C6. Use turn signal when entering?			
	Incorrect	Correct	Total
Not confident can drive through roundabout	107	22	129
Confident can drive through roundabout	837	132	969
Total	944	154	1098
Chi-Squared Value	1.112		
Significance	0.292		

Table C.59 Hypothesis 7 Cross Tabulation Results for Question C7

Question C7. Use turn signal when exiting?			
	Incorrect	Correct	Total
Not confident can drive through roundabout	55	74	129
Confident can drive through roundabout	289	680	969
Total	344	754	1098
Chi-Squared Value	8.685		
Significance	0.003		

Table C.60 Hypothesis 7 Cross Tabulation Results for Question C8

Question C8. What to do if emergency vehicle (at yield)?			
	Incorrect	Correct	Total
Not confident can drive through roundabout	43	86	129
Confident can drive through roundabout	107	862	969
Total	150	948	1098
Chi-Squared Value	47.960		
Significance	0.000		

Table C.61 Hypothesis 7 Cross Tabulation Results for Question C9

Question C9. What to do if emergency vehicle (in circle)?			
	Incorrect	Correct	Total
Not confident can drive through roundabout	93	36	129
Confident can drive through roundabout	469	500	969
Total	562	536	1098
Chi-Squared Value	25.576		
Significance	0.000		

Table C.62 Hypothesis 7 Cross Tabulation Results for Question C10

Question C10. Where to wait for pedestrians?			
	Incorrect	Correct	Total
Not confident can drive through roundabout	70	59	129
Confident can drive through roundabout	257	712	969
Total	327	771	1098
Chi-Squared Value	41.896		
Significance	0.000		

Table C.63 Hypothesis 7 Cross Tabulation Results for Question C11

Question C11. What is the truck apron?			
	Incorrect	Correct	Total
Not confident can drive through roundabout	122	7	129
Confident can drive through roundabout	841	128	969
Total	963	135	1098
Chi-Squared Value	6.395		
Significance	0.011		

Ordinal Regression Model

The results of the initial ordinal regression model are reported in table C.64.

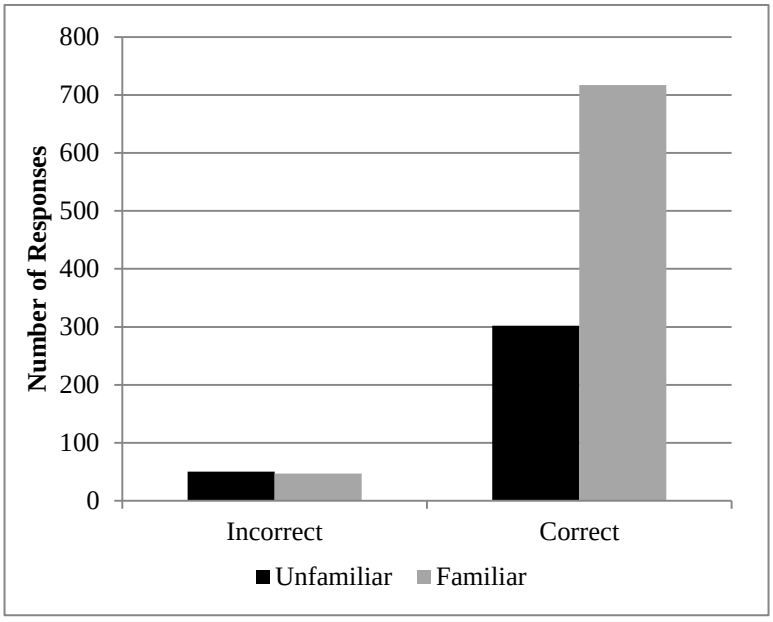
Table C.64 Initial Ordinal Regression Analysis

Model Fitting Information			
Chi-Square	137.119		
Degrees of Freedom	14		
Significance	0.000		
Parameter	Estimate	Std. Error	t-value
familiar	0.397	0.173	2.289
drvr.type	0.520	0.179	2.909
platts	-0.334	0.229	-1.462
older	-0.465	0.212	-2.197
high.trips	0.113	0.135	0.833
dislike	-0.273	0.165	-1.656
can.drv	1.235	0.210	5.871
gender	0.580	0.142	4.081
commute	0.002	0.003	0.799
driv.spd	-0.120	0.090	-1.332
hv.pssngr	-0.120	0.141	-0.857
seat.belt	0.654	0.188	3.471
avd.sfty	-0.053	0.172	-0.311
avd.cong	0.265	0.140	1.894

Variables were removed from the model if their respective t-values were below the 95% confidence level threshold. The final model with parameter effects on the model can be seen in Chapter 5.

Appendix D Graphical Representation of Significant Results

Hypothesis 1



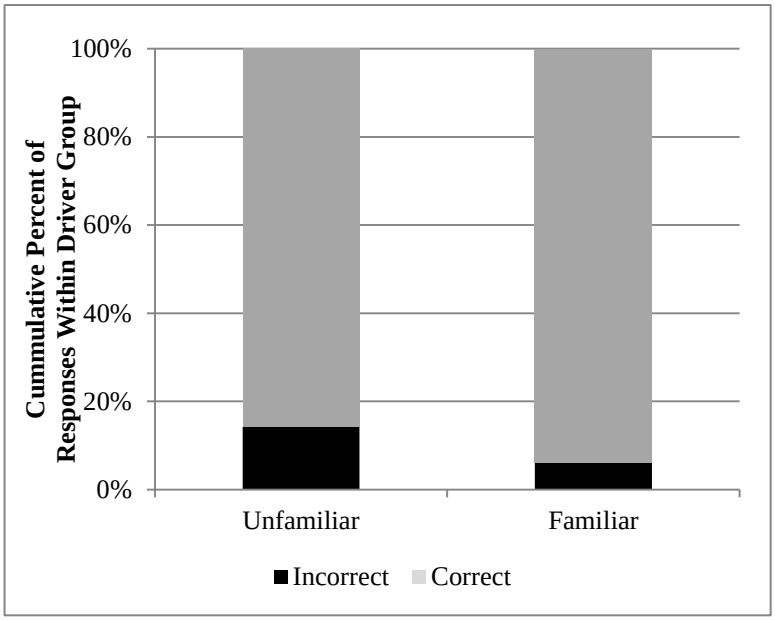


Figure D.1 Question C2 Graphical Results for Hypothesis 1

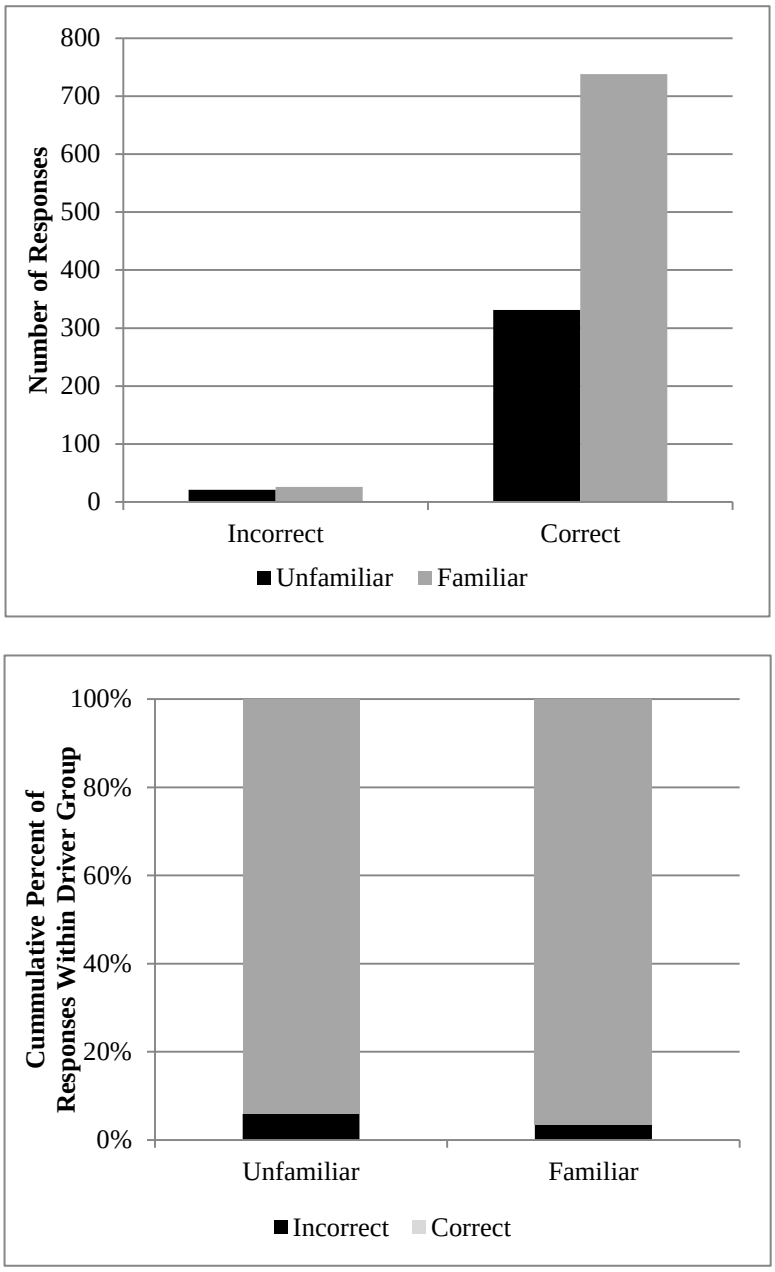


Figure D.2 Question C4 Graphical Results for Hypothesis 1

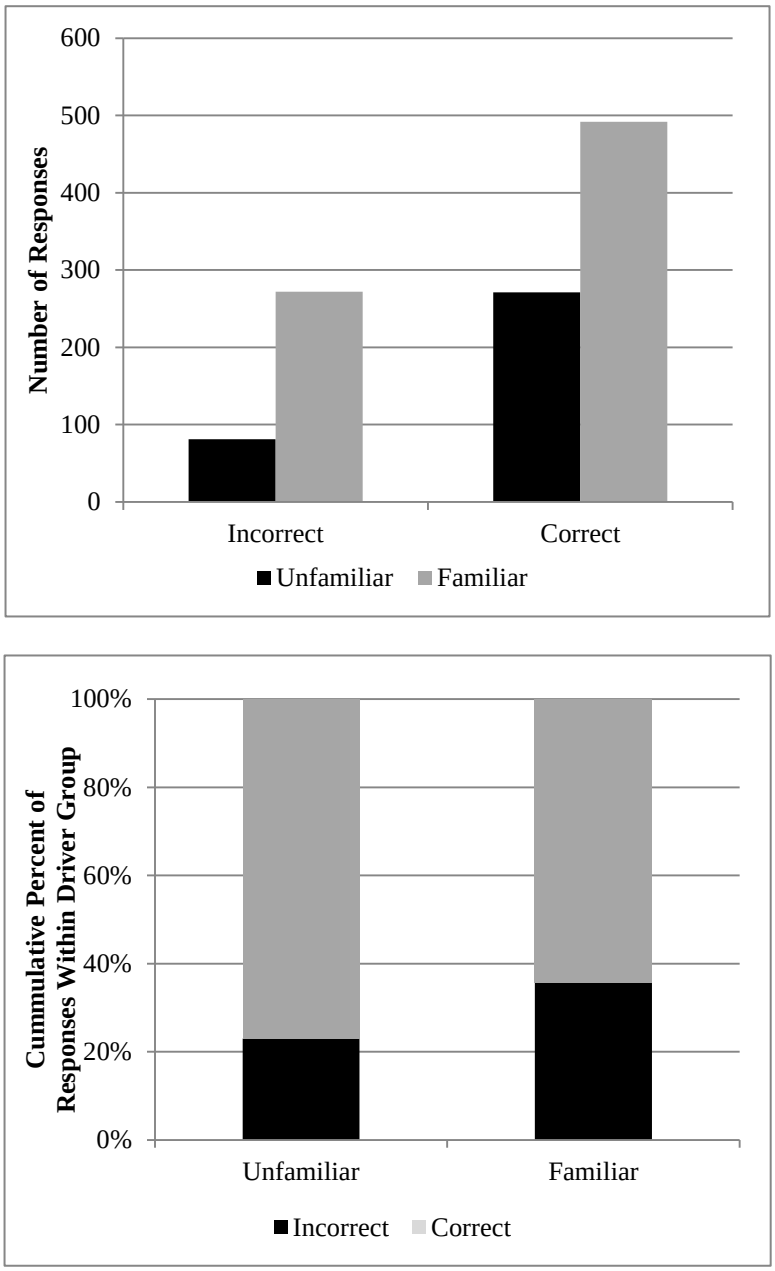
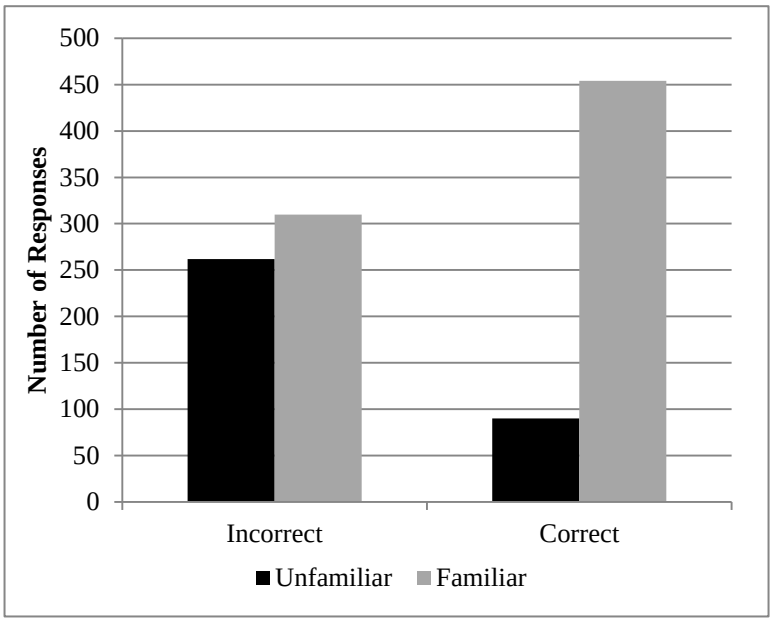


Figure D.3 Question C7 Graphical Results for Hypothesis 1



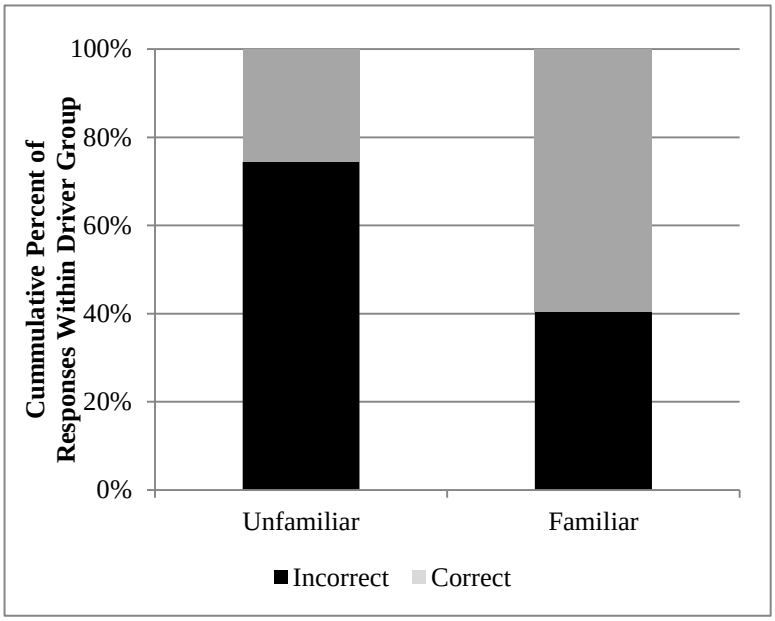


Figure D.4 Question C9 Graphical Results for Hypothesis 1

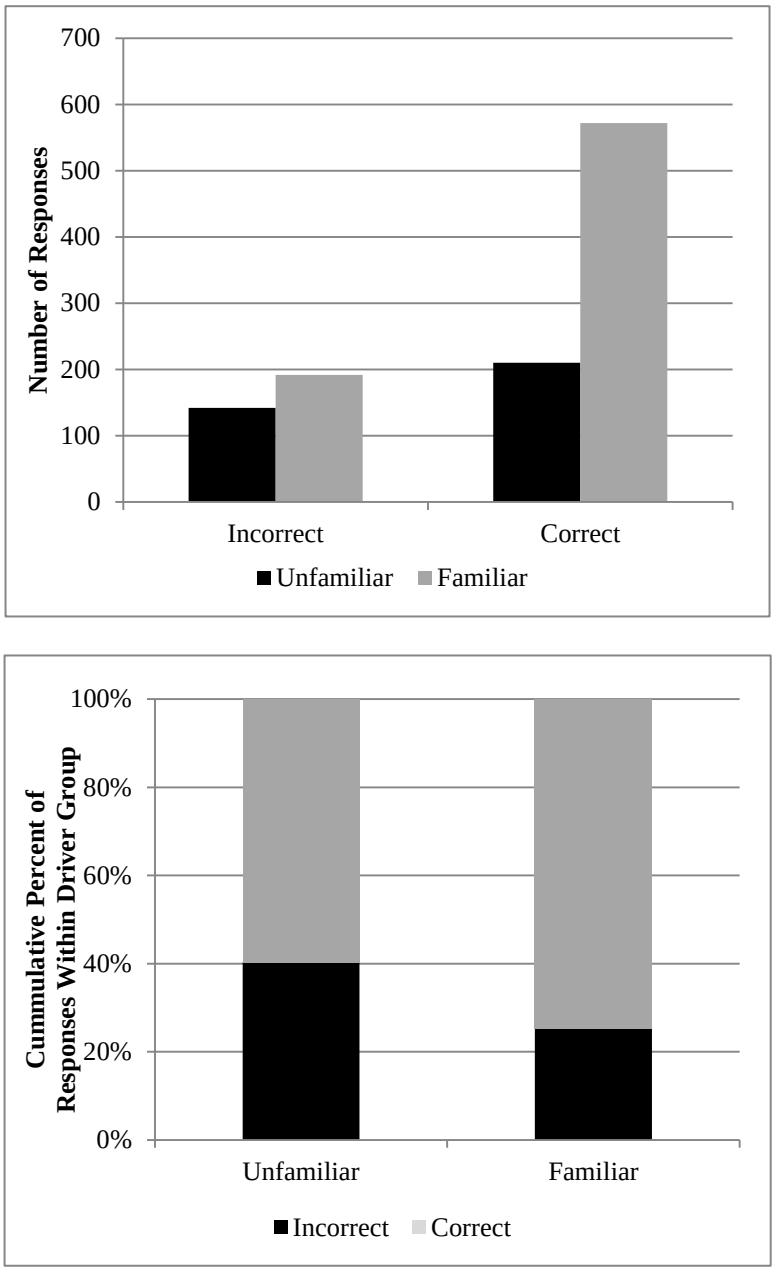


Figure D.5 Question C10 Graphical Results for Hypothesis 1

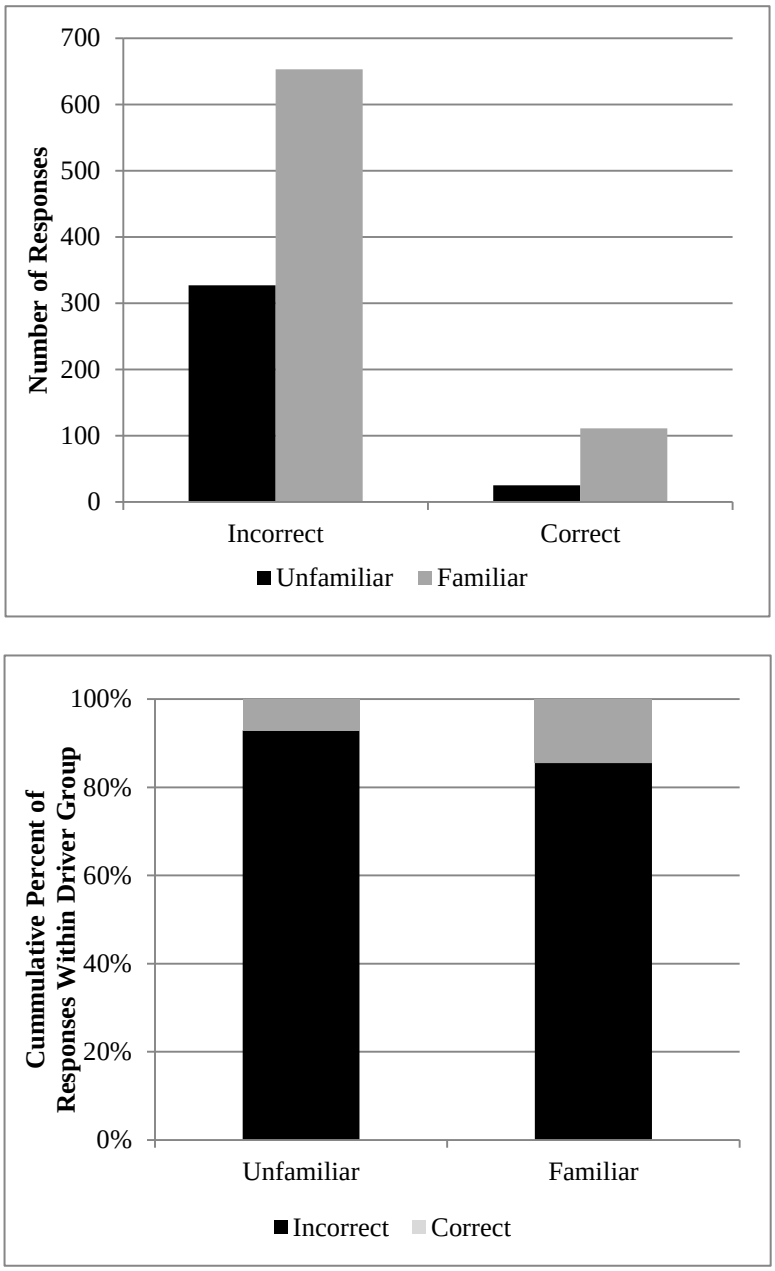
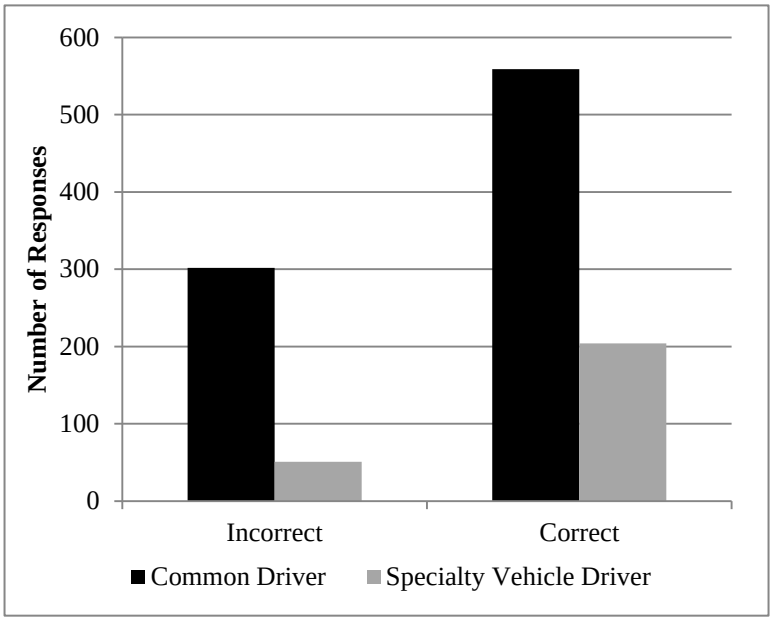


Figure D.6 Question C11 Graphical Results for Hypothesis 1

Hypothesis 2



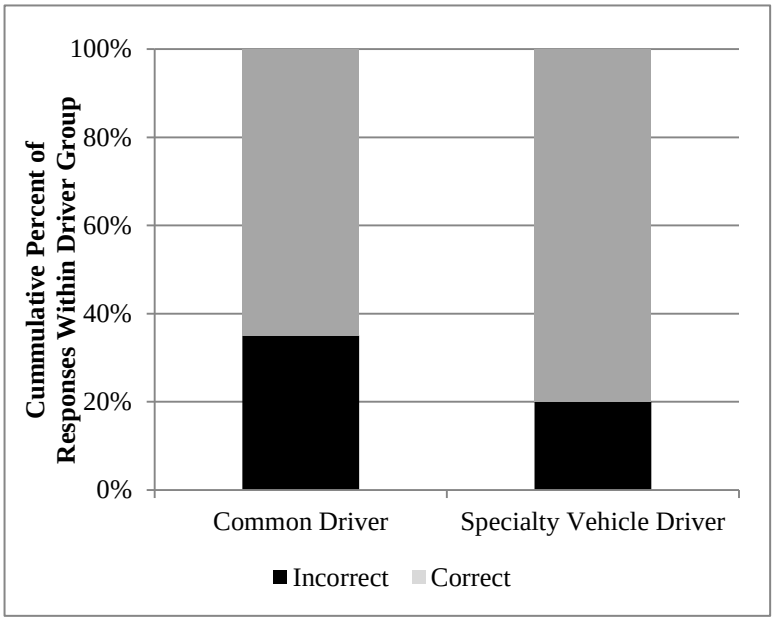
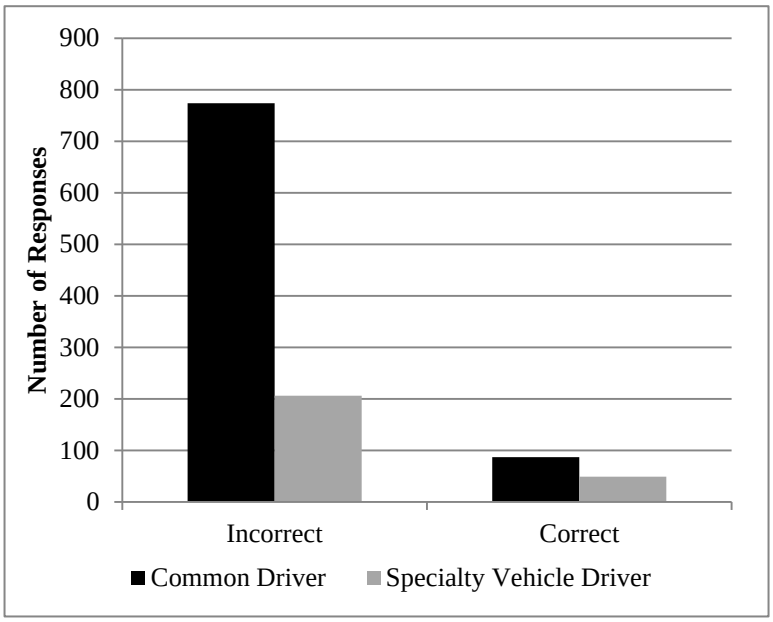


Figure D.7 Question C7 Graphical Results for Hypothesis 2



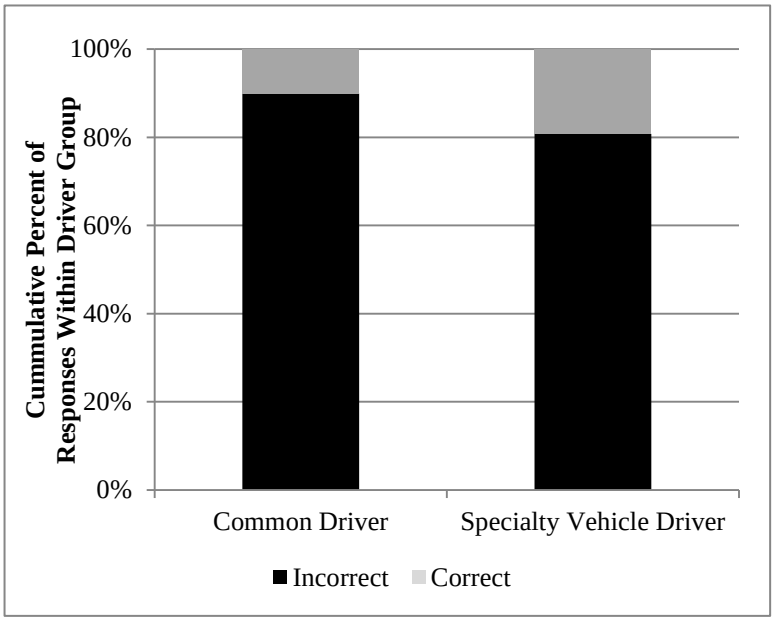
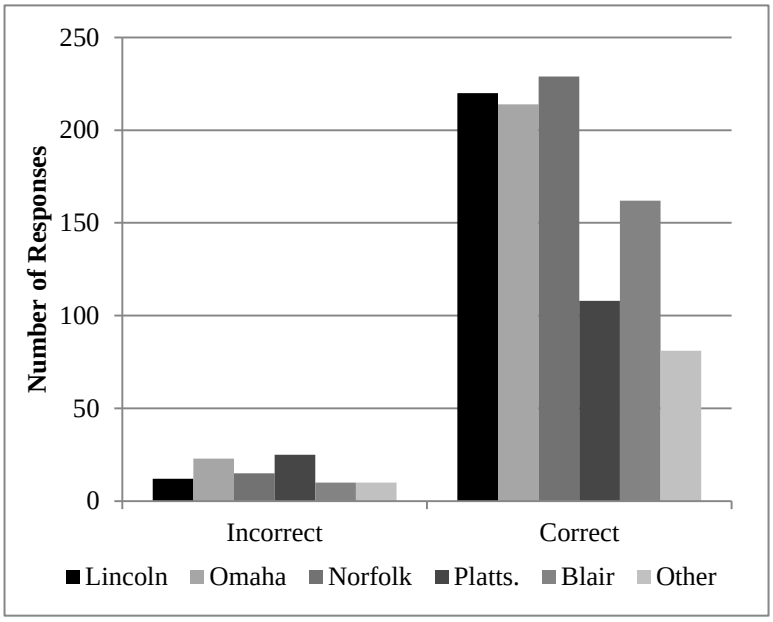


Figure D.8 Question C11 Graphical Results for Hypothesis 2

Hypothesis 3



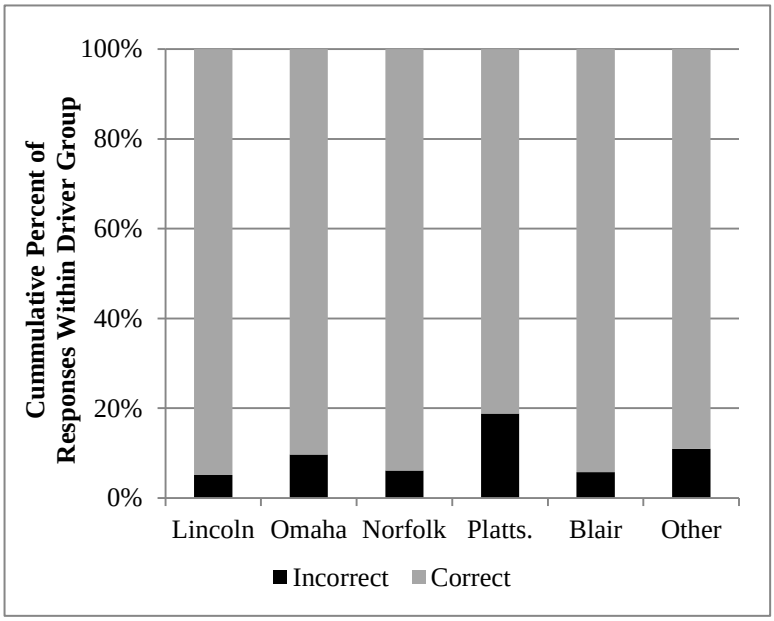
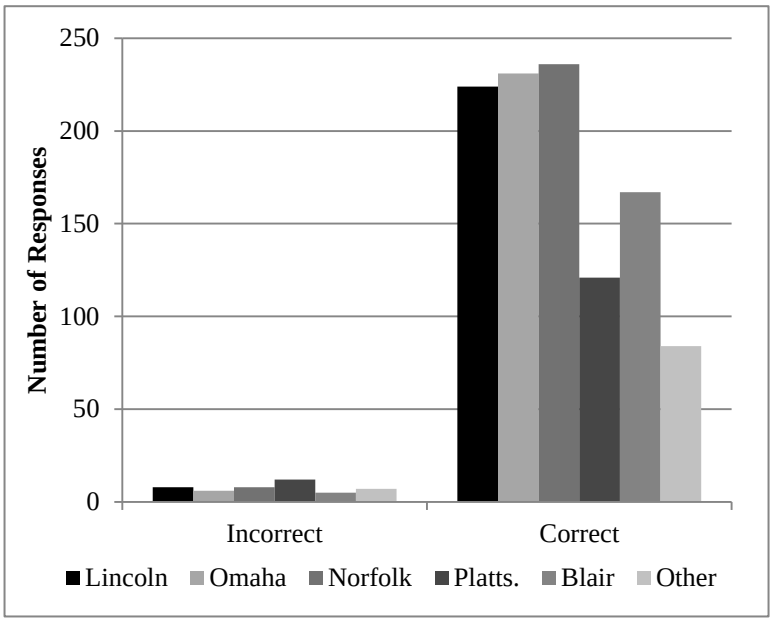


Figure D.9 Question C2 Graphical Results for Hypothesis 3



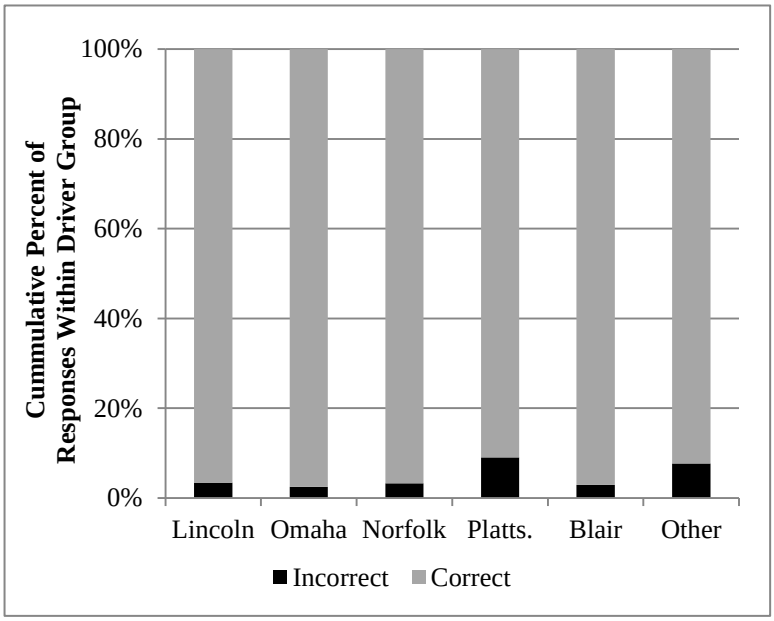


Figure D.10 Question C4 Graphical Results for Hypothesis 3

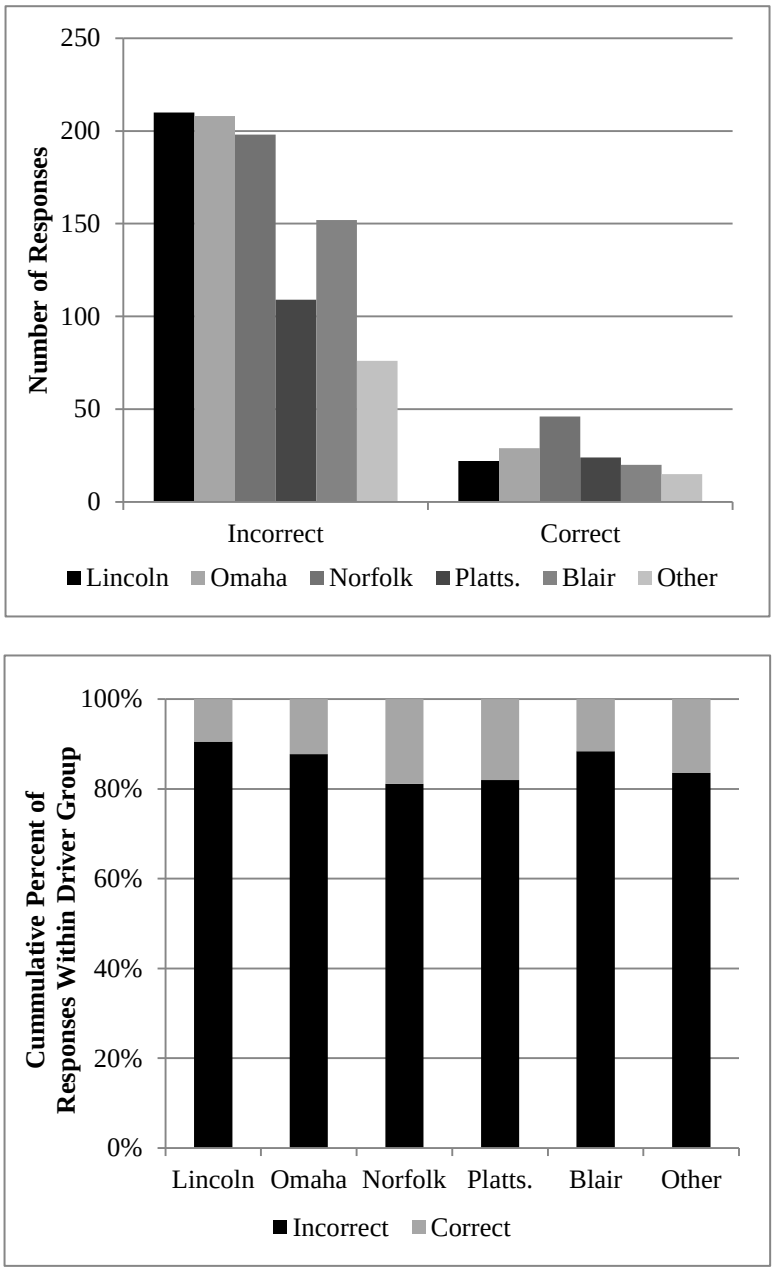
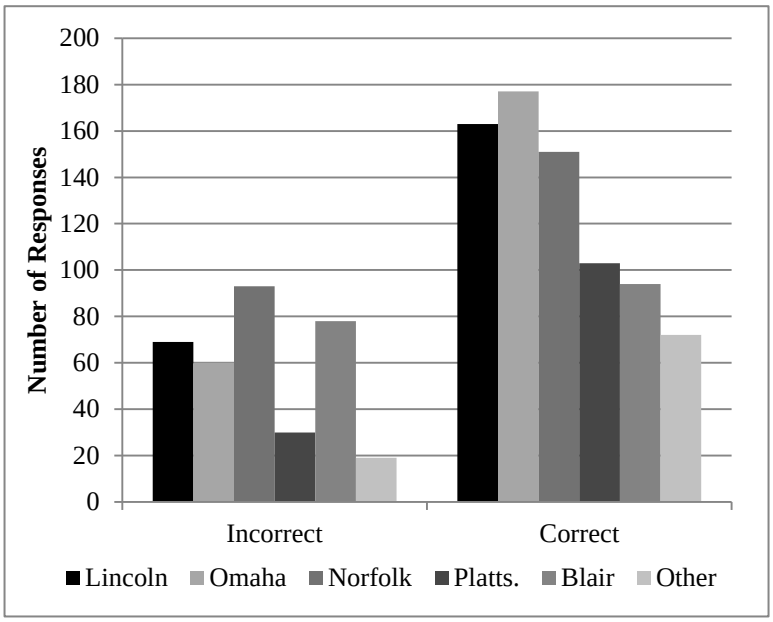


Figure D.11 Question C6 Graphical Results for Hypothesis 3



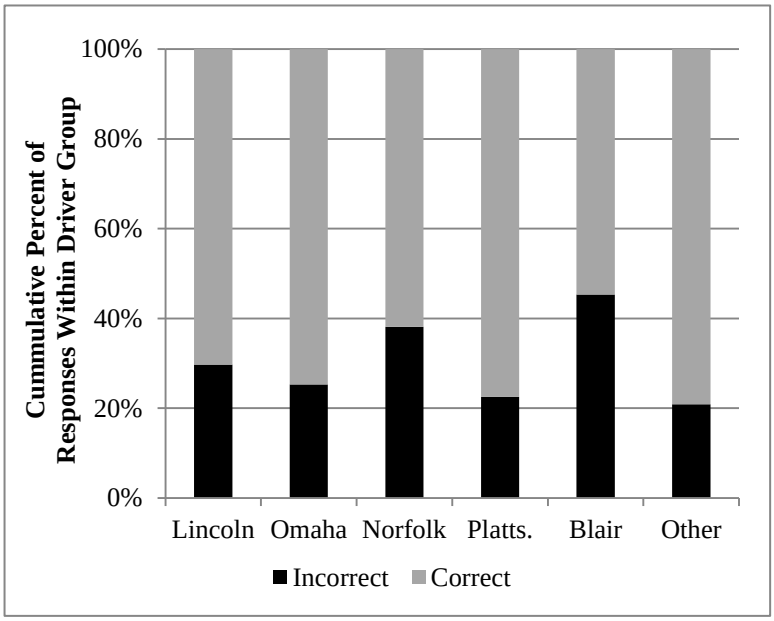
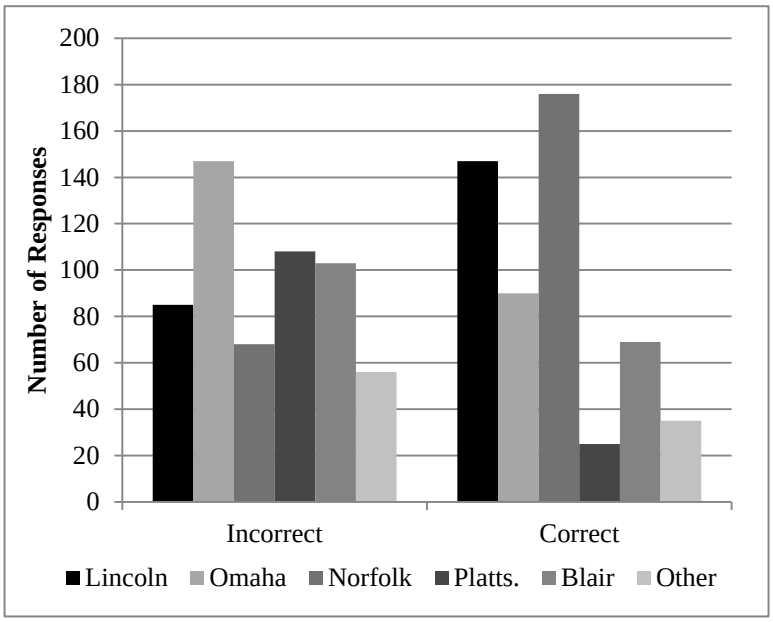


Figure D.12 Question C7 Graphical Results for Hypothesis 3



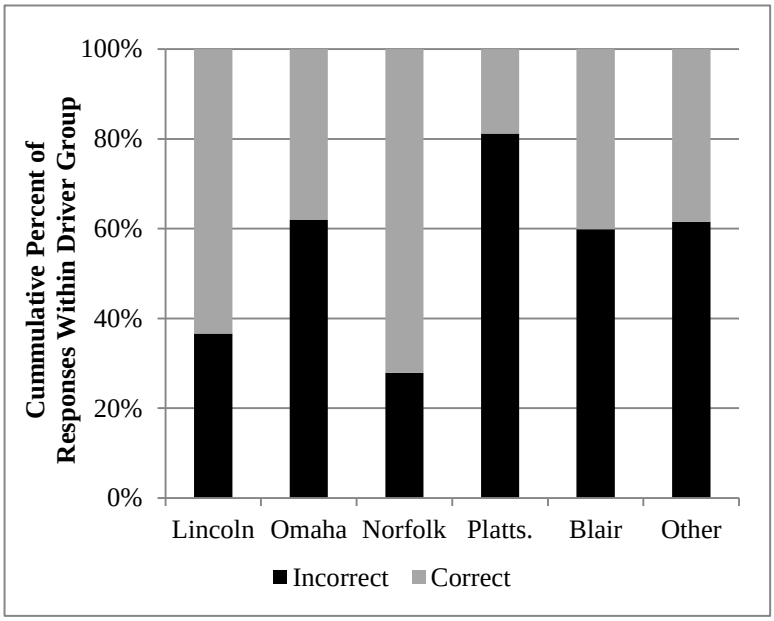


Figure D.13 Question C9 Graphical Results for Hypothesis 3

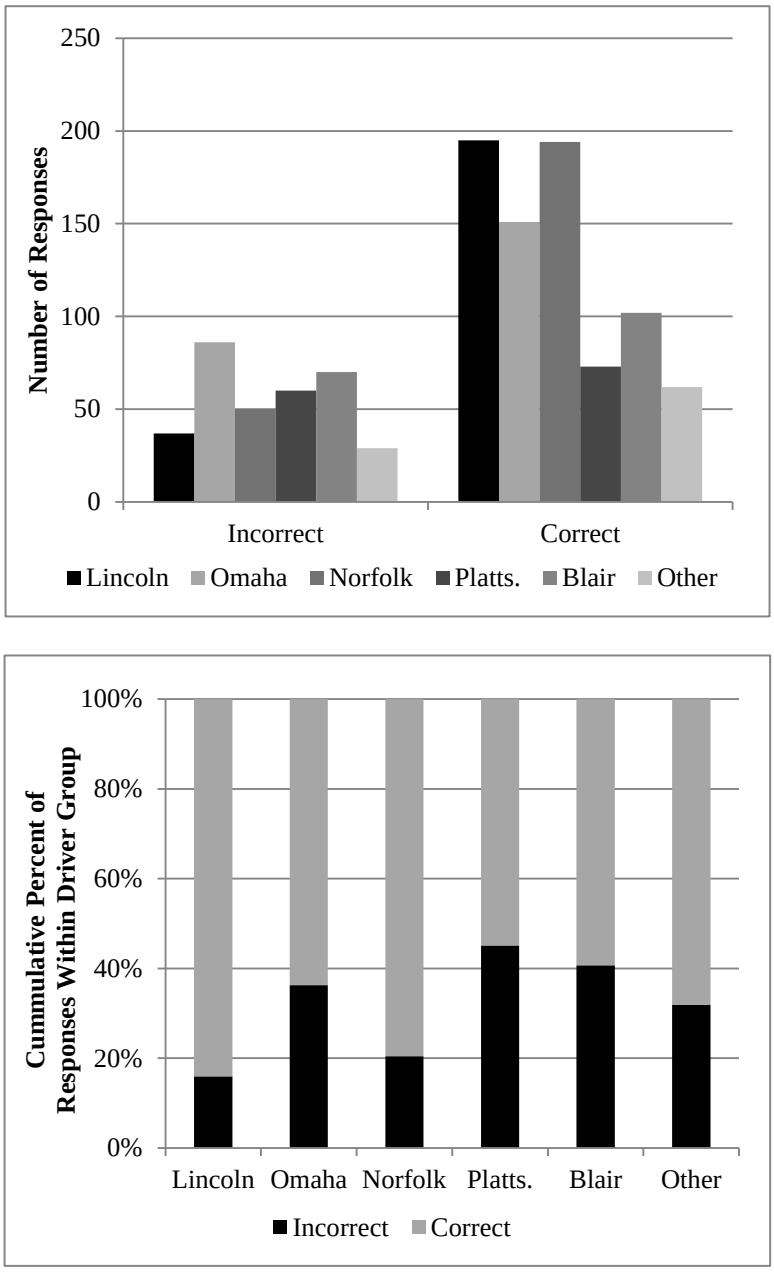
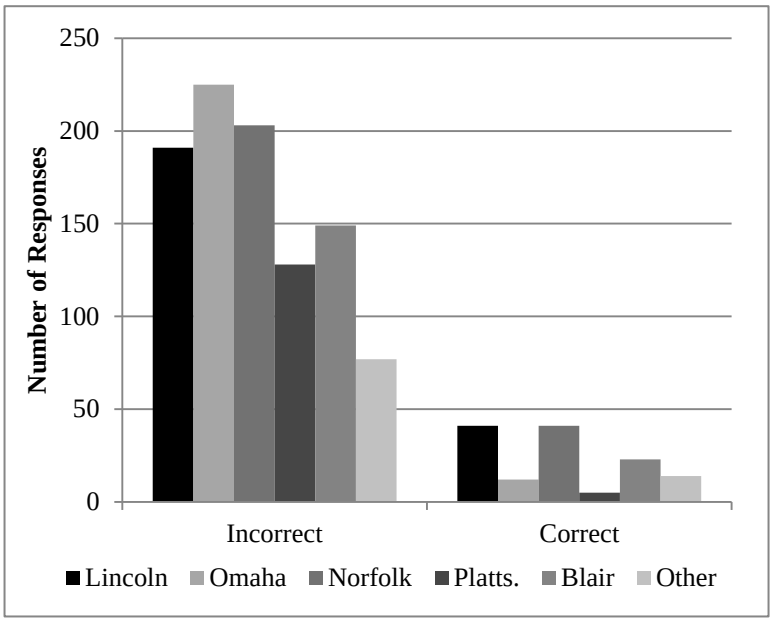


Figure D.14 Question C10 Graphical Results for Hypothesis 3



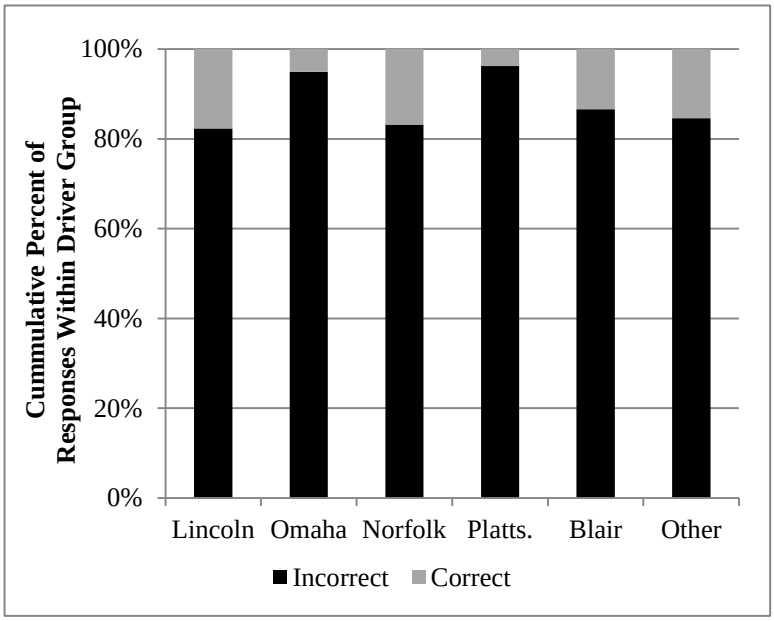
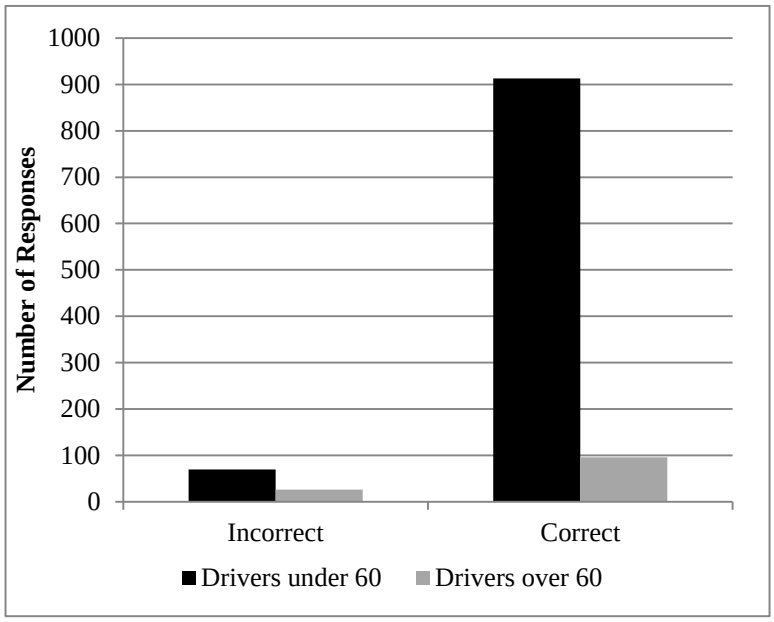


Figure D.15 Question C11 Graphical Results for Hypothesis 3

Hypothesis 4



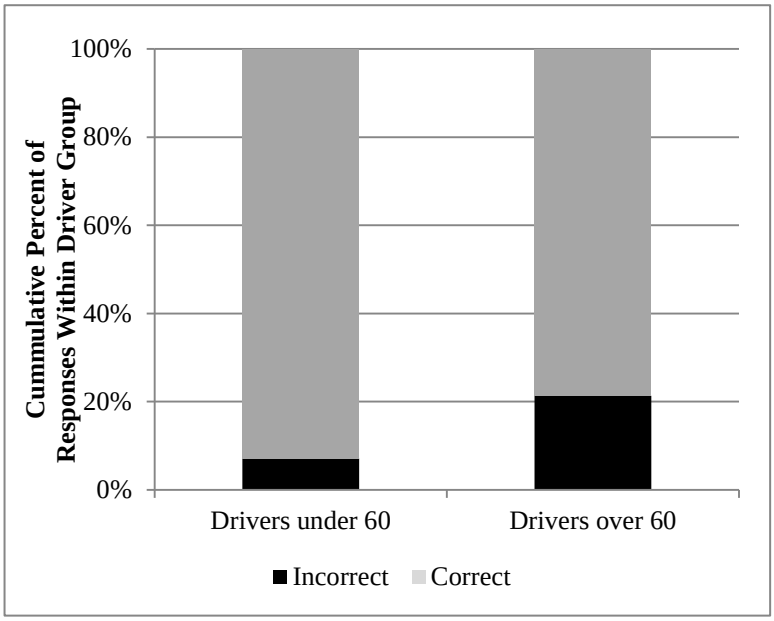
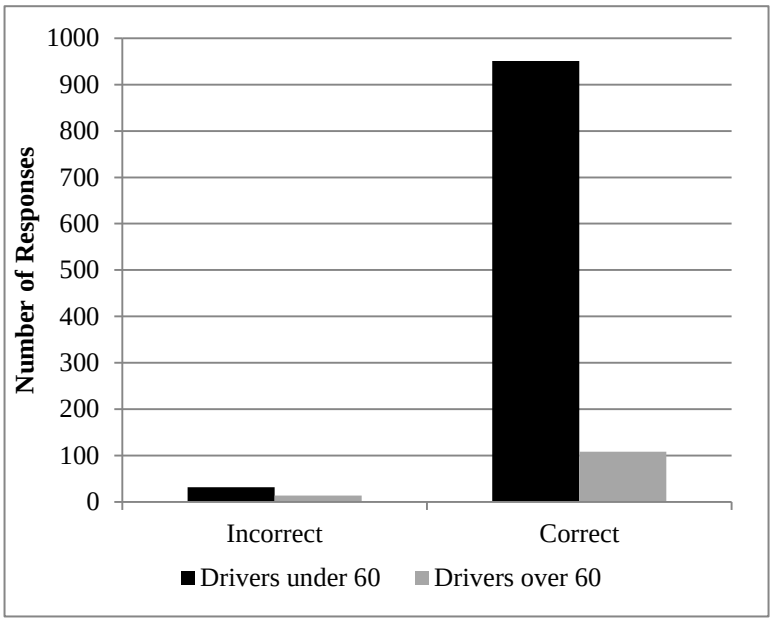


Figure D16 Question C2 Graphical Results for Hypothesis 4



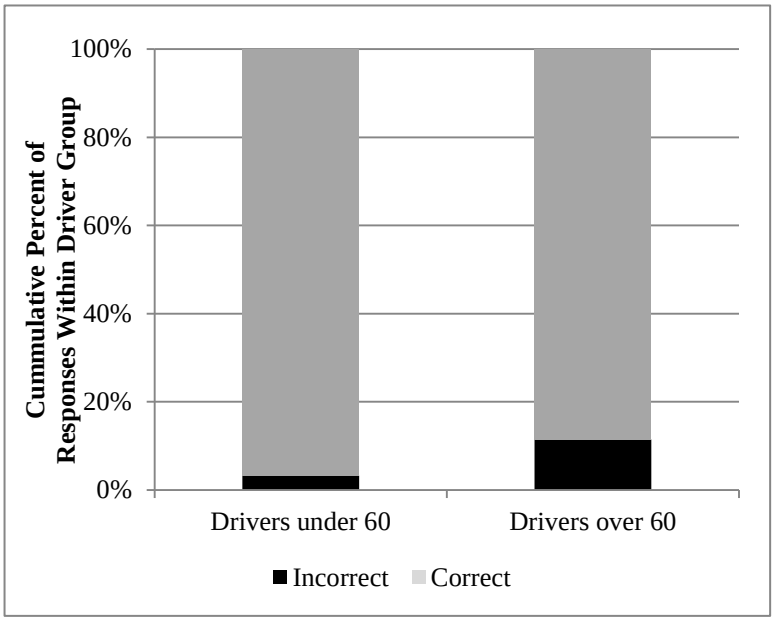
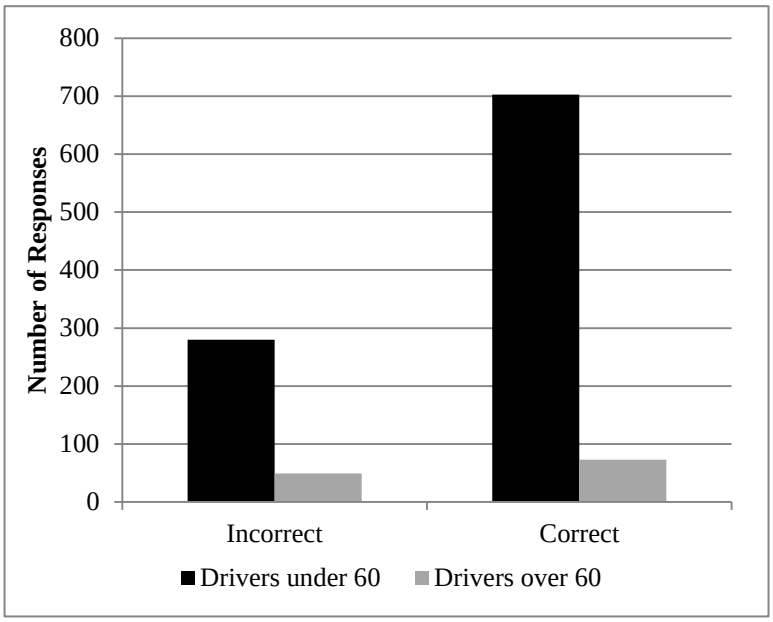


Figure D.17 Question C4 Graphical Results for Hypothesis 4



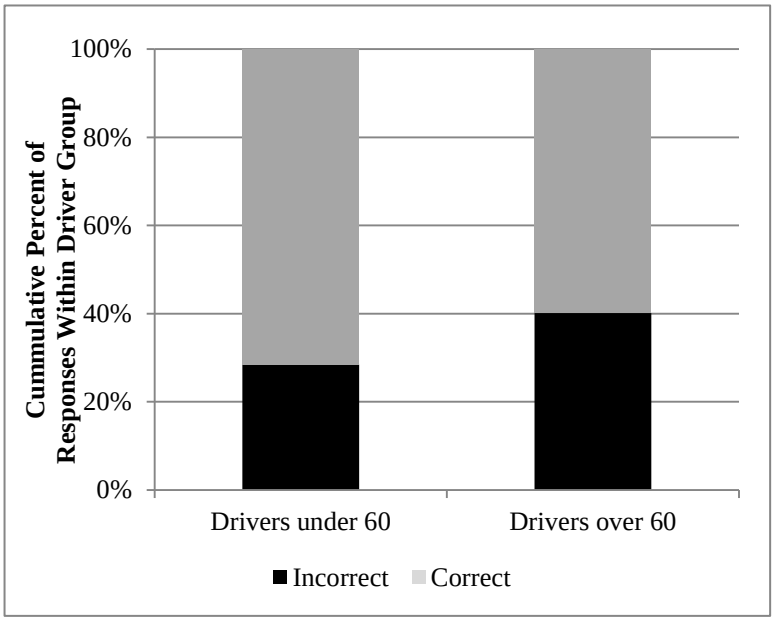


Figure D.18 Question C10 Graphical Results for Hypothesis 4

Hypothesis 6

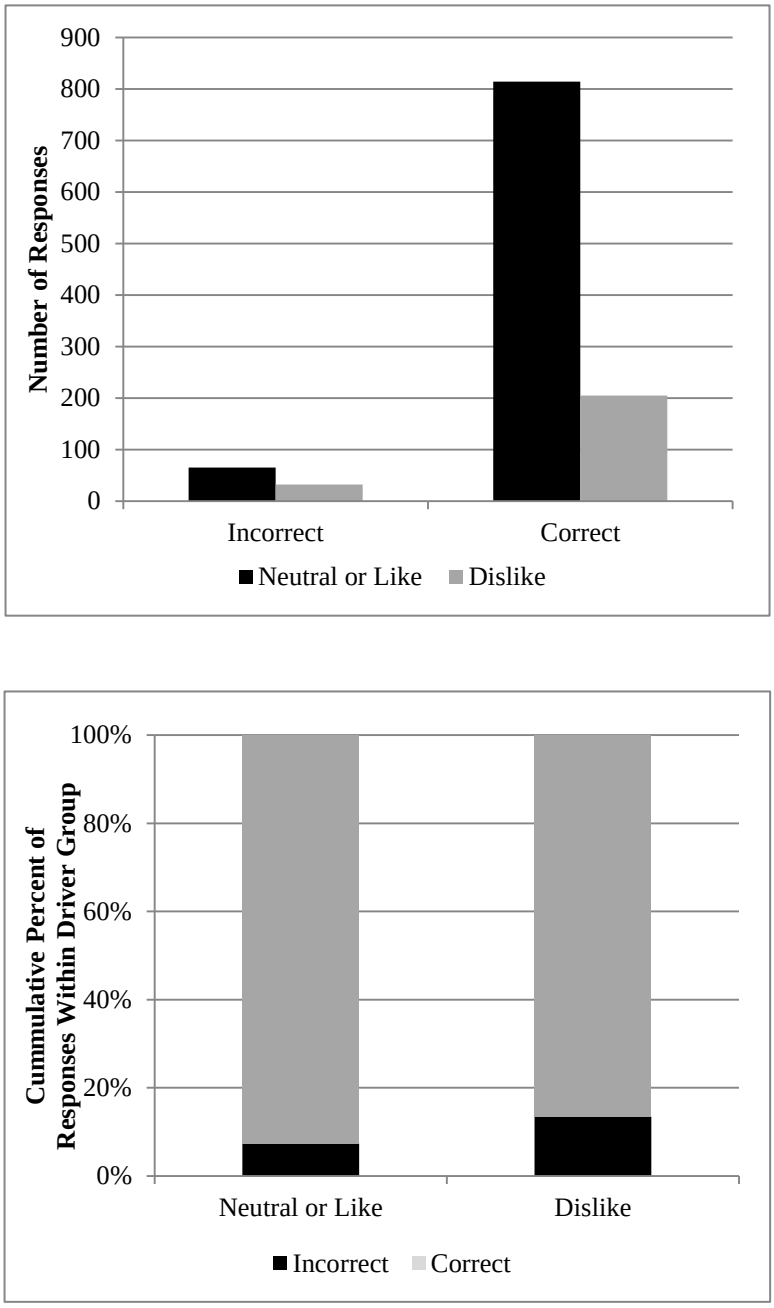
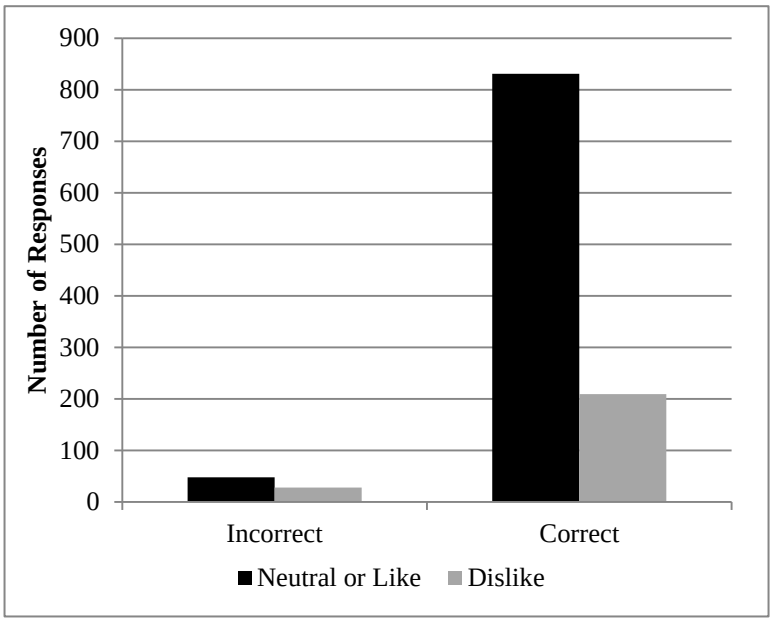


Figure D.19 Question C2 Graphical Results for Hypothesis 6



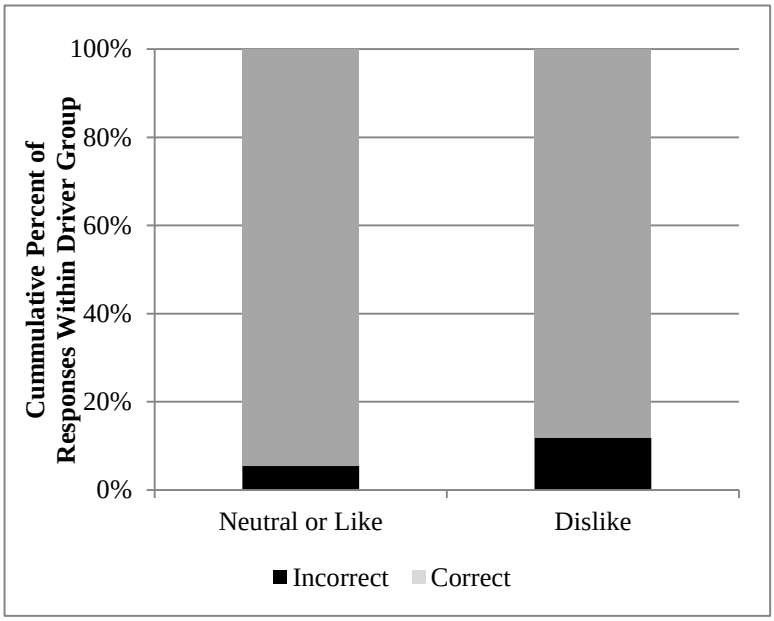
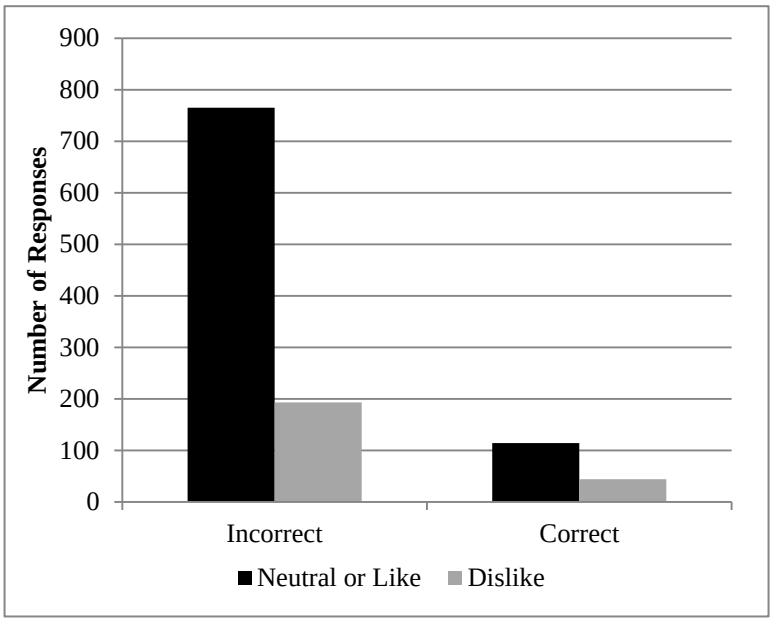


Figure D.20 Question C5 Graphical Results for Hypothesis 6



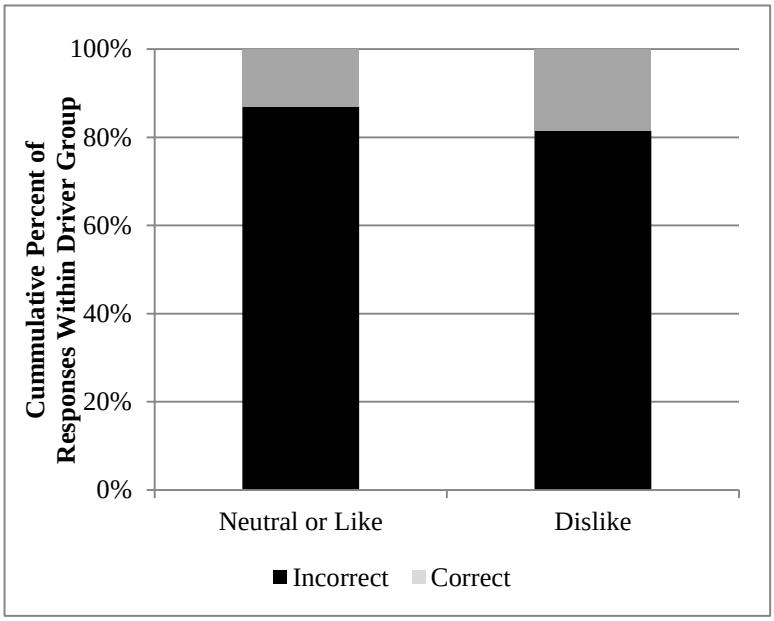
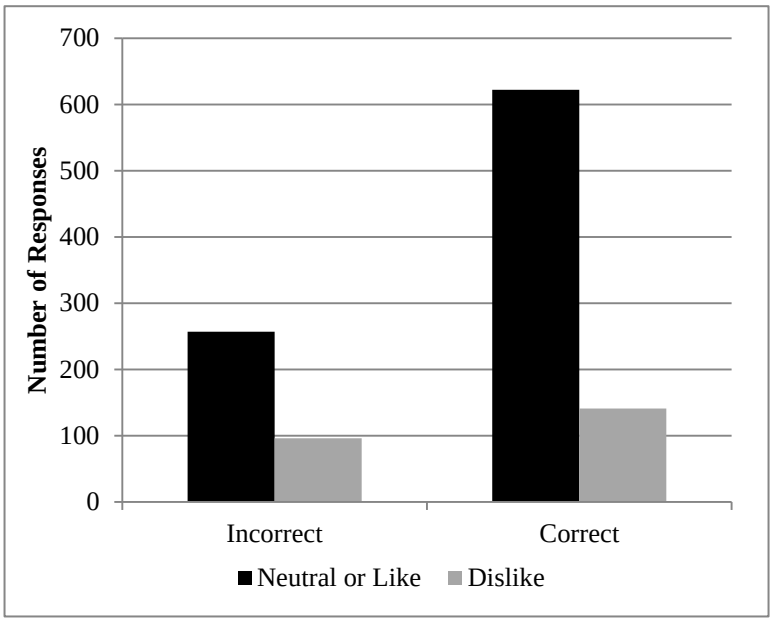


Figure D.21 Question C6 Graphical Results for Hypothesis 6



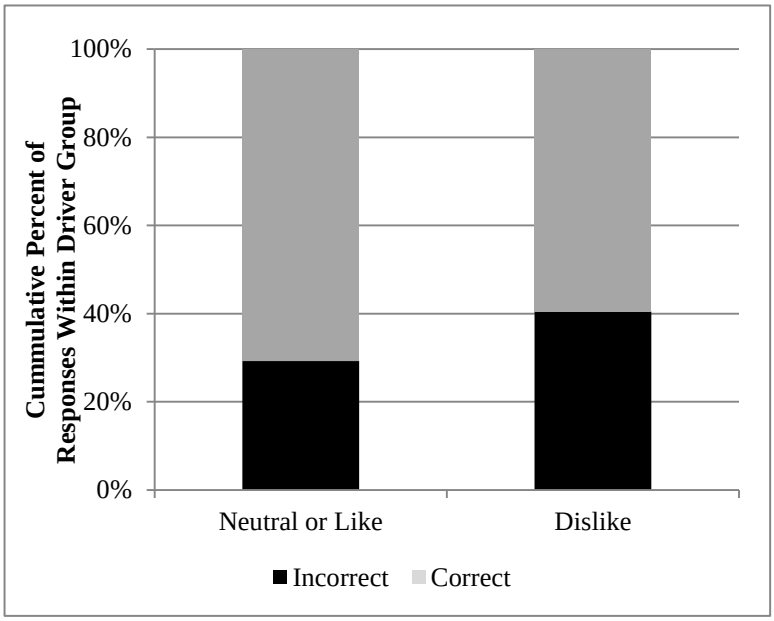
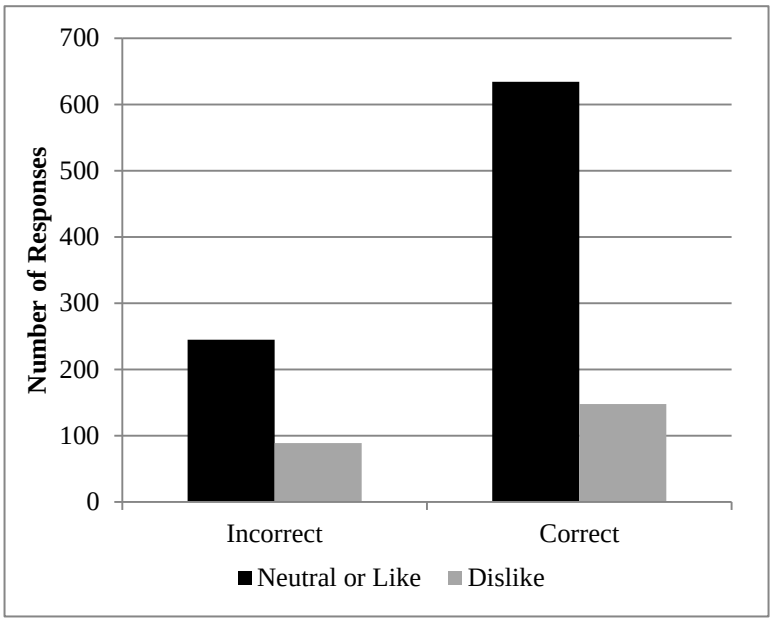


Figure D.22 Question C7 Graphical Results for Hypothesis 6



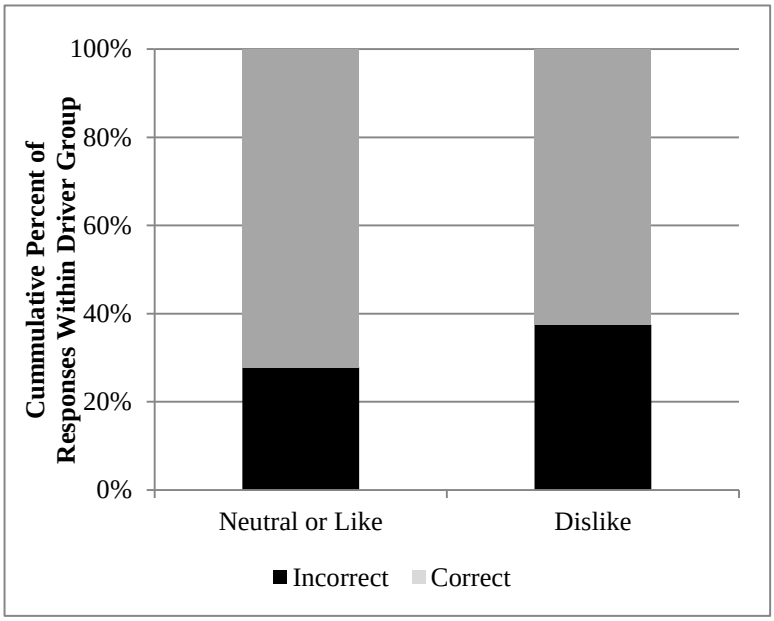


Figure D.23 Question C10 Graphical Results for Hypothesis 6

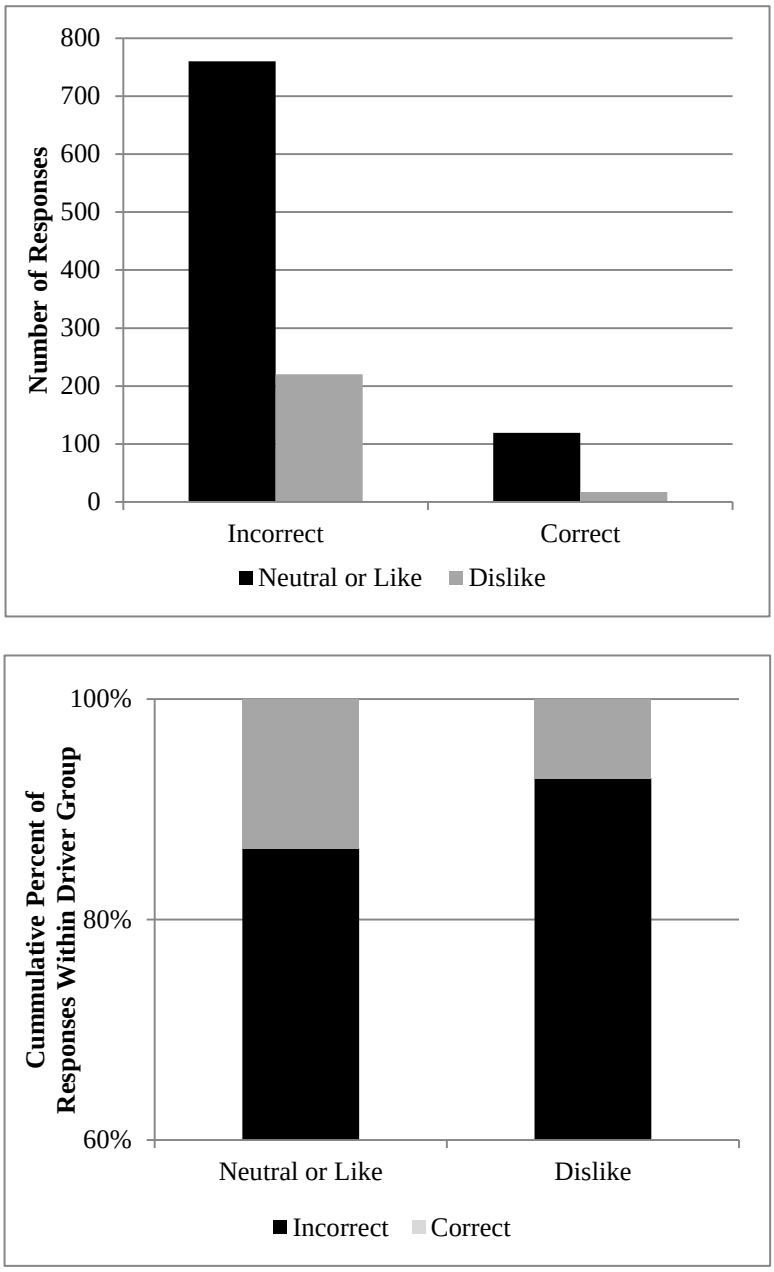


Figure D.24 Question C11 Graphical Results for Hypothesis 6

Hypothesis 7

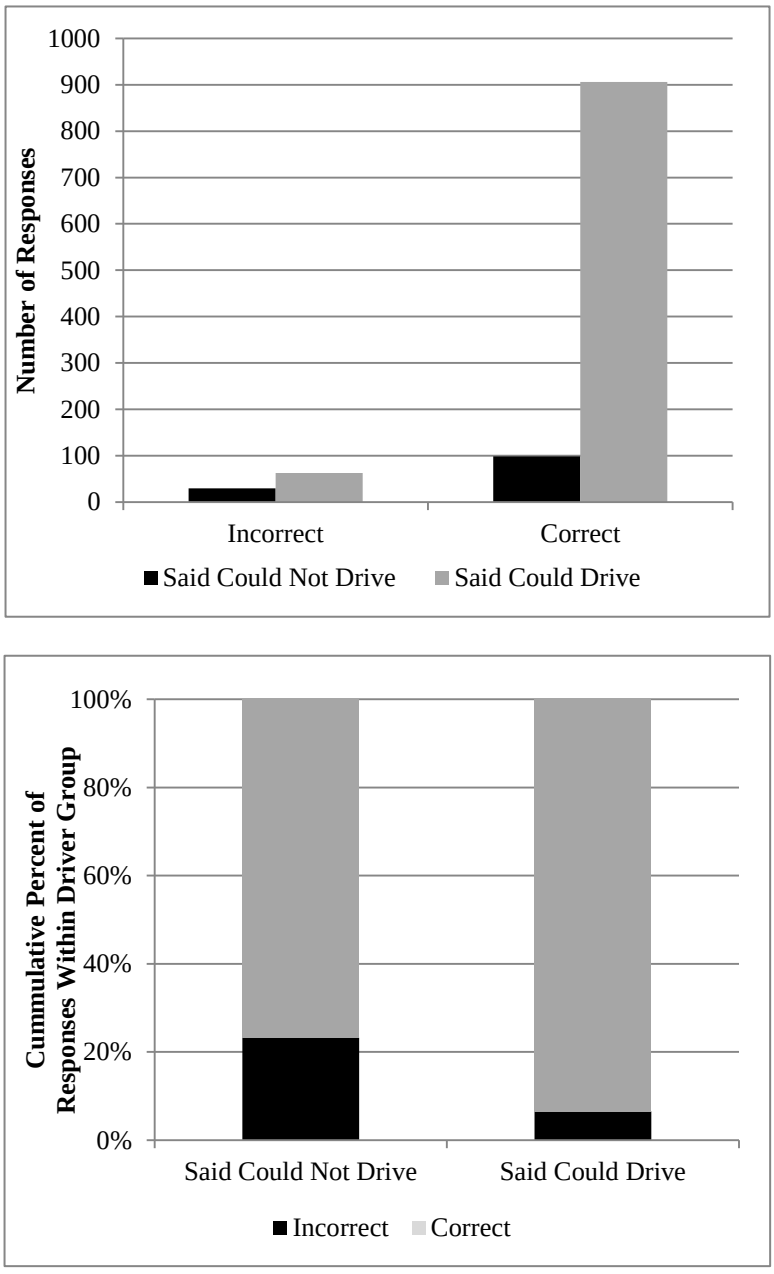


Figure D.25 Question C2 Graphical Results for Hypothesis 7

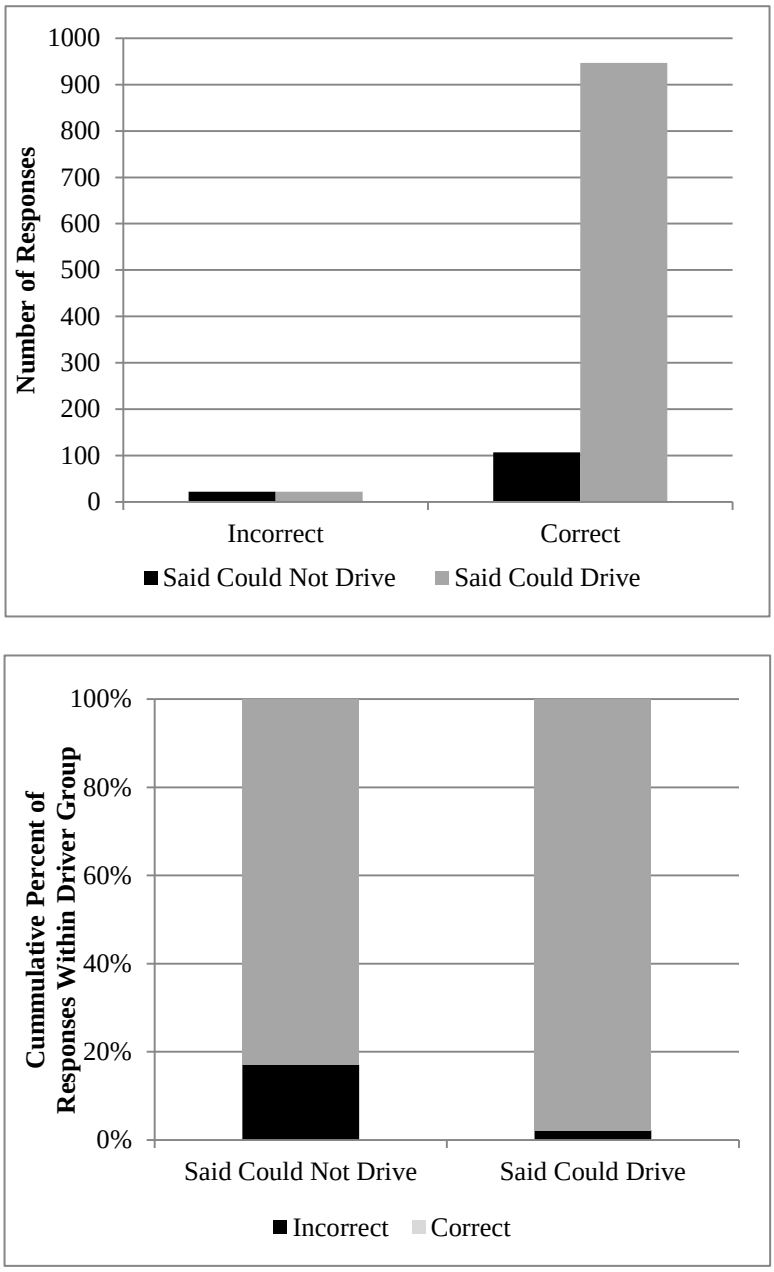


Figure D.26 Question C4 Graphical Results for Hypothesis 7

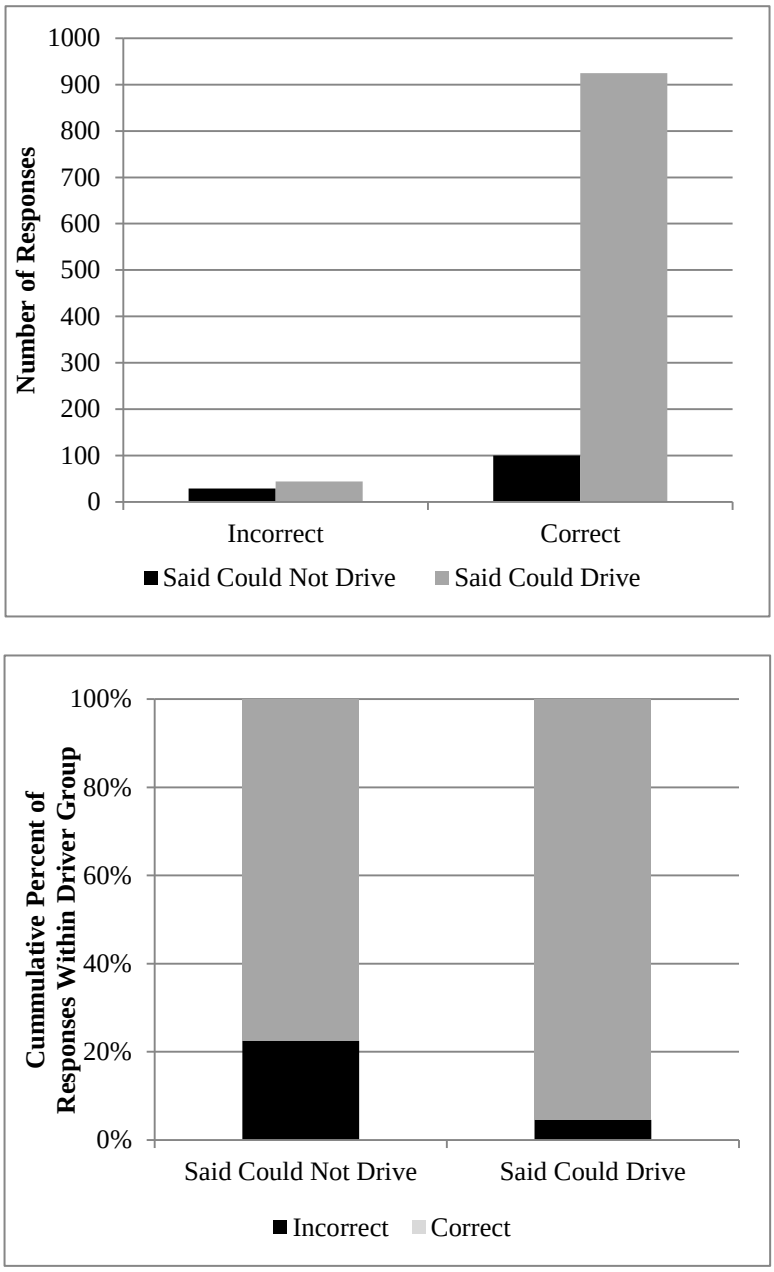
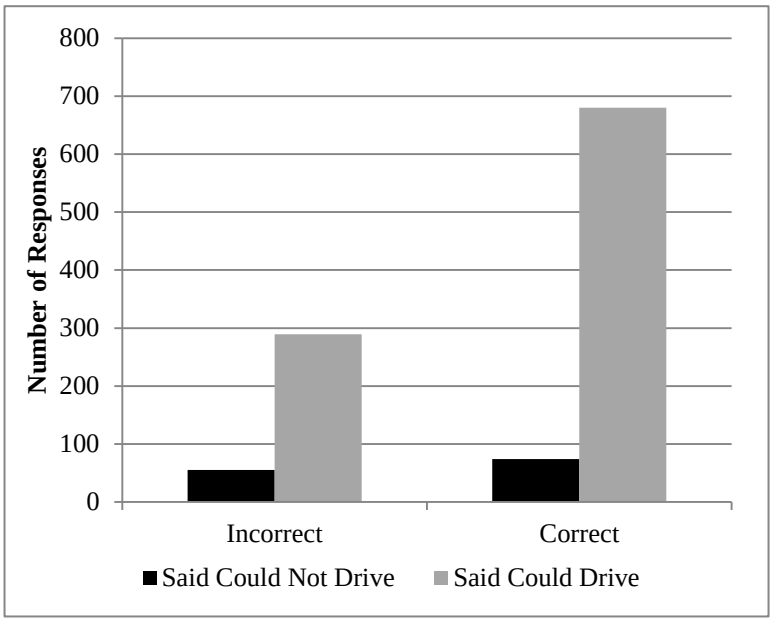


Figure D.27 Question C5 Graphical Results for Hypothesis 7



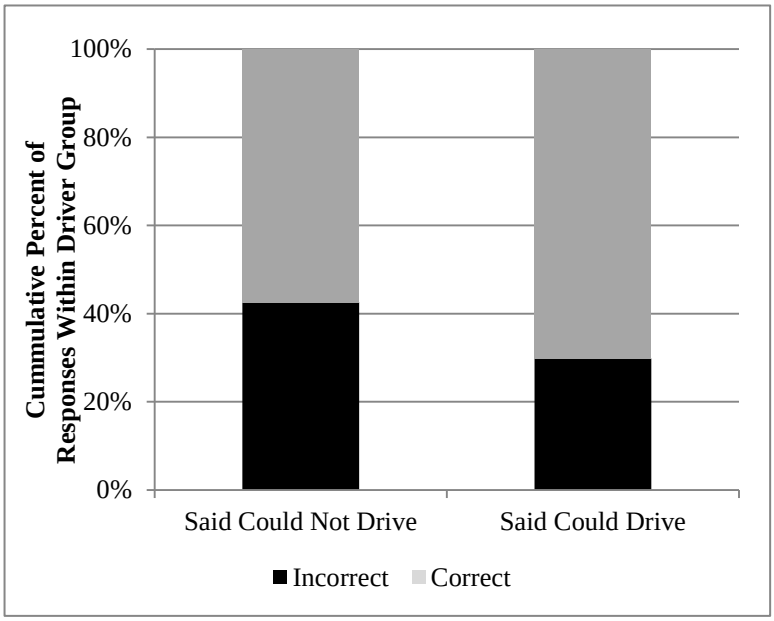


Figure D.28 Question C7 Graphical Results for Hypothesis 7

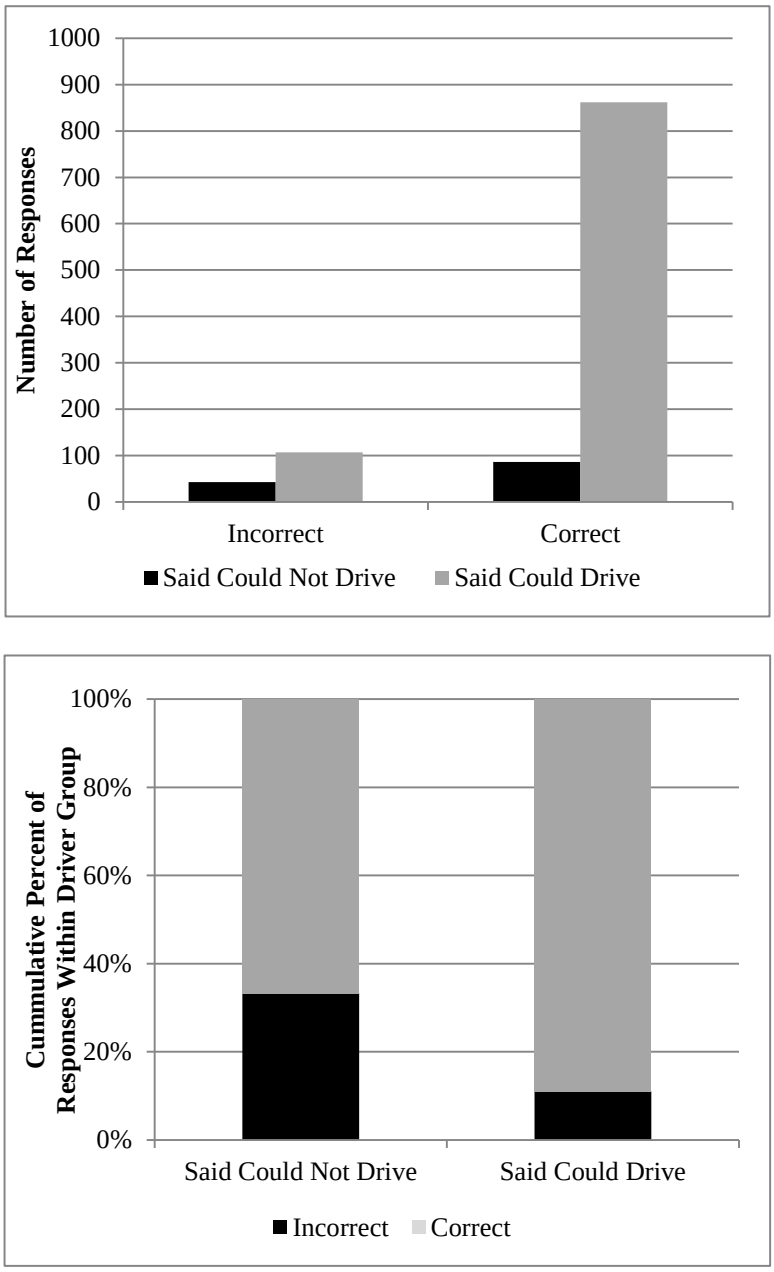


Figure D.29 Question C8 Graphical Results for Hypothesis 7

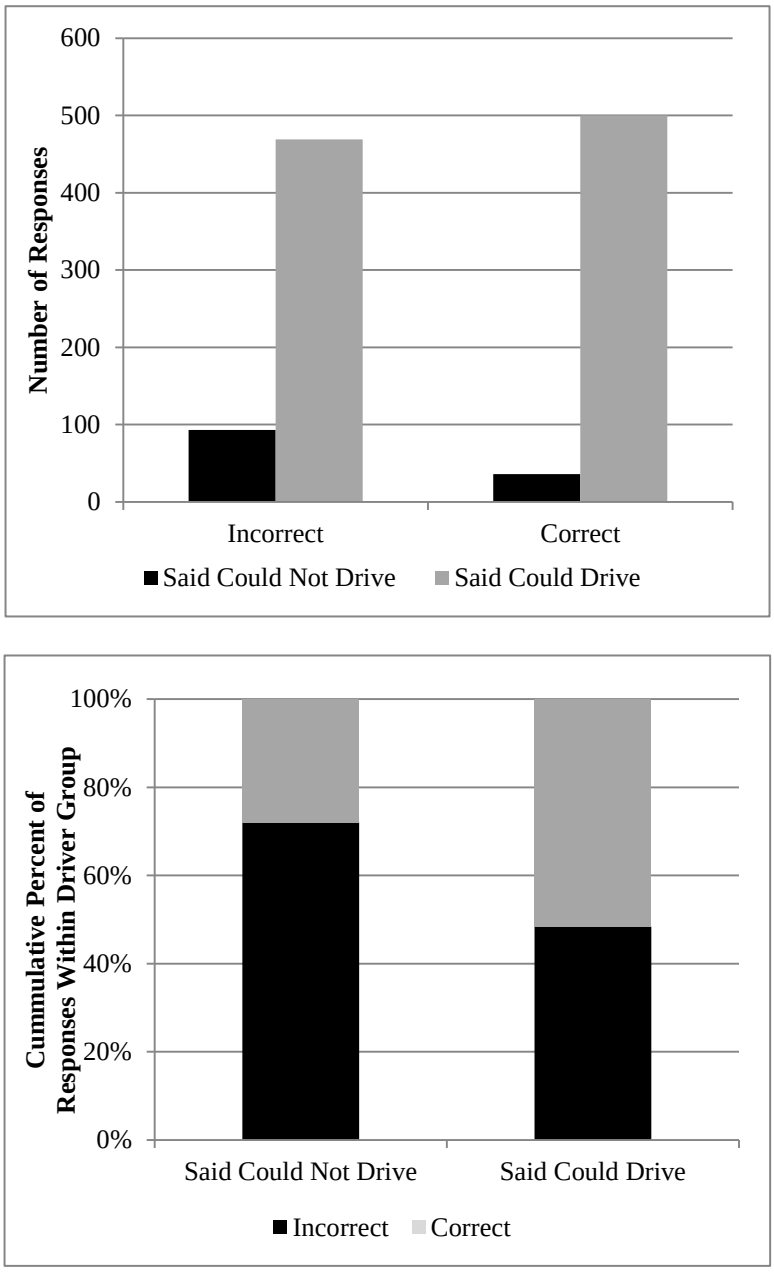


Figure D.30 Question C9 Graphical Results for Hypothesis 7

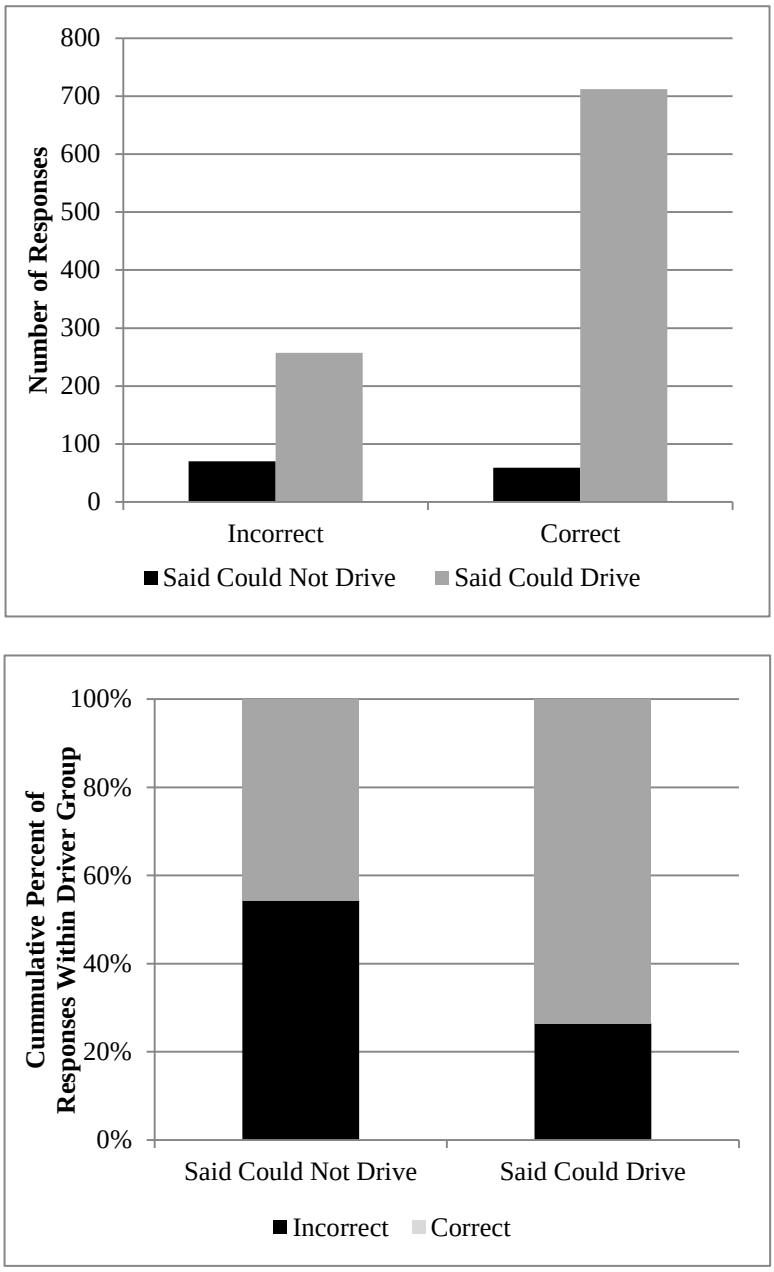
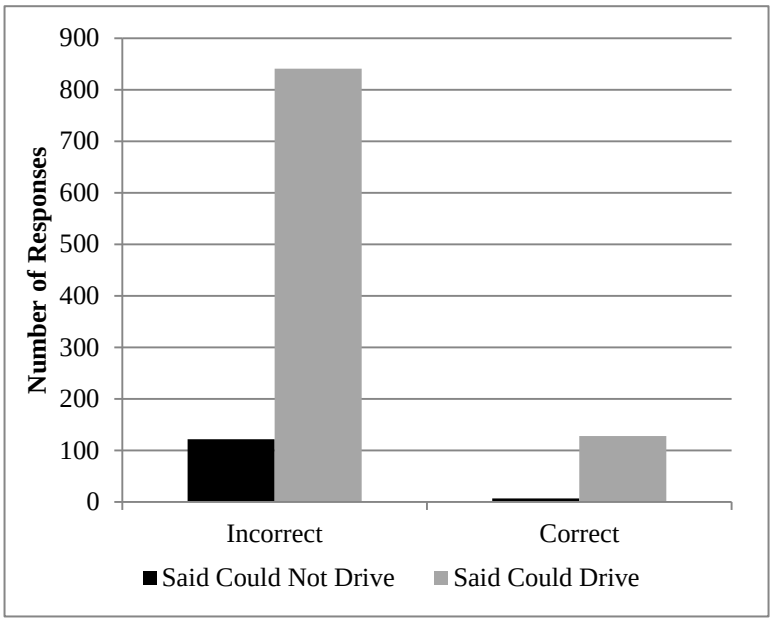


Figure D.31 Question C10 Graphical Results for Hypothesis 7



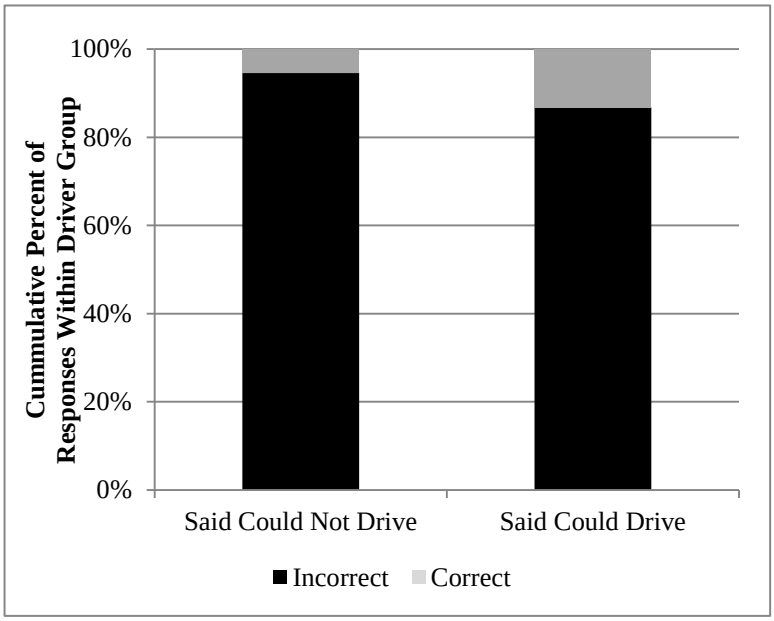


Figure D.32 Question C11 Graphical Results for Hypothesis 7

Appendix E Roundabout Information from Nebraska Driver's Manual

Information on roundabout negotiation in the 2008 Nebraska Driver's Manual (English) was reviewed and discussed with the project technical advisory committee. The survey data analysis indicated that respondents wanted to receive roundabout information via the driver's manual. The research team and TAC members felt that the current information on roundabouts in the manual (section 4A-4, page 42; see Figure E.1) was limited and discussed supplementing existing information with guidelines on proper response when emergency vehicles are encountered in roundabouts and guidelines on proper usage of roundabout aprons. Section 4A-6 may need clarification with respect to roundabouts and emergency vehicles as pulling as close as possible to the curb or edge of the roadway and that stopping is not appropriate in a roundabout when an emergency vehicle is encountered.

Additionally, the research team reviewed the current Nebraska Manual for Commercial Driver's Licensing, the Nebraska Motorcycle Operator Manual (both supplements to the Nebraska Driver's Manual), and manuals from surrounding Midwestern states to identify presence of roundabout-related information in those documents.

4A-4 Roundabout Intersections

A roundabout is a one-way circular intersection without traffic signal equipment designed to slow traffic while lowering delays and handling higher traffic volumes.

- Enter a roundabout only when there is an adequate and safe gap in traffic.
- Use your right turn signal for right turns.
- When approaching a roundabout, slow down to advisory speed.

Figure E.1 Existing Information in Nebraska Driver's Manual (31)