RITA *Intelligent Transportation Systems Joint Program Office*

Validation Study – On-Road Evaluation of the Stop Sign Assist Decision Support Sign:

(CICAS-SSA Report # 5)

November 2009

U.S. Department of Transportation
Research and Innovative Technology Administration

Intelligent Transportation Systems Institute
Center for Transportation Studies
University of Minnesota
511 Washington Avenue SE, Suite 200
Minneapolis, Minnesota 55455

HumanFIRST Program
Department of Mechanical Engineering
University of Minnesota

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Validation Study – On-Road Evaluation of the Cooperative Intersection Collision Avoidance System – Stop Sign Assist Sign: CICAS-SSA Report #5	5. Report Date November 2010 6. Performing Organization Code:
7. Author(s) MICHAEL RAKAUSKAS, JANET CREASER, MICHAEL MANSER, JUSTIN GRAVING, MAX DONATH	8. Performing Organization Report No. CTS Project #2006050
9. Performing Organization Name and Address Department of Mechanical Engineering University of Minnesota 111 Church Street S.E. Minneapolis, Minnesota 55455	10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address United States Department of Transportation, Federal Highway Administration 1200 New Jersey Ave, S.E. Washington, DC 20590	13. Type of Report and Period Covered Work started January 2008. Draft report submitted to Mn/DOT: February 2009. 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The CICAS-SSA sign is a roadside driver support system that is intended to improve gap rejection at rural stop-controlled intersections. The CICAS-SSA system tracks vehicle locations on a major roadway and then displays a message to a driver on the minor road via an active LED icon-based sign. The basis of this sign is a "Divided Highway" sign that is commonly presented in traffic environments. Overlaid on the roadways of the sign are yellow or red icons that represent approaching vehicles that are at a distance at which the driver on the minor road should *proceed with caution* or at a distance that is considered *unsafe* to enter the intersection.

Previous research conducted in a driving simulation environment indicated potentially beneficial changes in driver decision-making relative to approaching vehicle gap sizes and indicated that drivers perceive the system as being both useful and satisfying. While simulation-based evaluations provide a wealth of useful information, their ability to replicate the full array of behavioral, cognitive, and perceptual elements of a driving environment do have some limitations. It is because of these limitations that it is useful to confirm simulation-based findings in a real-world environment.

The primary goal of the current work was to evaluate the candidate CICAS-SSA sign in a real-world setting to confirm previously identified benefits and identify any unintended consequences of sign usage. This goal was accomplished through a validation field test performed at the intersection of US Highway 52 and County Road 9 in Southern Minnesota. The findings of the work are summarized in this report.

17. Key Words Rural highways, Unsignalized intersections, Highway safety, Collisions, Gap acceptance, Cooperative Intersection Collision Avoidance Systems-Stop Sign Assist (CICAS-SSA) program, Warning signs, Automobile drivers, Human factors, Driver Behavior, Graphical user interfaces, Information display systems, Driving simulator	18. Distribution Statement No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161

19. Security Class if. (of this report) Unclassified	20. Security Class if. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TECHNICAL REPORT DOCUMENTATION PAGE

Acknowledgements

This work is funded by the United States Department of Transportation Federal Highway Administration (US DOT FHWA) and the Minnesota Department of Transportation (Mn/DOT through Cooperative Agreement DTFH61-07-H-00003, and by State Pooled Fund Project TPF-5(086).

Listed below are the currently available reports in the CICAS-SSA Report Series (as of August 2010):

Determination of the Alert and Warning Timing for the Cooperative Intersection Collision Avoidance System – Stop Sign Assist Using Macroscopic and Microscopic Data: CICAS-SSA Report #1

Prepared by: Alec Gorjestani, Arvind Menon, Pi-Ming Cheng, Craig Shankwitz, and Max Donath

The Design of a Minimal Sensor Configuration for a Cooperative Intersection Collision Avoidance System – Stop Sign Assist: CICAS-SSA Report #2

Prepared by: Alec Gorjestani, Arvind Menon, Pi-Ming Cheng, Craig Shankwitz, and Max Donath

Macroscopic Review of Driver Gap Acceptance and Rejection Behavior at Rural Thru-Stop Intersections in the U.S. – Data Collection Results in Eight States: CICAS-SSA Report #3

Prepared by: Alec Gorjestani, Arvind Menon, Pi-Ming Cheng, Bryan Newstrom, Craig Shankwitz, and Max Donath

Sign Comprehension, Considering Rotation and Location, Using Random Gap Simulation for Cooperative Intersection Collision Avoidance System – Stop Sign Assist: CICAS-SSA Report #4

Prepared by: Janet Creaser, Michael Manser, Michael Rakauskas, and Max Donath

Validation Study – On-Road Evaluation of the Cooperative Intersection Collision Avoidance System – Stop Sign Assist Sign: CICAS-SSA Report #5
Prepared by: Michael Rakauskas, Janet Creaser, Michael Manser, Justin Graving, and Max Donath

Additional reports will be added as they become available.

TABLE OF CONTENTS

Appendices

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

In the United States it is recognized that crashes in rural areas are a cause for concern, especially crashes at rural intersections where inherent speeds may be associated with higher fatality rates (FHWA, 2004). Recent work has shown gap acceptance problems to be the key factor contributing to these crashes (Laberge, Creaser, Rakauskas, & Ward, 2006) as opposed to stop sign violation (Preston & Storm, 2003). However, the majority of intersection decision-support systems implemented at intersections have not attempted to provide specific information about the nature of available gaps in the approaching traffic or provide adequate information that supports a driver's gap acceptance decision. To reduce the crash risk at rural stop-controlled intersections, it has been recommended that intersection decision-support systems be developed and deployed to assist drivers in responding to safe gaps (Preston, Storm, Donath, & Shankwitz, 2004). The Cooperative Intersection Collision Avoidance System-Stop Sign Assist (CICAS-SSA) sign is an infrastructure-based driver support system that is intended to improve gap rejection at rural stop-controlled intersections. The CICAS-SSA system tracks vehicle locations on a major roadway and then displays a message to a driver on a minor road via a changeable message sign. The basis of this sign is a "Divided Highway" sign that is commonly presented in traffic environments. Overlaid on the roadways of the sign are yellow or red icons that represent approaching vehicles that are at a distance at which the driver on the minor road should proceed with caution or at a distance that is considered unsafe to enter the intersection.

Previous research conducted in a driving simulation environment indicated potentially beneficial changes in driver decision making relative to approaching vehicle gap sizes and indicated that drivers perceive the system as being both useful and satisfying. While simulation-based evaluations provide a wealth of useful information, their ability to replicate the full array of behavioral, cognitive, and perceptual elements of a driving environment do have some limitations. It is because of these limitations that it is useful to confirm simulation-based findings in a real-world environment.

The primary goal of the current work was to evaluate the candidate CICAS-SSA sign in a real-world setting to confirm previously identified benefits and identify any unintended consequences of sign usage. This goal was accomplished through the conduct of a validation field test performed at the intersection of US Highway 52 and Goodhue County Road 9 in Southern Minnesota. In this study, 48 participants from three target age groups (young, middle-age, and senior) were recruited in order to determine the influence of driver age on performance while using the CICAS-SSA sign. An additional 13 truck drivers completed the study using a large truck to better understand the value of the CICAS-SSA sign to drivers of heavy vehicles that react slowly to driver input and provide for a significantly higher viewpoint when compared to passenger vehicles. The intersection, instrumented vehicle, and instrumented truck were outfitted with recording equipment that collected data while drivers made gap decisions in relation to actual traffic at the intersection while making crossing and turn maneuvers. Data included rejected gap size, lead gap size, maneuver type (one-stage vs. two-stage), crossing and wait times, and safety margins.

Overall, results indicated that a majority of participants used the CICAS-SSA sign to reduce their risk level at the intersection and that drivers had a positive opinion of the sign. The use of the CICAS-SSA sign was associated with the rejection of shorter, unsafe gaps as evidenced by the increase in 80th percentile rejected gap. In addition, the 7.5 second critical gap threshold used by the CICAS-SSA sign was shown to be in agreement with the driver's gap selection performance. The sign did not appear to have an effect on the intersection crossing metrics of accepted gap length, lead gap length, or time-to-contact. The lack of significant differences across these metrics (which provide an indication of crossing performance) along with the differences observed in the 80th percentile rejected gap suggests that the CICAS-SSA sign may have a positive effect on performance at the intersection through reduced decision making risk while not drastically altering how drivers make maneuvers at the intersection. This finding is promising because it indicates the CICAS-SSA sign can be implemented without influencing how drivers

perceive their task of maneuvering their vehicle through an intersection. It also suggests that there were no unintended consequences of using the sign while making a crossing decision.

Subjective measures were collected and analyzed in order to determine how drivers understood the CICAS-SSA sign functioning and served to assess whether the sign assisted drivers' perceived confidence, safety levels, and usefulness; poor subjective measure ratings would indicate general dislike of the sign that may result in non-use. Subjective measures included mental effort, comfort/stress, usefulness, satisfaction, and comprehension related to CICAS-SSA sign use. Results of the subjective response analyses indicated that the CICAS-SSA sign was perceived as being usable and that it served an advisory role. Specifically, a majority of drivers reported that they used the sign to validate their own decisions and perceptions of safety while entering the intersection. This is promising because it affirms the intent of the CICAS-SSA sign, that being to confirm/facilitate drivers' own perceptions of safety before entering the intersection as opposed to controlling their actions. Overall, 66% of all car drivers and 50% of drivers in the older age group reported that they used the CICAS-SSA sign. This is promising because older drivers are typically less willing to accept new technologies and they are more likely to be involved in a crash at the test intersection. Given that some drivers may never accept the CICAS-SSA sign, it may be necessary to deploy a positive advertising campaign (particularly aimed at older drivers) in order to inform drivers of the benefits of using this particular ITS application. Collectively, the results of this study suggest that the information presented on the CICAS-SSA sign is beneficial to drivers' gap decision-making process while not adding undue stress.

Findings from the current work examining the utility of the CICAS-SSA sign were consistent with those observed in previous studies conducted in the HumanFIRST driving simulator. In particular, findings from the Random Gap study (Creaser, Manser, & Rakauskas, 2008) indicated that drivers using the CICAS-SSA sign reduced their risk while making gap selection decisions. Continuity of results across studies suggests increased confidence that the results obtained are robust and may be used to make tentative predictions regarding driver performance if the CICAS-SSA sign is deployed. The predications of driver performance are tentative due to limitations in the simulation and on-road testing methodologies, including 1) modified perception of driver risk due to the lack of actual risk in a simulated environment or perceptions of reduced risk within the on-road study due to needed safety precautions, 2) an inability to exhibit absolute normative behaviors due to participant's use of a vehicle that was different from their "daily driver", 3) potential imposition of experimental equipment (e.g., eye tracker) on performance, and 4) potentially modified behaviors because participants were aware they were being observed while making maneuvers. Finally, it is important to note that the simulation and on-road based studies evaluated driver performance, workload, and usability across a relatively short period of time. A longer-term field operational test would provide valuable information regarding "how" drivers adapt to the CICAS-SSA over multiple exposures (e.g., days, weeks, months). In light of the notion that long-term testing in a naturalistic environment that allows drivers to use their own vehicles and interact with the CICAS-SSA will provide insight into the veridical utility of the CICAS-SSA, we recommended that a field operational test be conducted. The results of a field operational test will validate the utility and the absence of unintended consequences due to CICAS-SSA sign use.

1 Introduction

Crashes at rural intersections more often result in fatalities than those at urban intersections due to the high speeds involved on rural highways (FHWA, 2004). In particular, intersections where a high-volume, high-speed multi-lane road is intersected by a lower-speed, lower-volume road controlled by a stop sign pose a particular problem due to the high speeds present on the main road and the need for drivers on the minor road to accelerate from a stop to enter this fast-moving traffic (see Figure 1 for an example depiction of a rural thru-stop controlled intersection). AASHTO recognized the significance of rural intersection crashes in its 1998 Strategic Highway Safety Plan (AASHTO, 1998) and identified the development and use of new technologies as a key initiative to address the problem, specifically Neuman, et al. (2003, Objective 17.1.4) stated: "Assist drivers in judging gap sizes at Unsignalized Intersections." Previous research identified gap acceptance problems as a significant contributor to these crashes (Laberge, Creaser, Rakauskas & Ward, 2006) as opposed to stop sign violation (Preston & Storm, 2003). To reduce the crash risk at rural stop-controlled intersections, recommendations have been made to develop and deploy intersection decision-support (IDS) systems to assist drivers in responding to safer gaps (Preston, Storm, Donath, & Shankwitz, 2004).

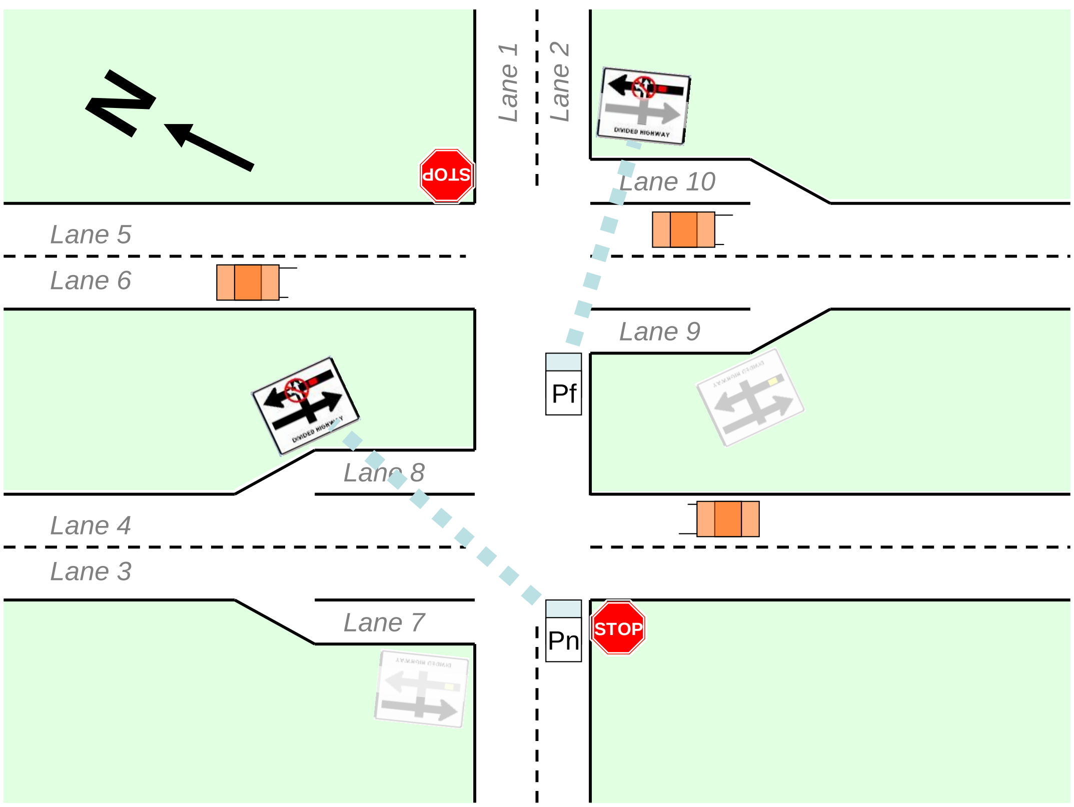


Figure 1. Diagram of a stop-controlled trunk-highway thru-stop intersection with relative location of CICAS-SSA signs. Viewing locations while entering the highway from the minor road are indicated by a white car labeled 'Pn' (from stop sign, "near") and 'Pf' (from median, "far"). Labeled lanes 3 & 4 constitute "Southbound" traffic and lanes 5 & 6 constitute "Northbound" traffic.

1.1 Previous CICAS-SSA Study Efforts

The ultimate goal of the CICAS-SSA project was to identify a single sign that would provide the greatest utility in terms of driver performance (e.g., gap selection, crossing behaviors) and usability at a real-world rural intersection. The study presented in this report accomplishes this goal by using a field study to evaluate the final sign design. Reaching this goal required that several preliminary questions already be answered. To appreciate the study presented in this report it is beneficial to review briefly the preliminary research questions, their associated research efforts, and their answers. The following is a list of the preliminary research questions.

What type of gap-related CICAS-SSA sign information (e.g., prohibitive or warning message) is understood to the greatest degree?

What is an appropriate gap threshold to reduce the risk of gap acceptance at the intersection?

What sign interface design best supports driver performance and usability, without producing unintended consequences due to the use of the sign's information?

Where should a CICAS-SSA sign be placed at the intersection in order to maximize visibility and comprehension?

Using a well-designed sign that has optimal timing and that is placed in optimal locations at the test intersection; can a candidate CICAS-SSA sign reduce the acceptance of risky gaps at intersections?

The remainder of section 1.1 summarizes briefly the studies that were conducted to answer these preliminary questions. For further information regarding these studies the reader is encouraged to obtain copies of the CICAS technical reports, including these studies which are referenced within this report:

IDS Studies– Intersection Decision Support, previous to the CICAS efforts, this study began with an evaluation of gap decision making at rural intersections and current interventions to assist drivers as well as a simulation study to evaluate driver behavior using a series of prototype interface designs. *See* Laberge, Creaser, Rakauskas, & Ward, 2006; Creaser, Rakauskas, Ward, Laberge, & Donath, 2007.

CICAS-HF 2.2 – Microscopic Model, Summer 2007 field test at the intersection of US 52 & CR9 to get real world baseline crossing behavior. *See* Gorjestani, Menon, Cheng, Shankwitz & Donath, 2008.

CICAS-HF 3.1 & 3.2 – Comprehension Studies, Fall 2007 paper-and-pencil tests at the University of Minnesota to refine the designs of the CICAS-SSA interfaces. *See* Creaser, Manser, Rakauskas, & Donath, 2008.

CICAS-HF 3.3 – Rotation and Location Studies, Winter 2007/2008 simulator non-driving studies in the HumanFIRST Driving simulator at the University of Minnesota to determine the optimal placement of the CICAS-SSA signs. *See* Creaser, Manser, Rakauskas, & Donath, 2008.

CICAS-HF 3.4 – Random Gap Study, Spring 2008 simulator driving study to test the final CICAS-SSA interfaces using randomized gap patterns in the HumanFIRST Driving simulator at the University of Minnesota. *See* Creaser, Manser, & Rakauskas, 2008.

CICAS-HF 4.2 – Validation Study, Summer 2008 field test at the intersection of US 52 and CR9 to test the usage of the Icon sign design. *See current report*

1.1.1 Evaluating Candidate CICAS-SSA Sign Concepts

The initial phase of this research identified what type of gap-related information (e.g., alerting only, multiple stage-warning or indication of available gap size) was best understood by drivers. This testing included four prototype interface designs and was conducted using driving simulation (IDS Studies: Laberge et al., 2006; Creaser et al., 2007). At the end of this study, three concept sign interfaces were chosen for further testing during the CICAS-SSA research project. All three interfaces operate on a prohibitive framework. That is, they indicate to drivers when it is unsafe to cross the intersection rather than when it is safe to do so. This strategy is employed for liability reasons and because the signs are not intended to be regulatory, but instead provide warning information about unsafe traffic conditions. Before testing could begin, the three interface concepts had to be re-designed to better conform with MUTCD guidelines for non-regulatory signs.

Two additional tasks evaluated several recommended interface design changes for each sign (HF 3.1 & 3.2: Creaser et al., 2008). The first task was a paper-and-pencil test that employed questionnaires and sign drawings as a preliminary measure of design comprehension, preference and usefulness by drivers. The second task presented the interface design options using software for limited time periods. Comprehension was assessed by how well participants could select the correct behavioral response from a multiple choice list after each presentation. This task helped identify potential weaknesses with quick comprehension of a particular design option. The combined results of these two tasks resulted in a final design for each of the three sign interfaces that would be moved forward for testing in the simulator. Overall, these two studies supported the findings of the initial simulator study (IDS: Creaser et al., 2007) that the Icon concept sign (see Figure 2 for an example state; a complete set of sign states with descriptions can be found in Table 2) produced better comprehension than the other two concepts. For example, the Icon sign's "do not cross/turn left" design option had a much higher comprehension rate (40%) than the same state design for the Countdown sign (<10%).

Figure 2. Icon concept sign employed in Creaser et al; 2007.

1.1.2 Identification of a Safe Gap Threshold

The initial simulation study used gap information from the research literature to identify a preliminary gap threshold for use with the CICAS signs (IDS: Creaser et al., 2007). This threshold required that a minimum of 7.5 seconds be available for crossing 2 lanes of traffic (i.e., either the near lanes from the stop sign or the far lanes from the median) before an approaching vehicle on the main road arrived at the intersection. This original threshold was not intended as the final threshold and it was necessary to compare this research-derived value with gap acceptance and rejection data collected at the actual MN test intersection where the CICAS-SSA would eventually be deployed.

During HF 2.2, Gorjestani et al. (2008) collected data at the MN test intersection between September 2004 and December 2007. This data included information about gap patterns, size of accepted gaps by vehicle type (e.g., car, truck), size of gaps rejected by drivers, and number of crashes. Patterns of rejected gaps (i.e., gaps between approaching vehicles and the intersection on the main road that were not accepted by drivers on the minor road) were examined at the test intersection relative to the type of maneuver performed by the driver on the minor road (right turn, left turn, straight crossing). Data were assessed based on time of day, vehicle type, the range of gap sizes available to the driver before making a maneuver, and time spent waiting at the intersection before a gap was accepted. Rejected gaps were of interest because a clear threshold can be ascertained for what size gap most drivers will not accept at the intersection, whereas accepted gaps vary by the size of gaps available to the driver and are less consistent. A rejected gap distribution can be used as the basis of the warning threshold for the CICAS-SSA because the largest gap value that is rejected by most drivers at the intersection likely represents an unsafe gap threshold. The CICAS-SSA warning logic is based on presenting drivers with information about unsafe gaps that they should reject to reduce their risk of a collision at the intersection.

As discussed at length by Gorjestani et al. (2008), the key to alert and warning timing is to choose values which both affirm a driver's previous decision and warn a driver who has yet to decide that a gap is unsafe. It was determined that the average largest gap size consistently rejected by 80% of drivers at the intersection was 6.5 seconds, thus, gaps of 6.5 seconds or less are likely to be unsafe for allowing drivers clear passage across the intersection. This result was consistent across maneuvers and appeared to be independent of time of day, vehicle type, time spent waiting at the intersection, and the average available gap. This suggests that the majority of drivers perceive a gap below 6.5 seconds to be unsafe for crossing;

therefore, this gap serves as the baseline threshold for developing the warning threshold for the CICAS-SSA. Because drivers will need time to comprehend the SSA messages before initiating a maneuver, a 1 second buffer was added to this threshold to account for the human perceptual processing time needed to identify and comprehend a sign message before initiating a crossing maneuver. A 1 second addition brings the warning threshold for the SSA to 7.5 seconds for crossing two lanes of traffic (either the near lanes from the stop sign or the far lanes from the median). This 7.5 second warning threshold is consistent with the previously derived estimation of an appropriate warning threshold based on a variety of research (e.g., AASHTO, 2001; Harwood et al., 1999; Lerner et al., 1995). Thus, the 7.5 second threshold is derived both from actual data collected at the test intersection and is also supported by our research into gap acceptance at other stop-controlled intersections.

This threshold applies to crossing either set of lanes after stopping at either the stop sign or in the median. One goal of the CICAS-SSA is to encourage stopping in the median, or the completion of a "two-stage" crossing maneuver, to facilitate safer crossing of the far lanes. If a driver crosses completely over the intersection or turns left into the far lanes without stopping in the median, it is considered a "one-stage" maneuver. At the stop sign, the top portion of the sign uses an 11 second threshold (the range of the sensors) to indicate traffic in the far lanes. If a vehicle is detected within 11 seconds of the intersection on the far side while a driver is at the stop sign, the top portion of the sign will indicate that it is not safe to enter the far lanes, even if it is safe to enter the near lanes. Ideally, the far-lanes threshold would be 12.5 seconds from the stop sign, which accounts for crossing the near lanes (7.5 s) with 0.5 seconds added for each additional lane (including the width of the median measured in lanes) to cross (using AASHTO, 2001; FHWA, 2001 data and recommendations). This 12.5 second threshold also includes a 0.5 second buffer to account for the processing requirements of elderly drivers (FHWA, 2001). However, to reduce costs at the intersection, the minimal identified sensor set allows the SSA to track vehicles out to 11 seconds from the intersection. Therefore, the placement of the sign is intended to encourage drivers to re-evaluate traffic in the far lanes upon entering the median. Because the sensor set tracks out to 11 seconds, it means that by the time a driver considering a one-stage maneuver enters the median any vehicles that were within 12.5 seconds of the intersection while the driver was at the stop sign will have entered the range of the sensors and the prohibitive message will appear on the median sign.

Ultimately, a two-stage maneuver is considered safer because drivers in the median are assumed to have stopped to reassess the oncoming traffic. However, the SSA sign cannot assume that a two-stage maneuver will be completed and, thus, attempts to account for both eventualities by providing information about both sets of lanes at the stop sign and providing information about the far lanes while the driver is in the median. At the Minnesota test intersection most crashes occur in the far lanes (Preston et al., 2004) when drivers perform a one-stage maneuver. Evaluations of stop-controlled intersections in partner states, such as Wisconsin and Iowa, also found several intersections with significantly more far-lane crashes than near-lane crashes (e.g., Preston, Storm, Donath & Shankwitz, 2006; Preston, Storm, Donath & Shankwitz, 2007). Therefore, it is important to warn for both one-stage and two-stage maneuvers and, by providing a second sign for the median, it is hoped that drivers will be encouraged to stop and reassess the traffic in the far lanes before crossing or turning.

Finally, the range of the minimal sensor set also takes into account a maximum warning threshold for drivers (i.e., the warning that indicates drivers should initiate a maneuver with caution). Research has shown that drivers will almost always accept gaps greater than 12 seconds (Teply et al., 1997; Kittleson & Vandehey, 1991). As a result of work conducted by the ITS Institute Intelligent Vehicles Laboratory, it was found that a sensor set configuration (that could be deployed at the test intersection) that most closely matched this 12-second timeframe provided a maximum warning threshold of 11 seconds. Providing sensor coverage to detect vehicles up to 12 seconds from the test intersection would have required a marked increase in the quantity of intersection equipment that would result in significant increases in purchasing, installation, and maintenance costs. Therefore, 11 seconds was employed as the maximum warning threshold for the current experiment, based on a review of the needed gap thresholds for each maneuver type.

1.1.3 Sign Rotation and Location

In order for drivers to use the sign appropriately, it must be placed in a location that is easy to view and which also allows drivers to map information from the sign to the oncoming traffic. Two studies were conducted in the simulator to determine the best location of the sign and what angle was required to ensure maximum comprehension of the sign messages ("Rotation Study" in HF 3.3: Creaser et al., 2008). Results of the study examining sign rotation angle at these locations indicated that a CICAS-SSA sign should be placed at an angle between parallel and 45 degrees to the mainline roadway. On a practical level, these results suggest that a trade-off exists for sign rotation. Placing a sign such that it is parallel to the roadway it represents would result in the highest degree of comprehension due to the consistent mapping between the sign and roadway but would also result in low levels of visibility (i.e. a low level of visibility equals a high level of visual obstruction, and vice versa) that may impair performance. Rotating a sign such that it faces the driver would result in a lower degree of comprehension due to poor mapping but would result in high visibility. Traffic safety professionals should consider this trade-off when contemplating sign rotation for the CICAS-SSA sign and other traffic control devices.

The second study investigated the optimal location of the CICAS-SSA sign at the test intersection ("Location Study" in HF 3.3: Creaser et al., 2008). The study involved presenting drivers with the candidate CICAS-SSA signs at several locations at the test intersection within a simulated environment. While viewing the CICAS-SSA signs at each location set with active traffic streams on the main road, participants reported to which traffic the signs were referring. Results of the work examining sign location, combined with observations of sign locations in the real world indicated a CICAS-SSA that was placed on the shoulder of the near-side road on the left side (for the driver positioned at the stop sign) along with a second sign located in the median in front and to the right of the driver (for a driver positioned in the median) was most preferred and resulted in adequate understanding. However, observations of sign locations at an actual intersection suggested that visibility of the signs may be poor and the potential of the signs to obscure expressway traffic was highly probable; especially for those drivers seated in larger vehicles (e.g., heavy trucks). In light of this finding it was decided that for drivers at the stop sign a CICAS-SSA is best positioned in the left-side median and that for drivers in the median a CICAS-SSA is best positioned on the far right shoulder (see Figure 1 for final placement of the CICAS-SSA signs). In general, these findings suggest that signs placed towards a vehicle's forward field of view increase the understandability and comprehension of sign information for drivers wishing to cross an intersection.

1.1.4 Identification of Candidate Interface

The goal of the simulation study was to evaluate driver performance of the CICAS-SSA prototype after their re-design (HF3.3: Creaser et al., 2008). Additionally, it was useful for evaluating the warning threshold and the chosen locations and rotation of the signs at the intersection. The ultimate goal of the simulation was to identify which prototype resulted in reduced risky gap acceptance and resulted in no unintended consequences during use. The sign that best met these goals would be moved forward for field testing. The simulation study evaluated driving performance and usability for the three prototype SSA signs (Icon, Hazard, and Countdown signs; see Creaser et al., 2008 for more details on these designs) and compared the results to a baseline driving condition. The simulation was a direct replication of the MN Test Intersection (US 52 & CR 9) and included traffic patterns that were randomly generated by the simulator using data about gap patterns collected at the actual test intersection.

Overall, participants in the simulator rejected more than 80% of the gaps presented that were smaller than the 7.5 second alert threshold for all conditions, but the Icon sign resulted in no unintended consequences and the least risky gap acceptance compared to the other SSA signs. The Icon sign condition had a similar rate of two-stage maneuvers when compared to baseline, as did the Hazard sign. In contrast, the Countdown sign resulted in more one-stage maneuvers compared to baseline and the other two SSA signs. This indication of increased risky behavior while using the Countdown sign suggests that drivers may have been encouraged to take a one-stage crossing maneuver using the sign, possibly due to misinterpretation of the messages or because the design somehow promoted unsafe decision making. The Icon sign also had safety margins that were similar to baseline, despite the potential for increased processing time needed by the driver to interpret the sign's information. The Countdown sign had smaller safety margins when compared to the baseline condition, which may be partly attributed to inappropriate use of the sign. For example, drivers reported using the sign differently than intended, such as accepting a 5 second gap when it was displayed on the sign because they "knew" they could cross in that time, rather than waiting for a gap larger than the warning threshold.

The Icon and Countdown signs also promoted slightly larger waiting times at the intersection (5 seconds, on average). Because traffic streams were random for each trial, the longer wait times in the Countdown and Icon conditions suggested participants were responding to the information on the signs and may have delayed gap acceptance base on the CICAS-SSA information. This is a positive result for both signs because one goal of the SSA is to encourage drivers to wait and reject unsafe gaps in the traffic stream, rather than prematurely accepting a shorter gap due to high traffic volume and a feeling of pressure to accept a gap just to make it through the intersection. In contrast, the Hazard sign resulted in drivers waiting for excessively long periods of time at the intersection before making a decision. The participant comments indicated the drivers were confused by the Hazard sign's design and the waiting was related to this design issue. This is a negative result as confusion about the meaning of the sign is problematic. Finally, drivers reported using the Icon (67.8%) and Countdown (81.4%) sign designs most to help with their crossing decisions and rated both favorably in terms of their usefulness and driver satisfaction. In contrast, only 30.5% of drivers said they used the Hazard sign's information to help with their gap acceptance decisions, and this sign was not rated as favorably in terms of usefulness and driver satisfaction.

1.1.5 Summary

Collectively, the results of these studies indicated that comprehension of message states was best for the prohibitive framework laid out for the CICAS-SSA and when the signs were placed within the driver's forward field of view. Additionally, the Icon sign produced the highest comprehension rates of all signs tested and resulted in no negative results or unintended consequences when examined in the driving simulator environment, whereas the other two designs showed some negative results related specifically to their designs. Because the Icon sign produced no unintended consequences during use when compared to the Countdown sign and the Hazard sign, and resulted in less risky behaviors at the simulated intersection it was selected as the best design for use in the field test. In terms of the warning threshold, data on rejected gaps collected at the test intersection matched well with previous research on the development of an appropriate warning threshold to reduce the risk of gap acceptance at intersections controlled by a stop sign. This threshold was further validated in the simulator study and will be used during the field test.

1.2 CICAS-HF 4.2 Validation Study: Research Goals

The optimal test of any CICAS-SSA sign is how it may support driver performance and be usable for drivers in a real-world environment. The previous research conducted in a driving simulation environment indicated that drivers were assisted in rejecting unsafe gaps using the CICAS-SSA. This research also indicated that drivers perceive the system as being both useful and satisfying, and because of this, drivers reported high confidence in their gap selection decisions. Results from the simulation environment are quite useful in determining the patterns of behavior and attitude we should expect to find in the real world. While simulation-based evaluations provide a wealth of useful information, their ability to replicate the full array of behavioral, cognitive, and perceptual elements of a driving environment do have some limitations. It is because of these limitations that it is beneficial to confirm simulation-based findings in a real-world environment.

The goal of the current work was to validate the utility of the Icon CICAS-SSA sign design in a real-world setting and verify that the lack of unintended consequences seen in the simulator study also translated to the real world. To accomplish this, an instrumented vehicle and sensors installed at the intersection were used to collect driving performance data. Paper-and-pencil surveys were used to collect drivers' subjective impression of their experiences at the intersection. To assess the sign validity, driving performance, visual attention, and subjective impressions while using the sign ("Sign On" condition) were compared against a no CICAS-SSA sign baseline condition ("Sign Off" condition). The performance of smaller vehicles and heavy trucks was analyzed since a concern of the sponsor is whether these signs can be used for both vehicle classes, as well as how the placement of the signs affect visibility for all driver types.

The study evaluated the icon CICAS-SSA interface at the Minnesota test intersection (US 52 & CR 9). To better understand how the sign's use may influence driver performance metrics relative to measures of rejected gaps, safety margins, movement time, wait time, and crossing maneuver type were collected. The study also evaluated the appropriateness of the 7.5 second gap threshold for crossing a set of lanes via these measures. It was expected that drivers would perceive the warning threshold to be appropriate and to accept gaps above that threshold based on the CICAS-SSA information. Because sign usability may significantly impact the employment of signs, this study also utilized subjective responses that included mental workload, usability, sign use, sign preference, and open-ended comments.

Driver age was also considered important to evaluate during this study. Older drivers are over-represented in rural intersection collisions (Staplin & Lyles, 1991; Preusser et al., 1998) and may also have more difficulty understanding traffic signs and signals (Shinar et al., 2003; Dewar, Kline, & Swanson, 1994). For this reason three age groups of drivers ranging from 19 to 72 were recruited for this study.

We expected the results of this study would be congruent with those from the previous simulator experiments, specifically those from the Random Gap study (HF 3.4: Creaser et al., 2008), given the high degree of ecological validity offered by the simulator. The CICAS-SSA signs should lead drivers to take fewer risks when entering the thru-stop intersection in terms of rejecting more shorter gaps, selecting gaps with larger safety margins, and exhibiting safer crossing behaviors, such as by using a two-stage versus a one-stage maneuver. We also expect that drivers will find the information on the CICAS-SSA signs to be comprehended easily and be perceived as being useful. Observing these trends would, 1) give strong evidence that the results are robust, especially if the results are consistent with previous studies; 2) give us confidence that similar results would be observed in future FOTs or deployment; and 3) reassure us that no adverse effects will occur in the real-world while deploying the CICAS-SSA sign.

2 Methodology

2.1 Participants

Two samples of drivers were used in this study, one from the general population who drove cars and another from heavy vehicle fleet drivers who were qualified to operate a heavy truck.

2.1.1 Car Driver Participants

Car driver participants were recruited from the "outer" suburbs (i.e. outside the I-494/I-694 loop around the Minneapolis/St. Paul metropolitan area) and rural areas around the test intersection to test participants who were experienced with rural roadways and intersections. These participants were contacted through a local recruiting agency and were screened prior to scheduling to verify that they possessed a driver's license for at least a year, had no more than 3 speeding violations within the past 3 years, had no DUI or reckless driving citations, and to verify they did not participate in past CICAS efforts (Participants in past CICAS evaluations were ineligible to participate because previous experience with the CICAS-SSA signs may have biased driver performance and subjective responses). Screening based on these criteria ensured participation by those drivers who were deemed to be similar to the general driving population. To examine the influence of age on driver performance and usability, 48 drivers were recruited across three age groups. Each age group was approximately balanced for sex (see Table 1). Participants were compensated $250 cash for their participation at the completion of the study

Table 1. Age and sex of participants for the car driving sample.

Age Group	Young	Middle	Older	All Ages
Recruited Range	19 – 25	35 – 50	60 – 72	
Mean Years	23.3	43.8	68.8	
SD Years	1.6	4.4	3.9	
Females	9	8	8	25
Males	9	7	7	23
Both Genders	18	15	15	48

2.1.2 Truck Driver Participants

13 truck driver participants (12 male and 1 female) were recruited through local contacts at the Minnesota Department of Transportation and Goodhue County, MN. The mean age of the truck drivers was 50.5 years (*SD*=8.3 years). Truck drivers were not reimbursed for their participation because participation in this study was considered a work related duty.

2.2 Equipment

2.2.1 Infrastructure Data Collection System

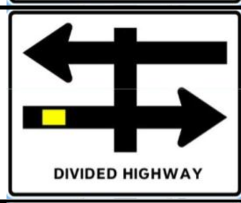
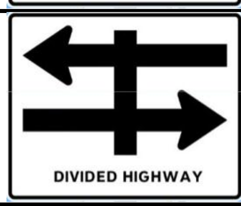
The following is an abbreviated description of the data collection system of the intersection and experimental vehicles (i.e., car and truck) (see Gorjestani et al., 2008 for a complete description). Mainline roadway sensing was provided by an array of radar sensors spaced 122m (400 ft) apart and connected to the central processor through an IEEE 802.11b wireless local area network. Minor road sensing was provided by a fusion of radar and scanning lidar sensors, also connected to the central processor through the local wireless network. Minor road sensing was designed to detect the presence, location, and speed of a vehicle approaching the major road. Intersection surveillance was accomplished using an array of scanning lidar sensors, also connected to the central processor via the local wireless network. The purpose of the intersection sensor was to determine the presence and location of vehicles located in the median of the intersection. A full description of the mainline sensor system, the minor road sensor system, the intersection sensor system, central processor, and power distribution systems is presented in Alexander , Cheng, Donath, Gorjestani, Menon, Newstrom, and Shankwitz, 2006.

The research system serves three purposes. First, it allows the collection of macroscopic data related to driver gap acceptance and rejection. This is done by recording the trajectories of vehicles entering and crossing the mainline traffic stream while simultaneously recording the trajectories of vehicles travelling on the mainline. This is a unique system in that it relies solely on sensor data. Second, because of wireless capabilities, it is possible to support the collection of microscopic data acquired from an in-vehicle instrumentation suite, and synchronize that data with macroscopic data collected by the infrastructure-based macroscopic system. The ability to precisely define and measure the point at which a vehicle is committed to cross or enter a traffic stream at a rural intersection provides significant insight into gap acceptance behavior, and provides a complement to the objective of supporting accurate unsafe gap rejection. Third, the system provides a basis with which to evaluate the prototype CICAS-SSA sign before it is exposed to the general public. With the examination of the alert and warning timing threshold, the driver interface could be tested *in-situ* at the research intersection. This allows a new traffic control device to be tested in a controlled manner before it is released fully to the public.

2.3 Icon Sign Design

The paper and pencil and random gap tests indicated that the Icon sign design would be the best design option to support driver performance and usability. The Icon sign presents an overview of the highway and the direction of travel of vehicles on a highway. This sign uses icons to indicate when traffic is detected near the intersection in each set of lanes; where “near lanes” indicates traffic traveling towards the right, relative to the driver, while “far lanes” indicates traffic traveling towards the left, relative to the driver. When a vehicle is detected approaching the intersection, but is not considered too close to the intersection to negatively impact safety a yellow icon lights up (indicating the presence of a vehicle at a safe distance). This icon is yellow to indicate that it may be safe to cross, but that the driver should proceed cautiously. As a vehicle continues to travel toward the intersection and is within a predetermined safety threshold (7.5 seconds for near lanes when at the stop sign or for far lanes when stopped in the median; 12.5 seconds for far lanes when at the stop sign) a red block (indicating a vehicle) is illuminated and a prohibitive symbol indicates that it is unsafe to enter the intersection. If no vehicles are detected near the intersection by the CICAS system, no blocks or prohibitive symbols are illuminated. See Table 2 for a depiction of each display state of the icon sign design.

Table 2. All display states of the icon design CICAS-SSA sign.

Display States	Meaning of Display State
	Do not enter the intersection; a vehicle is detected too close to the intersection in the near lanes (approaching from the left, < 7.5 seconds from the intersection).
	Do not enter the intersection; vehicles are detected too close to the intersection in both the near (approaching from left, < 7.5 seconds from the intersection) and far lanes (approaching from right, < 12.5 seconds from the intersection).
	You may turn right; no vehicles detected approaching from the left in the near lanes. Vehicles are detected approaching from the right and are too close to the intersection (< 12.5 seconds from the intersection); do not cross or turn left into the far lanes.
	A vehicle is detected approaching from the left in the near lanes (> 7.5 seconds from the intersection). You may be able to cross or turn, but proceed with caution.
	No vehicles are detected approaching in the near (from the left) or far lanes (from the right). You may be able to cross or turn.

2.3.1

2.3.2 Experimental Vehicles

A 2004 Infiniti M45 served as the instrumented vehicle for car drivers while a 1999 International Model 2540 served as the heavy vehicle for truck drivers. Both vehicles were similarly outfitted with data collection equipment that included a dual frequency carrier phase differential GPS (accurate to between 2-5 cm) which provided position measurements at 10 Hz, a six axis (three axes of rotational rates, three axes of acceleration) Inertial Measurement Unit (IMU), brake sensors (indicating brake actuation), a throttle position sensor, and eight channels of video (driver's forward view, driver's hands, driver's feet, driver's face, vehicle left side, and vehicle right side).

Critical to the utility of the instrumented vehicle was the capability to synchronize on-board data collection with data collection at the intersection. Inter-computer synchronization was handled via NTP – Network Time Protocol. The NTP was manifest through the use of a local 802.11b wireless network located at the test intersection.

2.4 Procedures

Participants were instructed to meet the experimenters at the Goodhue County Mn/DOT truck station in Cannon Falls, MN, which is approximately 8 miles north of the experimental intersection. Two sessions were conducted each day (one participant per session). Testing of car drivers occurred between the hours of 12pm and 7:00pm to test during increased traffic density times on US 52. Testing of truck drivers occurred between the hours of 8am and 4:00pm because drivers were required to participate during normal working hours.

Upon arrival, participants were given a short introduction that included a warning that they would be driving in heavy traffic conditions. Participants then completed the informed consent process as mandated by the University of Minnesota's Institutional Review Board when conducting studies involving human subjects (Appendix A). This was followed the completion of a driver information form required by Infiniti/Nissan, who owned the experimental vehicle (Appendix B) along with demographic and driving history background questionnaires (Appendix C) and experimental instructions (Appendix D).

Participants were then provided with an introduction to the study that included a generic description of how a CICAS-SSA sign might work at the intersection and the types of information that would be provided by the sign. Specific operational details of the CICAS-SSA sign were not disclosed. The instructions that were read to each participant stated:

These "smart" signs are located both in the median and across the far lanes of traffic. The information displayed on each sign changes in real time depending on the flow of traffic near the intersection. These signs present information that helps you, the driver, make decisions about when to cross or turn at the intersection based on current traffic conditions. The message on each sign corresponds to the actual traffic conditions present at the intersection—the messages for each sign may be different from one another, but will convey one of three options for making a maneuver at the intersection. These options are, a) Do not enter the intersection, b) Enter the intersection to turn right only, or c) Enter the intersection to cross over, turn right, or turn left. Your primary goal is to drive safely as you normally would while making each maneuver.

Participants were also given a brief overview of the types of driving maneuvers they would be asked to complete during the study, including images similar to those shown in Figure 2.

a.

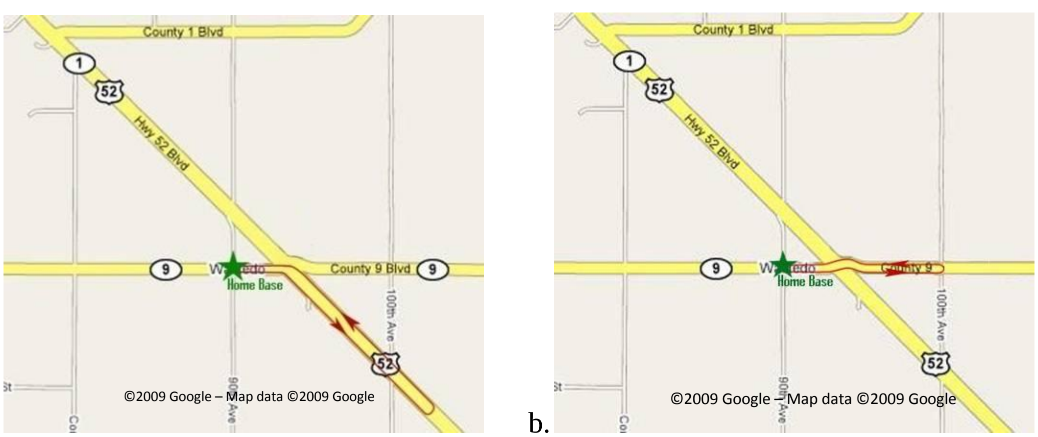


Figure 3. Depictions of the a) Right Turn and b) Crossing maneuvers that will be shown to participants.

Participants then drove to the starting position located on CR9 to the east of the US 52 and CR9 intersection (see "Home Base" in Figure 2). They then completed practice drives to experience the maneuver types they would be asked to complete during the experiment (i.e., right turn, crossing maneuver, and left turn). Each maneuver started from Home Base, which faced east on CR9 approximately one quarter mile west of the intersection. An experimenter was always seated in the rear of the vehicle to monitor safety levels throughout each trial as well as to initiate data collection at the start of each trial. A second experimenter monitored approaching traffic to identify traffic streams that were density and duration. Once a candidate traffic stream was identified the experimenter then radioed the in-vehicle experimenter to initiate a trial. The participant then drove to the intersection. This process ensured that each participant experienced a continuous stream of gaps upon arrival at the intersection.

Participants then completed two blocks of experimental trials that were differentiated according to sign condition (i.e., CICAS-SSA "sign on" and "sign off"). To reduce the possibility of confounding effects due to order, block presentation order was counterbalanced across participants. Each block of trials consisted of six maneuver types that included two left-turn, two right-turn, and two crossing maneuvers. Due to scheduling constraints, truck drivers completed two left-turn and two crossing maneuvers within each block. Maneuver type was randomized within each block to further control for order effects (however, no maneuver type was repeated sequentially within a block of trials). Appendix E presents all block and maneuver type presentation orders for all participants.

After each trial, participants completed a post-maneuver questionnaire (Appendix F) to assess their behavior and effort during the last trial. They then completed a set of Post-Drive Questionnaires (Appendices G & H) to assess the degree to which the CICAS-SSA sign helped them make their crossing decisions and were then asked to explain why they did or did not use the CICAS-SSA. Participants then received a description of sign functioning and completed the usability questionnaire (Van der Lann, Heino, & de Waard, 1997) to assess participants' perception of usefulness and acceptance (Appendix G). At the conclusion of the study, the participant returned to the meeting location and then completed a post-drive questionnaire before being debriefed and reimbursed.

2.5 Dependent Variables

2.5.1 Performance Dependent Variables

Crossing performance dependent variables describe the relationship between the participants' vehicle and approaching vehicles on the main highway (US 52). However, to calculate these variables it was necessary to define and identify several indicators of vehicle position. See Table 3 for a description of these indicators.

Table 3. Performance dependent variable indicators when initiating a maneuver.

Indicator	Definition
Entrance	When the front bumper of the participant's vehicle crosses into the closest expressway lane (e.g., lane 3 or 6 in Figure 1). Time-to-contact (TTC) and Gap times which used the Entrance indicator were also verified to see if the participant vehicle entered the intersection before the last vehicle crossed through the intersection. In cases where this occurred (TTCs less than 3 seconds), the shorter gap was added to the proceeding larger gap that followed for our calculations.
Exit	When the rear bumper of the participant's vehicle crosses out of the furthest expressway lane (e.g., lane 4 or 5 in Figure 1).
Lane of Interest (LOI) Exit	When the rear bumper of the participant's vehicle crosses out of the expressway lane which harbors the next-closest approaching vehicle.

The performance dependent variables calculated from the indicators above provide insight into driver behavior changes relative to the employment of the candidate CICAS-SSA sign. The following list presents definitions of the performance dependent variables. These dependent variables will be analyzed separately for both stages of the crossing maneuver (i.e., from the stop sign and from the median.

80th Percentile Rejected Gaps – The 80th percentile gap from the distribution of all rejected gaps. See Figure 4 for a depiction of a gap. As an example, the warning threshold of the CICAS-SSA sign is based on an 80th percentile rejected gap of 7.5 seconds which indicates that 80% of all gaps rejected were equal to or smaller than 7.5 seconds. As described in the Microscopic Model analysis (Gorjestani et al., 2008) the 80th percentile rejected gap can be used as a surrogate measure of system performance to observe the effect of the CICAS-SSA sign. Given that the CICAS-SSA sign is intended to help drivers reject gaps that are smaller than 7.5 seconds, we expect the 80th percentile rejected gap to increase when drivers use the CICAS-SSA sign. Gaps 15 seconds or greater were removed from the data prior to analyses due to the fact that gaps larger than 15 seconds are generally accepted by drivers.

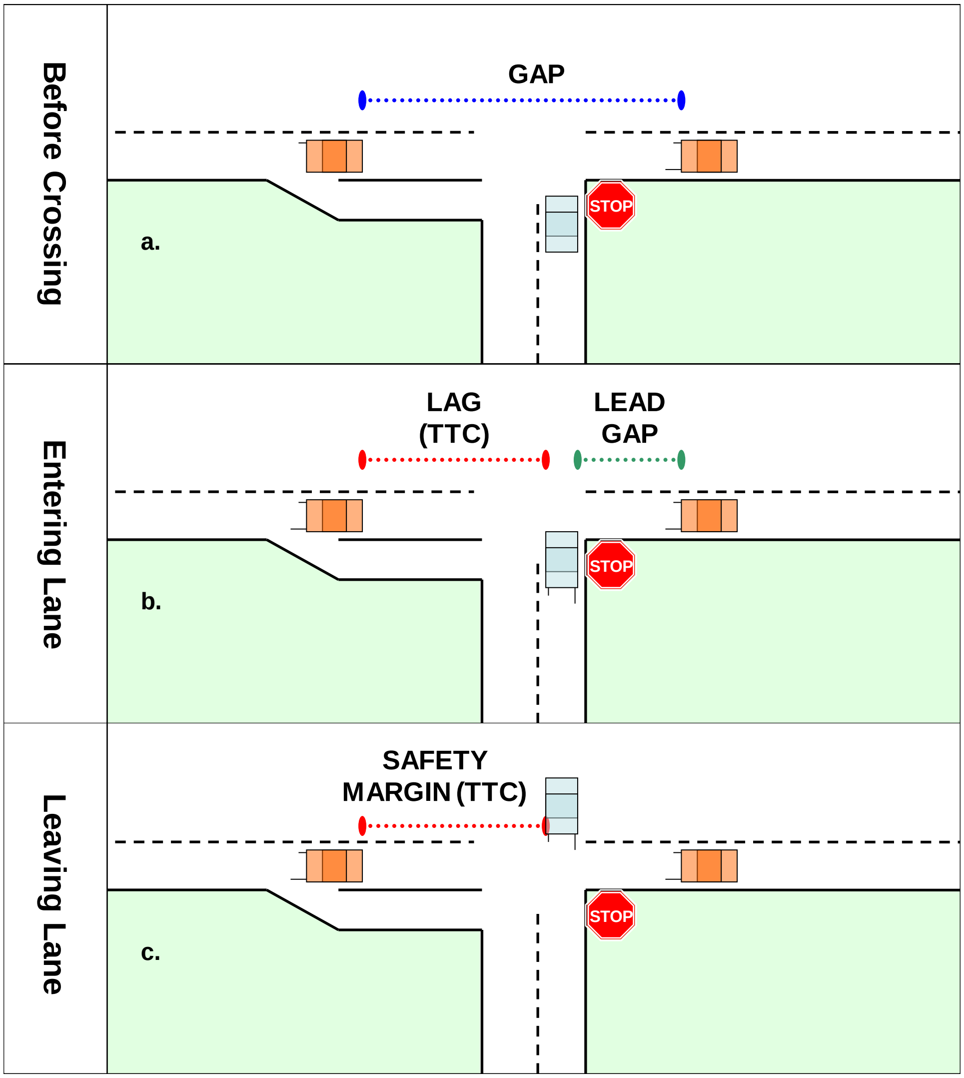


Figure 4. Depiction of a) gap, b) lag, lead gap, and c) safety margin, relative to the participants' vehicle crossing the test intersection.

Percentage of Rejected Gaps Smaller than the Critical Threshold – The percentage of rejected gaps smaller than 7.5 seconds across sex, age groups, and individual trials for each sign condition and maneuver. See Figure 4a for a depiction of a gap. As described in the Random Gap study (Creaser, et al., 2008), this measure is used to gauge the appropriateness of the 7.5 second critical gap threshold that the CICAS-SSA signs use to discern safe from unsafe intersection states. Participants in the Random Gap simulation study rejected more than 80% of gaps that were smaller than the alert threshold (which was similar to the naturalistic gap rejection pattern observed at the real intersection). The similarity in behavior between the CICAS-SSA conditions and the baseline condition in that study was expected because the alert threshold is derived from actual gap rejection behavior at the real intersection. The assumption for using the 80% rejection threshold as the basis for the alert threshold is that drivers are generally good at rejecting unsafe gaps at intersections (Gorjestani et al., 2008). We expect this finding should be replicated in the current experiment.

Accepted Gap - Total length of the original accepted gap taken by drivers, from rear bumper of lead vehicle to front bumper of following vehicle, measured when the participant enters the intersection. This dependent variable is also termed Absolute Gap. See Figure 4a for a depiction of a gap.
Accepted Gap = GAP @ Entrance Indicator

Lead Gap - Gap from participant's vehicle to the vehicle that passed the intersection. This dependent variable is used to determine when a driver decides to cross the intersection relative to how soon after the last vehicle passed. Longer lead gaps may indicate that the driver is viewing or interpreting the sign's information. See Figure 4b for a depiction of a lead gap.
LEAD GAP = GAP – LAG(TTC) @ Entrance Indicator

Time-to-Contact (TTC) - Remaining gap once participant enters the intersection. This metric indicates the time remaining before an approaching vehicle would arrive at the intersection. This is therefore a measure of the relative safety of a gap. See Figure 4b for a depiction of a lag.
TTC = LAG(TTC) @ Entrance Indicator

Safety Margins - Time-to-contact (TTC) from when a participant's vehicle exits the Lane of Interest. This indicates the amount of time remaining before the approaching vehicle would collide with a participant. This is therefore a measure of the relative safety of a gap. See Figure 4c for a depiction of a safety margin.
Safety Margin = LAG(TTC) @ LOI Exit Indicator

Movement Time – Time to cross each set of lanes from entrance to exit (see indicator definitions). This cannot be calculated for the right turn maneuver, or for the far set of lanes when making a left turn maneuver. Slower movement times across a set of lanes will result in a reduced safety margin. This metric was called "Time-to-Cross" during CICAS-HF 2.2 Microscopic field study (Gorjestani et al., 2008).
Movement Time = Time @ Exit Indicator – Time @ Entrance Indicator

Wait Time – Amount of time waits at the either the stop sign or in the median before crossing. This dependent variable may reflect time watching traffic, time watching and interpreting the CICAS-SSA sign information, and time making the decision to initiate a maneuver. Wait time is dependent on the gaps available to drivers. It is possible that the presence of the CICAS-SSA sign may increase wait time at the intersection. Wait times could increase with the CICAS-SSA sign because drivers are encouraged to reject a series of unsafe gaps in favor of waiting for a more acceptable gap. It is expected that a good CICAS-SSA sign design may increase wait time as a function of safety but not excessively when compared to baseline.
Wait Time = Time @ Entrance Indicator – Time @ Stop Indicator

Maneuver Stages – A one-stage maneuver indicates that a driver stopped once at the stop sign and then entered the intersection to perform either a left turn or crossing maneuver (e.g., not stopping at location Pn in Figure 1). A two-stage maneuver indicates that that a driver stopped once at the stop sign and then stopped in the median (e.g., stopping at location Pn in Figure 1). Stopping in the median was indicated by a speed less than 10 mph. This speed threshold was used because naturalistic data at the test intersection showed that a minimum of 87% of vehicle traffic leaving the median was found to be traveling at or below 10 mph. This also approximates the percentage of trials in the simulation study (HF3.4: Creaser et al., 2008) that were considered two-stage maneuvers for the baseline (no sign) condition. This dependent variable will indicate whether drivers are choosing to stop in the median, and in so doing, reassessing the traffic situation on the far side before crossing or making a left turn. This metric was called the "Crossing type maneuver" during CICAS HF3.4 simulation study. This cannot be calculated for the right turn maneuver.

Maneuver Type = two-stage (if Median-Stop Indicator is TRUE)
one-stage (if Median-Stop Indicator is FALSE)

2.5.2 Usability Dependent Variables

The usability dependent variables provide an indication of driver subjective perceptions of workload, comprehension, and use relative to the CICAS-SSA sign. Data from the truck drivers was not included in any of the usability dependent variable analyses, except for the question on whether they used the CICAS-SSA sign or not. There were two reasons for this exclusion, first was that the truck driver population is different enough from the car driver sample, in terms of experience and vehicle type, that it would not be prudent to compare subjective results. Second, the small sample of truck drivers (relative to the larger car driver sample) would misrepresent or falsely heighten any observed differences between the groups.

2.5.2.1 Effort Questionnaire

Driver effort relative to the use of a CICAS-SSA sign is an important element of system success due to the notion that if drivers expend excessive effort (e.g., mental effort, stress) interacting with the sign drivers may be less willing to use the sign during future maneuvers. Effort relative to CICAS-SSA sign use was measured through the use of an effort questionnaire that was provided to participants after each maneuver. Participants provided responses along a five-point Likert style scale where disagreement with the question was indicated by lower scores while agreement was indicated by higher scores. The questionnaire included the questions presented below (Appendix F).

Did you feel you rushed to make your maneuver (turn or cross) through the intersection?
Did you feel you had enough time to make your maneuver (turn or cross) through the intersection?
How safe was the gap in traffic that you chose while driving through the intersection?
How stressful was your experience at the intersection?
How much mental effort was needed to drive through the intersection?
How much physical effort was needed to drive through the intersection?
How would you rate the overall safety of your performance while driving through the intersection?

2.5.2.2 Sign Comprehension Questionnaires

Comprehension provides insight into how well drivers understood the CICAS-SSA sign content and functioning. Low comprehension of the CICAS-SSA sign could lead to errors in understanding sign content and increased frustration that may lead to sign non-use. Sign comprehension was measured through the use of two questionnaires: 1) comprehension and usage and 2) usability scale. Both questionnaires were provided to participants after they completed the block of CICAS-SSA sign trials and the CICAS-SSA sign functioning was explained to them (Appendices G & H).

2.5.2.2.1 Comprehension & Usage Questionnaire

The comprehension and usage questionnaire was composed of 10 questions that address issues of sign confusion, understanding, and confidence in sign use. Participants responded to each question using a five point Likert scale that ranged from "Strongly Disagree" to "Strongly Agree". In an effort to better understand the robustness of comprehension results the comprehension and usage questionnaire employed in the current work was identical to that employed in both the paper and pencil and simulation-based comprehension studies. The following questions were included in this questionnaire.

I felt confident using this sign.
I felt it was confusing to use this sign.
Using this sign made me feel safer.
I trusted the information provided by the sign.
I like this sign.
The sign was reliable.
I felt this sign was easy to understand.
The sign's information was believable (credible).
This sign was useful.
I could complete the maneuver the same way without using the sign.

In addition, participants were also asked to provide open-ended responses indicating whether they used the CICAS-SSA sign information to help make crossing decisions, what sign information they used, and how they used it.

2.5.2.2.2 Usability Scale

The Usability Scale (as described in Van der Laan, Heino & de Waard, 1997) is a measure of the perceived satisfaction and usefulness of a system (i.e., the CICAS-SSA sign). This measure requires participants to rate their perceptions on a number of bipolar adjective scales. These scales are then summed to produce separate scores for the level of perceived satisfaction and usefulness. These scores can be positive or negative with positive and increasingly larger values representing greater satisfaction and usefulness (the Usability Scale is the final questionnaire presented in Appendix G). Given that the Usability Scale is standardized the results can be compared to other assistive signs and systems. More importantly, results can be compared to previous CICAS-SSA sign evaluations (i.e., simulation study, HF3.4: Creaser et al., 2008).

2.6 Statistical Procedures

The independent variables included of Sign State (Sign On, Sign Off), Maneuver Type (Right Turn, Left Turn, Crossing), and Age Group (Young, Middle, Senior). Sign State and Maneuver Type were within-subjects variables (each participant experienced all levels of each variable) while Age Group was a between-subjects variable (each participant experienced only one level of each variable). Dependent variables were categorized according to Driving Performance, Mental Workload, and Usability metrics. All measures were analyzed separately for car and truck drivers. For the driving performance metrics, separate analyses were run for the stop sign (i.e., entering the intersection from the stop sign) and median (i.e., entering the intersection from the median) positions.

Dependent variables were analyzed using a 2 (Sign State) by 3 (Crossing Maneuver) by 3 (Age Group) mixed-model analysis of variance (ANOVA). The number of crossing maneuvers included in the model varied based on the particular metric due to the availability of that data. For example, it was not possible to collect wait times from the median when making a right turn maneuver. Differences between means were considered significant if $p \leq 0.05$ alpha level. The focus of the results will be on significant main effects (ME) or interactions, but results that approach significance ($p \leq 0.065$) may also be discussed as they may indicate a trend. Significant main effects and interactions were further analyzed with post hoc contrast analyses (*t tests*) using a Bonferroni correction to account for the additional statistical tests.

3 Results

3.1 Performance Dependent Variables

Drivers completed each Sign State and Maneuver Type combination twice (e.g., in the Sign On condition each participant made two right turns, two left turns, and two crossing maneuvers). When repeating the same maneuver, there is the possibility that drivers will learn from their first experience in that condition, resulting in a change of performance. Often this change results in improved performance due to the driver having a better understanding of the task and circumstances. In order to control for this possibility, participant's performance on the first trial (e.g., the first right turn while the sign was on) was compared to performance on the second trial (e.g., the second right turn while the sign was on) for the accepted gap, time-to-contact, safety margin, and wait time measures. A *t* test statistic was used to compare the two trials. The analysis indicated no statistically significant differences were present for any of the measures, suggesting that there were no significant learning effects between the first and second trials. Therefore for the results presented below, the results from trial one were averaged with the results for trial two within each Sign State and Maneuver Type condition for all dependent variable measures.

Due to a technical issue with the data collection software, intersection traffic data was missing for two participants (1 young male, 1 young female). As a result, these participants were only included in the wait time, movement time, and questionnaire dependent variable measures. A small number of participants were missing data for one of their two trials within a Sign State and Maneuver Type condition. In these instances, data from the non-missing trial was used in place of the average between the two trials.

Finally, the '80th percentile average rejected gap' and the 'percentage of gaps less than 7.5 seconds' dependent variables require a large sample size in order to make generalizable conclusions. In order to maximize the effectiveness and appropriateness of these measures with a large enough sample size, it was necessary to aggregate the entire data over all participants (a separate aggregation was completed for car and for truck drivers). The result of this was a single value for each measure for each Sign State and Maneuver Type combination; results were also aggregated over Maneuver Type to produce a single value for each Sign State. Because of this necessary data reduction, there are two limitations for the data analysis of these two dependent variables: 1) analyses of age and gender (for car drivers) was no longer possible, and 2) the ANOVA statistical procedure could not be run. Instead, comparisons were made between Sign On and Sign Off conditions following these stipulations:
For 80th percentile average rejected gap, a difference between Sign On and Off states greater than 0.5 second (for car drivers) or 1.0 second (for truck drivers) was considered significant for each maneuver.
For the percentage of gaps less than 7.5 seconds, a difference between Sign On and Off states greater than 2.5% (for car drivers) or 5.0% (for truck drivers) was considered significant for each maneuver.

3.1.1 80th Percentile Rejected Gap Size

Table 4 presents the 80th percentile rejected gap size by maneuver and sign state for car drivers. Selecting a larger gap is related to making a safer crossing maneuver and therefore a larger 80th percentile rejected gap indicates that drivers have rejected a greater number of smaller gaps, thereby indicating a reduction in the amount of risk they are willing to take. Overall, rejected gap size was larger while entering the intersection from the median than while entering from the stop sign. This was expected because drivers were told to begin their maneuvers when traffic was approaching in the close lanes (i.e., when they were at the stop sign) but traffic in the far lanes (i.e., when they were in the median) was, for all intents and purposes, random. It appears that while crossing when the sign was On, drivers had longer 80th percentile rejected gap sizes than while it was Off. Drivers seemed relatively unaffected by the sign state while making right turns and left turns, although drivers selected somewhat shorter (but still safe) gaps while crossing from the stop sign to the median to make a left hand turn while the sign was On. Although this final observation is interesting, it does not appear to impact the drivers' ability to safely cross the close traffic or to make their left turn maneuver. Below, results are examined in greater detail by the location at which each maneuver was made (i.e., stop sign vs. median).

Table 4. 80th Percentile rejected gap size, in seconds, for car drivers according to maneuver type and sign state. Note, the 'On-Off' notation indicates the difference in rejected gap size between sign states.

Maneuver	Sign State	At Stop Sign (*n*=4084)	At Median (*n*=1332)
Left	On	6.61	7.43
	Off	7.29	7.39
	On-Off	*-0.68*	*+0.04*
Cross	On	7.31	9.05
	Off	6.41	7.46
	On-Off	*+0.90*	*+1.59*
Right	On	6.60	-
	Off	6.94	-
	On-Off	*-0.34*	-
All	*On*	6.90	8.14
	Off	6.89	7.43
	On-Off	*-0.01*	*+0.71*

While making a crossing maneuver from the stop sign location (i.e., crossing over southbound traffic only) drivers rejected gaps that were an average 0.90 second longer during the Sign On condition. In contrast, rejected gaps were 0.68 seconds shorter while crossing that same traffic stream to make a left turn. Collectively this suggests that car drivers selected larger, safer gaps while crossing from the stop sign to the median when their goal was to make a crossing maneuver than when their goal was to make a left turn. Graphs that plot the cumulative distribution of rejected gaps for all three maneuvers separately and cumulatively ('All') are presented in Figure 5.

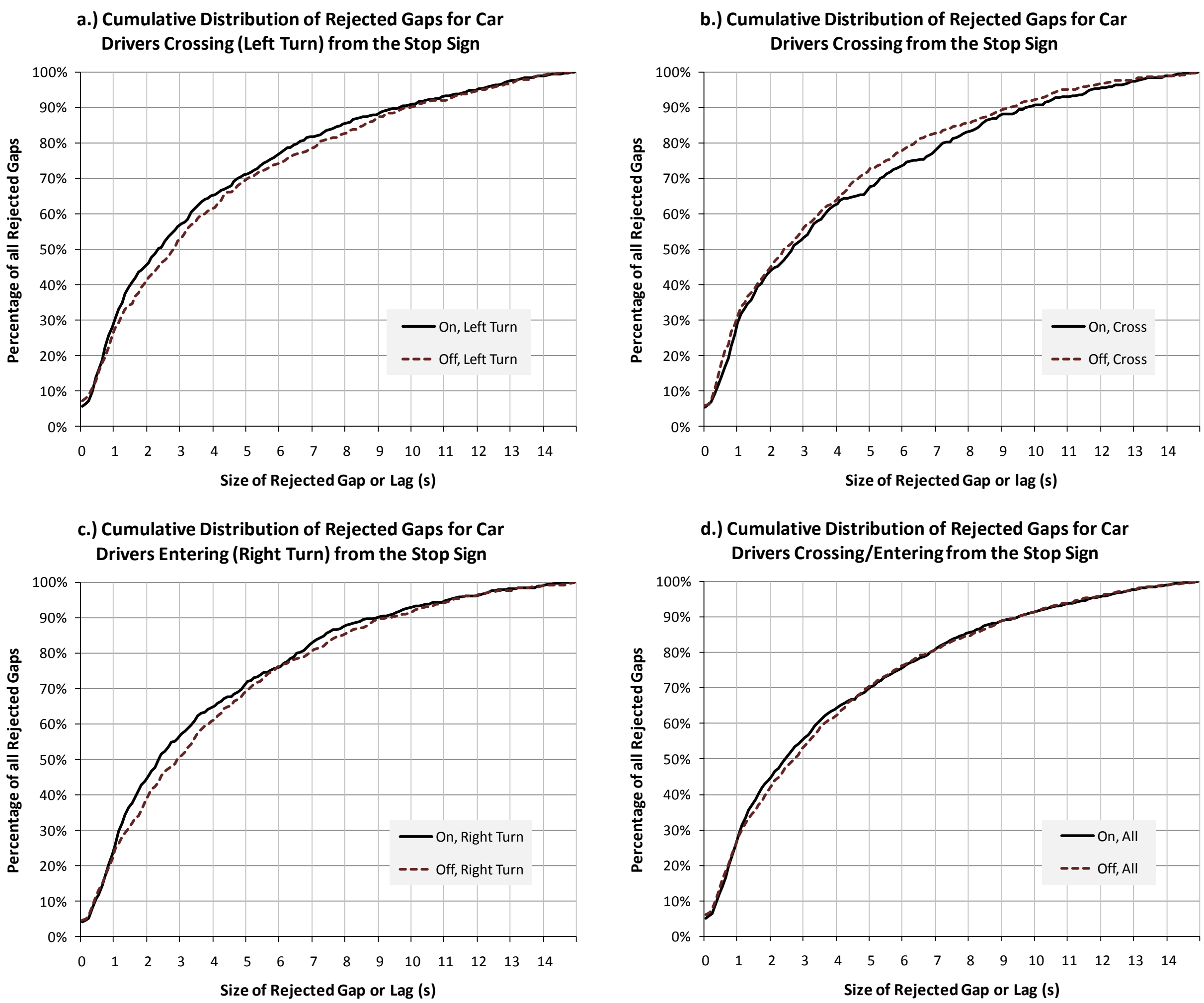


Figure 5. Cumulative frequency distributions of rejected gaps for car drivers positioned at the stop sign for a) left turns, b) crossing, c) right turns, and d) collectively for all maneuvers.

For car drivers positioned in the median, the 80th percentile rejected gap size across both (i.e., left turn and straight) maneuvers was 0.71 seconds larger for the Sign On condition compared to the Sign Off condition (see the 'All' Maneuver in Table 4). When these data are examined relative to each maneuver type, results indicate that when car drivers were positioned in the median they rejected gaps that were 1.59 seconds larger during the Sign On condition as compared to the Sign Off condition. Graphs that plot the cumulative distribution of rejected gaps for both maneuvers separately and cumulatively ('All') are presented in Figure 6.

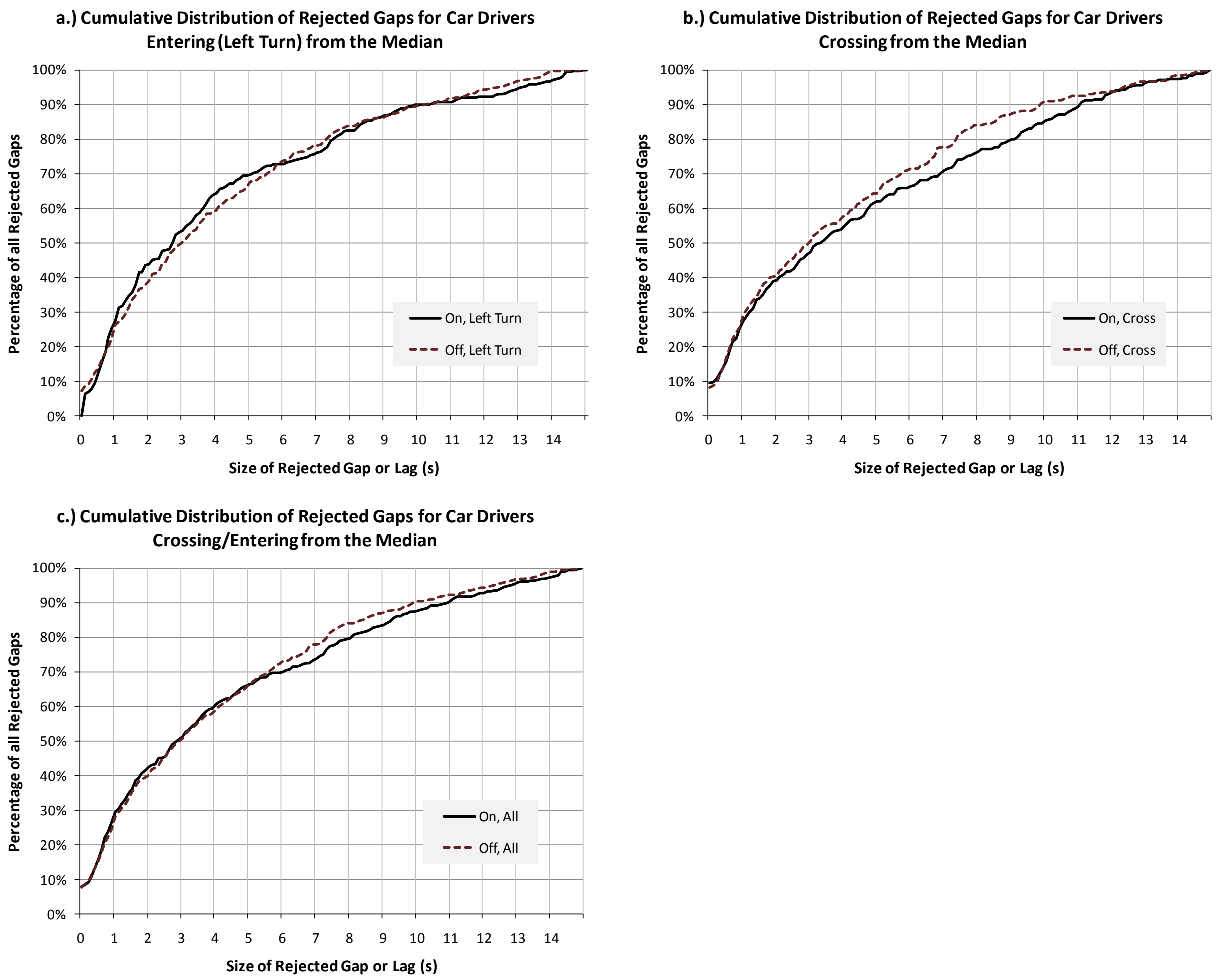


Figure 6. Cumulative distributions of rejected gaps for car drivers positioned in the median while making a a) left turn, b) crossing maneuver, or c) averaged across both maneuvers.

Table 5 presents the 80th percentile rejected gap size by maneuver type and sign state for truck drivers. Similar to the car drivers, rejected gap size was larger while entering the intersection from the median than while entering from the stop sign, as expected. It appears that while crossing when the sign was On, truck drivers had longer 80th percentile rejected gap sizes than while it was Off. Truck drivers seemed to select somewhat shorter (but still safe) gaps while crossing from the stop sign to the median and while entering traffic to make a left hand turn while the sign was On. Due to the smaller size of the truck driver sample, it is difficult to say for certain whether this observation is due to chance or is a direct effect of the sign, however it does not appear to impact the drivers' ability to safely cross or enter traffic while making this maneuver. Below, results are examined in greater detail by the location at which each maneuver was made (i.e., stop sign vs. median).

Table 5. 80th Percentile rejected gap size, in seconds, for truck drivers according to maneuver type and sign state. Note, the 'On-Off' notation indicates the difference in rejected gap size between sign states.

Maneuver	Sign State	At Stop Sign (n=508)	At Median (n=275)
Left	On	8.45	8.35
	Off	9.82	10.21
	On-Off	*-1.37*	*-1.86*
Cross	On	9.75	9.60
	Off	8.48	8.59
	On-Off	*+1.27*	*+1.01*
All	*On*	8.55	8.68
	Off	9.23	9.96
	On-Off	*-0.68*	*-1.28*

Significant differences were observed for the 80th percentile rejected gap size when the data were examined according to maneuver type. While making a crossing maneuver from the stop sign position (i.e., crossing over Southbound traffic only, see Figure 1) truck drivers rejected gaps that were 1.27 seconds larger during the Sign On condition as compared to the Sign Off condition. In contrast, rejected gaps were 1.37 seconds smaller while crossing that same traffic stream to make a left turn during the Sign On condition as compared to the Sign Off condition. Collectively, these results suggest that truck drivers selected both larger and safer gaps when performing a crossing maneuver from the stop sign position as compared to a left turn maneuver from the same location. Graphs that plot the cumulative distribution of rejected gaps for both maneuvers separately and cumulatively ('All') are presented in Figure 7.

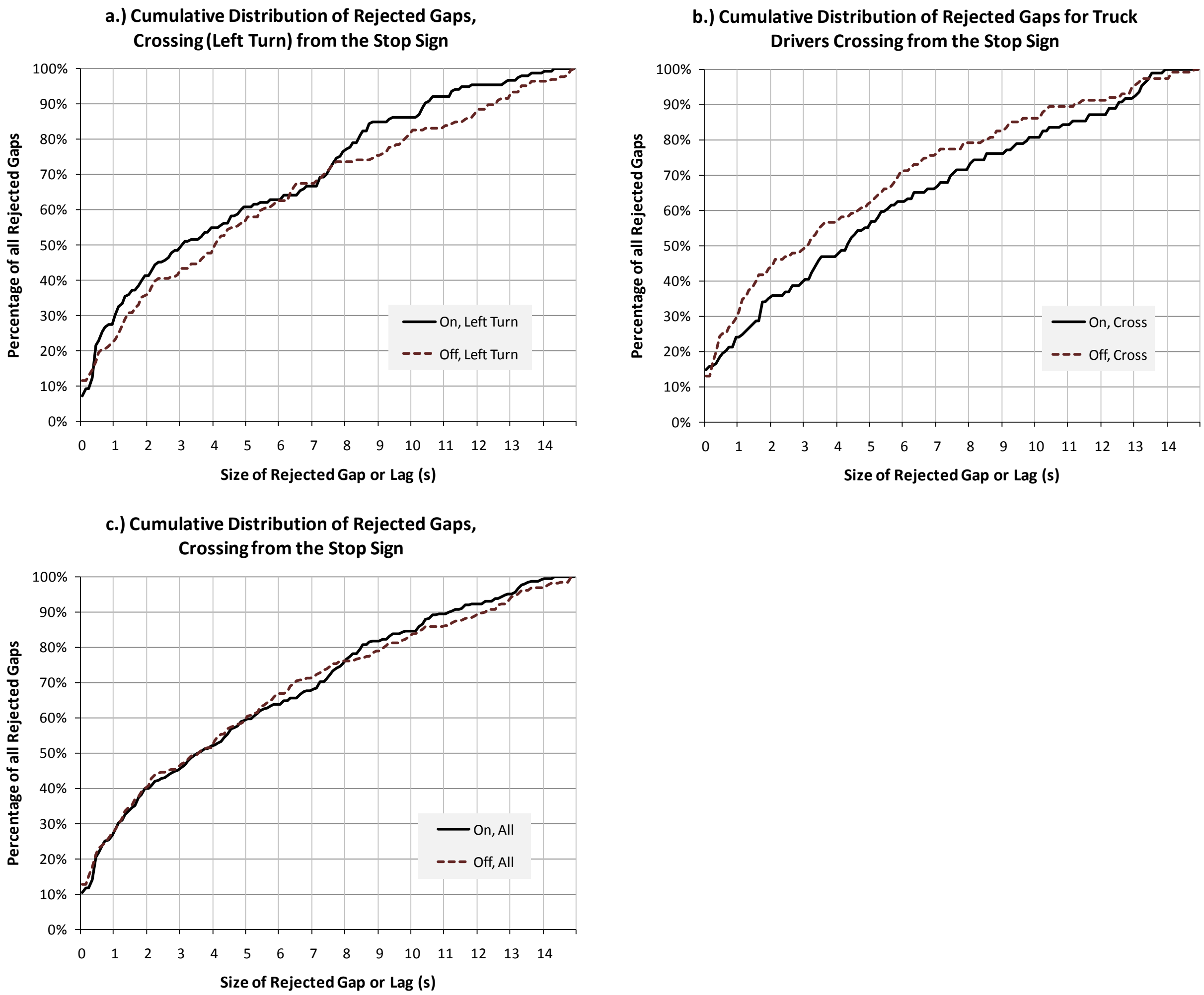


Figure 7. Cumulative distributions of rejected gaps for truck drivers at the stop sign location while making a a) left turn, b) crossing maneuver, or c) averaged across both maneuvers.

For the truck drivers positioned in the median, the 80th percentile rejected gap size across both maneuvers was 1.28 seconds smaller during the Sign On condition as compared to the Sign Off condition (Table 5). When these data were examined relative to maneuver type, results indicate that during the Sign On condition truck drivers' rejected gap size was 1.01 seconds larger than during the Sign Off condition while performing a crossing maneuver from the median. In contrast, their 80th percentile rejected gaps size was 1.86 seconds smaller when making a left turn maneuver while the sign was on. Collectively, these findings suggest that when truck drivers are positioned in the median they reject more of the shorter, less-safe gaps while performing a crossing maneuver as compared to when performing a left turn maneuver. Graphs that plot the cumulative distribution of rejected gaps for both maneuvers separately and cumulatively ('All') are presented in Figure 8.

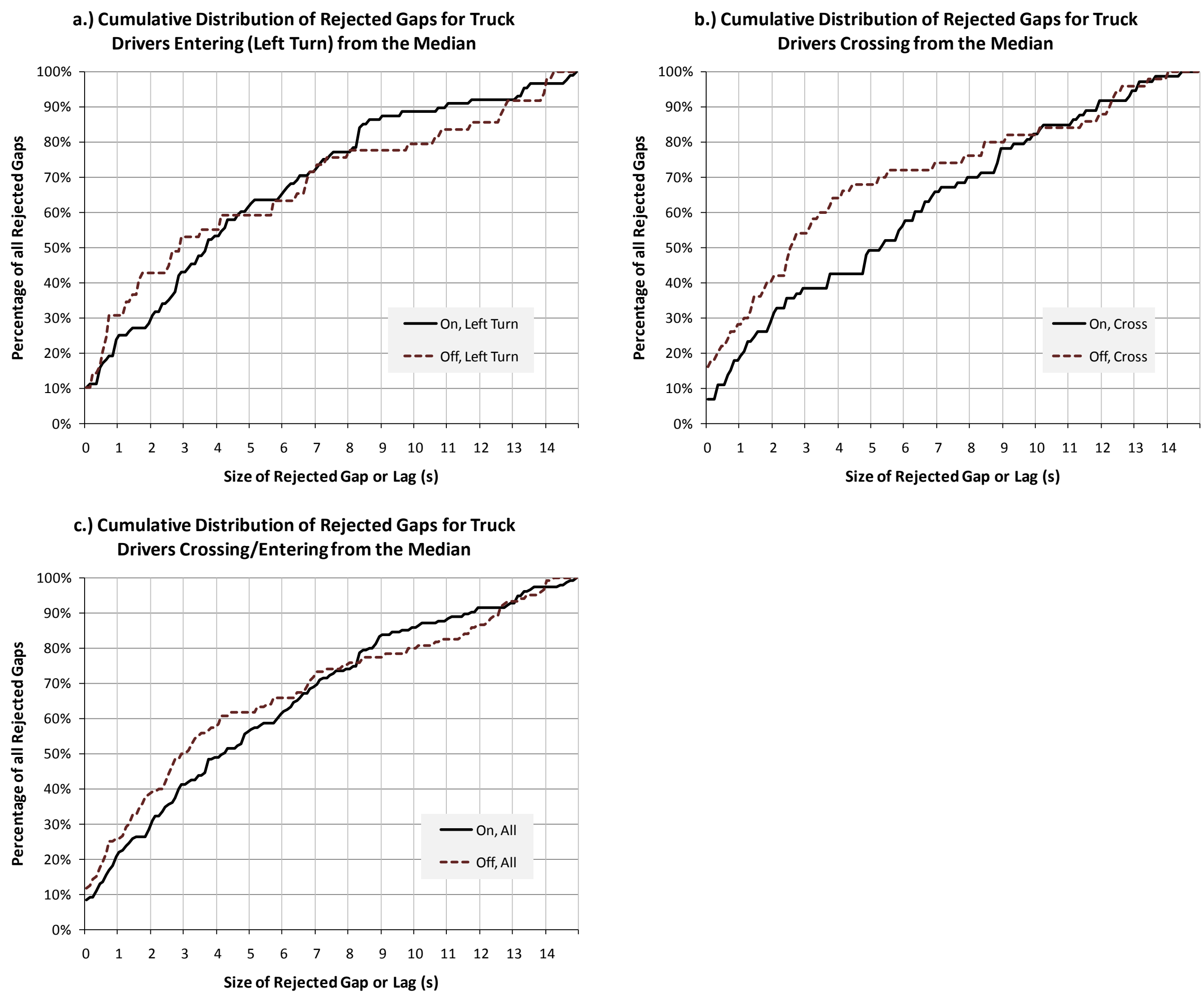


Figure 8. Cumulative distributions of rejected gaps for truck drivers crossing/entering from the median while making a a) left turn, b) crossing maneuver, or c) averaged across both maneuvers.

3.1.2 Percentage of Rejected Gaps Less than 7.5 seconds

Table 6 presents the percentage of gaps rejected that were smaller than the warning threshold of 7.5 seconds according to maneuver type and sign condition for car drivers. Selecting a larger gap is related to making a safer crossing maneuver. When a larger gap is selected then the driver is also more than likely to also reject gaps that are both larger and smaller than the critical gap threshold of 7.5 seconds. Therefore, drivers who tend to select larger gaps will also have a *smaller* percentage of rejected gaps less than 7.5 seconds because they will have rejected more gaps above the critical threshold, thereby showing a reduction in the amount of risk they are willing to take. Overall, it appears that while crossing during the Sign On condition, drivers had a smaller percentage of rejected gaps less than 7.5 seconds than while the sign was Off. Drivers seemed relatively unaffected by the sign state while making right turns and left turns, although drivers selected a somewhat higher percentage of gaps while crossing from the stop sign to the median to make a left hand turn during the Sign On condition. Although this final observation is interesting, when compared to crossing and right turn maneuvers, drivers making this maneuver with the Sign On have a smaller percentage of rejected gaps than they did while making a crossing maneuver with the Sign Off. This suggests that this difference may not impact the drivers' ability to safely cross the close traffic before making their left turn maneuver. Below, results are examined in greater detail by the location at which each maneuver was made (i.e., stop sign vs. median).

Table 6. Percentage of gaps rejected for car drivers that were smaller than 7.5 seconds within each sign condition. Note, the 'On-Off' notation indicates the difference in percentage of gaps rejected between sign states.

3.1.2.1

Maneuver	Sign State	At Stop Sign (*n*=4084)	At Median (*n*=1332)
Left	On	83.7%	80.3%
	Off	81.0	81.4
	On-Off	*+2.7*	*-1.1*
Cross	On	80.4	74.2
	Off	84.0	81.0
	On-Off	*-3.6*	*-6.8*
Right	On	85.6	-
	Off	82.9	-
	On-Off	*-0.5*	-
All	*On*	83.3	77.5
	Off	82.8	81.2
	On-Off	*+0.5*	*-3.7*

Significant differences between mean scores were observed when the percentage of rejected gaps was separated by maneuver type. Specifically, while making a crossing maneuver from the stop sign location, drivers rejected 3.6% fewer gaps during the Sign On condition when compared to the Sign Off condition. In contrast, car drivers rejected 2.7% more gaps when making a left turn maneuver from the same location. Collectively, these results indicated that car drivers were more likely to reject a gap larger than the alert threshold (7.5 seconds) when using the CICAS-SSA sign while performing a crossing maneuver, as compared to a left turn maneuver, from the stop sign.

When positioned in the median, car drivers rejected 3.7% fewer gaps that were smaller than 7.5 seconds across both maneuvers (i.e., left turn and straight) during the Sign On condition when compared to the Sign Off condition. When these data were examined within each maneuver type, results indicated that when car drivers were positioned in the median and subsequently performed a crossing maneuver, the Sign On condition (as compared to the Sign Off condition) was associated with a rejection of 6.8% fewer gaps that were smaller than 7.5 seconds. This suggests that drivers entering the intersection from the median were more likely to select a gap larger than the alert threshold while the sign was on, especially when positioned in the median waiting to perform a crossing maneuver.

Table 7 presents the percentage of gaps rejected that were less than the 7.5 s warning threshold by maneuver type and sign condition for truck drivers. It appears that while crossing when the sign was On, truck drivers had a smaller percentage of rejected gaps than while it was Off. Truck drivers seemed unaffected by sign state while making left turn maneuvers. Below, results are examined in greater detail by the location at which each maneuver was made (i.e., stop sign vs. median).

Table 7. Percentage of gaps rejected that were smaller than 7.5 s for both sign conditions for truck drivers. Note, the 'On-Off' notation indicates the difference in percentage of gaps rejected between sign states.

3.1.2.2

Maneuver	Sign State	At Stop Sign (*n*=508)	At Median (*n*=275)
Left	On	69.9%	76.1%
	Off	70.5	75.5
	On-Off	*-0.6*	*+0.6*
Cross	On	69.7	67.1
	Off	77.4	74.0
	On-Off	*-7.7*	*-6.9*
All	*On*	71.0	72.3
	Off	73.9	74.2
	On-Off	*-2.9*	*-1.9*

While making a crossing maneuver from the stop sign (i.e., crossing over Southbound traffic only) drivers rejected 7.7% fewer gaps during the Sign On condition when compared to the Sign Off condition. This suggests that truck drivers were more likely to reject a gap larger than the alert threshold (7.5 seconds) when the sign was On while performing a crossing maneuver from the stop sign.

When truck drivers were positioned in the median and performed a crossing maneuver they rejected 6.9% fewer gaps that were smaller than 7.5 seconds during the Sign On condition when compared to the Sign Off condition.

3.1.3 Accepted Gaps

For car drivers positioned at the stop sign there was a significant main effect for age for accepted gap size, $F(2, 23) = 4.26$, $p < 0.05$. Mean accepted gap size was 15.4, 14.1, and 20.0 seconds for the younger, middle age, and senior drivers, respectively. Post hoc analysis indicated senior drivers accepted significantly larger gaps as compared to middle age drivers.

The main effect for maneuver type for truck drivers positioned in the median approached significance, $F(1,11) = 4.44$, $p = 0.060$. Means for the left turn and crossing maneuver types were 21.4 and 27.7 seconds, respectively. These results suggest that truck drivers selected larger gaps during the crossing maneuver as compared to the left turn maneuver.

3.1.4 Time-to-Contact (TTC)

The age group analysis for TTC for car drivers positioned at the stop sign approached significance, $F(2,38) = 2.96$, $p = 0.064$. Mean TTC for the younger, middle age, and senior drivers were 7.0, 7.2, and 8.0 seconds, respectively. Post hoc analysis indicated significant differences between the senior and younger age groups.

There was a significant interaction between sign condition and maneuver type, $F = (1,12) = 7.18$, $p < 0.05$, for truck drivers positioned at the stop sign who made a left turn. Post hoc analyses indicated that drivers making a left turn maneuver displayed a shorter TTC during the Sign On condition than during the Sign Off condition, as shown in Figure 9. For the truck drivers positioned in the median, the main effect for maneuver type approached significance, $F(1,11) = 4.33$, $p = 0.062$, suggesting that truck drivers had longer TTCs during the crossing maneuver ($M = 8.8$ s) as compared to the left turn maneuver ($M = 6.4$ s).

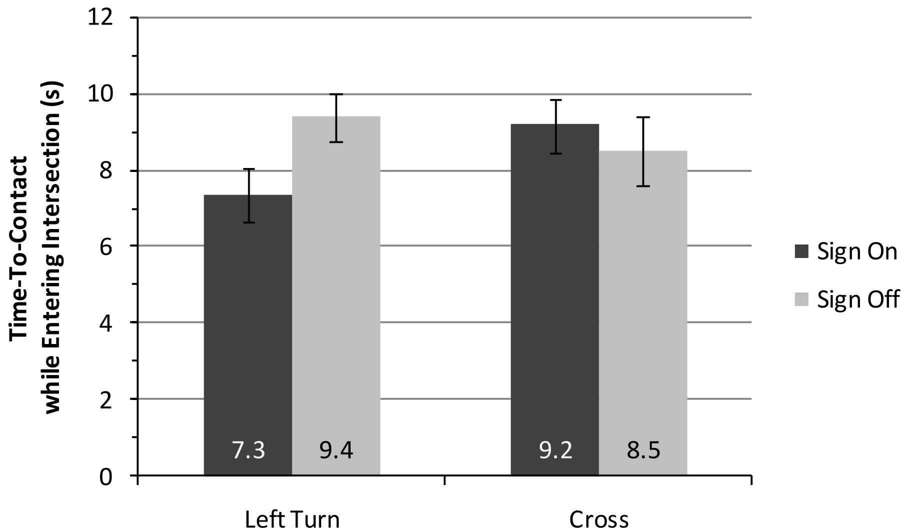


Figure 9. TTC for truck drivers while crossing from the stop sign for both maneuver types and sign conditions (standard error bars are shown).

3.1.5 Safety Margin

The main effect of age group approached significance, $F(2,35) = 3.19$, $p = 0.053$. Mean crossing safety margin for younger, middle age, and senior drivers was 6.3, 6.8, and 7.4 seconds, respectively. Post hoc analysis indicated significant differences between the safety margins of young and senior age group drivers.

There was a significant interaction between sign and maneuver type for truck drivers positioned at the stop sign, $F = (1,12) = 9.72$, $p < 0.01$. Mean safety margin scores for the Sign On and Off conditions for the left turn condition were 6.6 and 9.1 seconds, respectively. Mean safety margin scores for the Sign On and Off conditions for the crossing maneuver were 8.6 and 7.9 seconds, respectively. Post hoc analysis indicated that information gained from the CICAS-SSA was associated with significantly smaller safety margins while performing left turn maneuvers. Figure 10 presents a graphical depiction of this interaction.

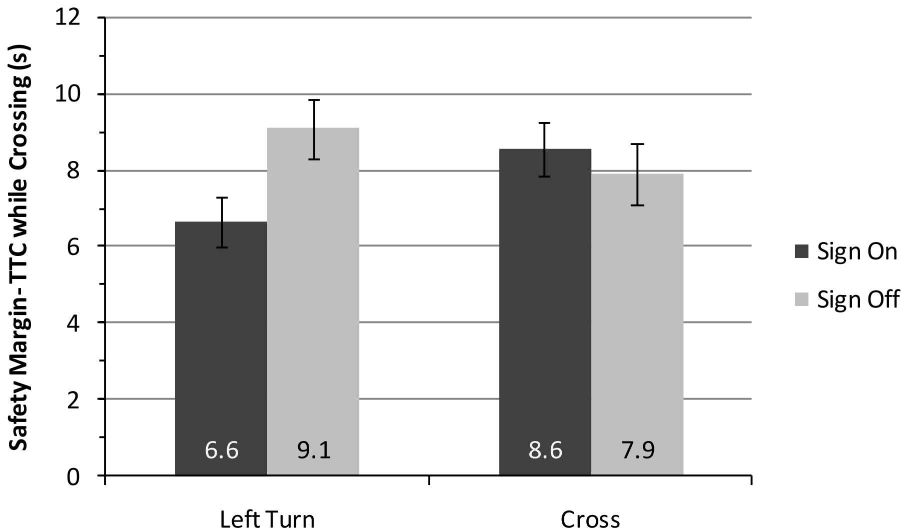


Figure 10. Safety margin for truck drivers while crossing from the stop sign for both left turn and crossing maneuvers (standard error bars are shown).

3.1.6 Movement Time

For the car drivers positioned at the stop sign, there was a significant main effort for sign condition, $F(1,45) = 4.25$, $p < 0.05$, suggesting that drivers took longer to cross the intersection during the Sign On condition ($M = 3.8$ s) when compared to the Sign Off condition ($M = 3.7$ s).

3.1.7 Wait Time

For the car drivers waiting at the stop sign, there was a significant main effect for the Sign On Off condition, $F(1,42) = 6.22$, $p < 0.05$. This finding indicated that car drivers had longer wait times during the Sign On condition ($M = 20.4$ s) as compared to the Sign Off condition ($M = 17.9$ s). There was a significant main effect for sex, $F(1,42) = 7.57$, $p < 0.01$, that indicated female car drivers had shorter wait times ($M = 18.3$ s) when compared to male car drivers ($M = 23.6$ s). There was a significant main effect for age group, $F(2,45) = 4.03$, $p < 0.05$., with mean wait times for younger, middle age, and senior drivers being 16.33, 17.66, and 23.33 seconds, respectively. However, the age group by maneuver type interaction, $F(4,84) = 3.25$, $p < 0.05$, supersedes the main effect for age group. Mean wait time scores for each age group by maneuver type are shown in Figure 11. Post hoc analysis indicated that during the right turn maneuvers senior drivers exhibited longer wait times than their younger and middle age counterparts. The analysis also indicated that during the crossing maneuvers senior drivers had longer wait times than their younger counterparts. Collectively, these findings suggest that senior drivers are either being more cautious while making a crossing or left turn maneuver or they are spending time using the CICAS-SSA sign information which results in longer wait times.

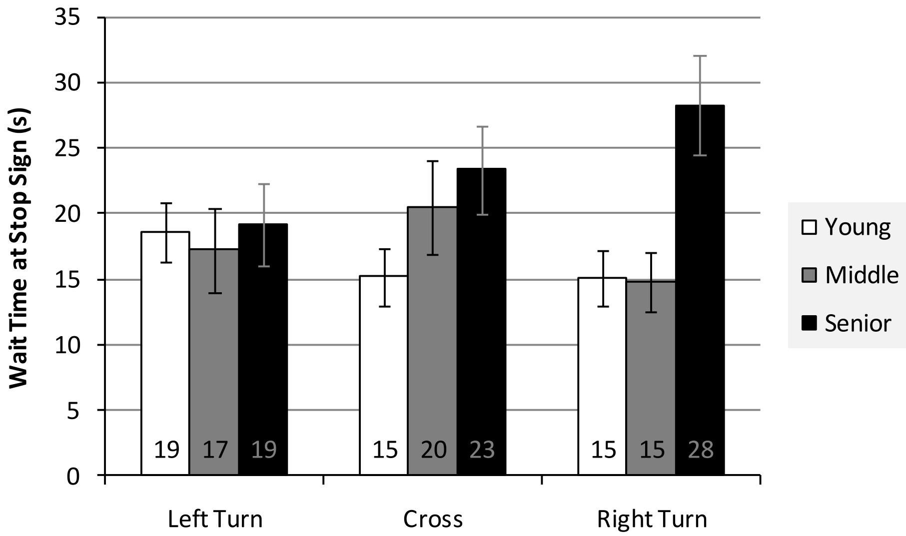


Figure 11. Wait time for car participants while waiting at the stop sign for all three maneuver types by age (standard error bars are shown).

For the truck drivers waiting in the median, there was a significant main effect for the sign condition, $F(1,12) = 5.05$, $p = .044$. Truck drivers had longer wait times during the Sign On condition ($M = 18.0$ s) as compared to during the Sign Off condition ($M = 10.1$ s).

3.1.8 Maneuver Stages

Across all trials there was only one instance of a one-stage maneuver. This occurred during the Sign Off condition by a male in the middle age group driving a car. No Truck driver made a one-stage maneuver.

3.1.9 Performance Summary

In terms of 80^{th} percentile rejected gap, both car and truck drivers selected larger, safer gaps while crossing from the stop sign to the median and while crossing from the median to the far side of the road when their goal was to make a crossing maneuver during the Sign On condition.

Similar trends were observed in terms of the percentage of selected gaps greater than 7.5 seconds in length. Both car and truck drivers were more likely to reject a gap larger than the alert threshold (7.5 seconds) during the Sign On condition while crossing from the stop sign to the median and when crossing from the median to the far side of the road when their goal was to make a crossing maneuver.

When the drivers' goal was to make a left turn they rejected fewer (unsafe) smaller gaps and they tended to have a lower percentage of gaps greater than the alert threshold during the Sign On condition. Because their average rejected gap size and percentage of rejected gaps were still relatively safe, this may not make a practical difference but instead suggests that drivers make different decisions while crossing to the median depending on their intended maneuver (e.g., crossing vs. left turn).

Senior car drivers tended to accept larger gaps while entering the intersection from stop sign regardless of sign state. Truck drivers accepted larger gaps during crossing maneuvers from the median as compared to making left turns from median.

There is some evidence that senior drivers may have had larger safety margins and TTCs when entering the intersection from the stop sign location when compared to younger drivers, regardless of sign state.

During the Sign On condition, truck drivers who planned to make a left turn had shorter TTCs and larger safety margins while crossing from the stop sign location when compared to making a crossing maneuver.

Car drivers took longer to cross during the Sign On condition compared to the Sign Off condition, suggesting that the sign was causing them to be more cautious while making a crossing decision.
Females had shorter wait times than did males regardless of sign state. Truck drivers had longer wait times during the Sign On condition as compared to during the Sign Off condition.
There was only one one-stage maneuver across all trials and conditions. This suggests that drivers (particularly car drivers) may have been more cautious in our experimental setting than they might be during their normal behavior at the intersection.

These findings suggest the following conclusions about drivers' use of the CICAS-SSA sign, as they relate to a reduction in risk during gap selection:
Drivers waited longer to cross the intersection while the sign was on, suggesting they were using the CICAS-SSA sign information.
Drivers rejected more unsafe gaps while the sign was on, suggesting they were using the information on the sign to assist in their gap selection.
Drivers maneuver times were longer while the sign was on (i.e., they drove slower through their selected gap), suggesting they thought the gap selected was of ample size.
There was no evidence that performance during any maneuver increased the risk of drivers while selecting a gap.

4 Usability Dependent Variables

4.1.1 Post Drive Questions: Effort

The mean response scores (i.e., collapsed across all conditions) and significant effects for car drivers for each question within the post drive effort questionnaire are presented in Table 8. All questions were scored on a five point Likert scale. Responses closer to 1 indicated a negative response (e.g., "Not enough time" for Question 1) while responses closer to 5 indicated a positive response (e.g., "More than enough time") (see Appendix F for specific response choices).

When car drivers were asked if they felt rushed to make their maneuver before entering the intersection (Question 1) there was a significant main effect for age group, $F(2,45) = 4.36$, $p < 0.05$. Mean Question 1 scores for younger, middle age, and senior drivers were 3.89, 4.34, and 4.46, respectively. Post hoc analysis indicated that the younger and older driver means were significantly different from each other which suggest that younger drivers felt less rushed to make their maneuver compared to senior age group drivers.

Table 8. Mean scores and significant effects for sign condition, maneuver type, gender, or age group.

Question		Overall Mean	Significant Effects
1	Did you feel rushed to make your maneuver?	4.27	Age Group
2	Did you feel you had enough time to make your maneuver?	4.17	-
3	How safe was the gap you chose?	4.01	Maneuver Type', Age Group', Age*Gender
4	How stressful was your experience?	1.75	Sign*Maneuver*Gender
5	How much mental effort was needed?	2.03	Maneuver Type
6	How much physical effort was needed?	1.58	-
7	How would you rate the overall safety of your performance?	3.82	-

' Denotes an effect that approaches significance, where p is between 0.065 and 0.050.

There existed a marginally significant age group main effect for Question 3 (how safe was the gap that they chose) for car drivers, $F(2,42) = 3.04$, $p = 0.058$. Mean scores for the younger, middle age, and senior drivers were 3.80, 4.05, and 4.19, respectively. This trend suggests that senior drivers may have thought that the gap they selected was safer as compared to the younger drivers. The main effect for the maneuver type condition also approached significance, $F(2,84) = 3.04$, $p = 0.053$, suggesting that car drivers may have thought the gap they selected during the right turn was safer ($M = 4.12$) as compared to the perception of gaps selected during the crossing ($M = 3.93$) and left turn maneuvers ($M = 3.99$). There was also marginally significant interaction between age group and gender for Question 3, $F(2,42) = 3.04$, $p = 0.053$. Post hoc analyses comparing driver gender within each age group suggests that young female drivers thought the gaps they selected were safer than their young male counterparts [$t(13) = 5.14$, $p < 0.05$] and that middle age female drivers thought their selected gaps were less safe than did middle age males [$t(13) = 13.56$, $p < 0.05$].

There was a significant three-way interaction between the sign, maneuver type, and gender conditions, $F(2,84) = 4.66$, $p < 0.05$, for Question 4 (i.e., how frustrating was their experience at the intersection). Results suggest that female drivers reported being more frustrated than male drivers in two instances: 1) while making a left turn when the CICAS-SSA sign was turned off, and 2) while making a right turn when the sign was turned on. It is unclear what the practical significance of this finding is towards the usability of the sign design.

Results indicated a main effect for maneuver type when car drivers were asked how much mental effort was needed to drive through the intersection, $F(2,94) = 3.78$, $p < 0.05$ (Question 5). Mean scores for the left turn, crossing, and right turn maneuvers were 2.10, 2.11, and 1.90, respectively. Post hoc tests indicate that left turn and crossing maneuvers were thought to involve more mental effort than were right turn maneuvers. However, because there was no effect for sign condition, these results speak more towards the difficulty of the tasks rather than the usability of the sign design.

4.1.2 Sign Comprehension

4.1.2.1 Comprehension & Usage Questionnaire

Table 9 presents a comparison of the Sign On condition mean scores for car drivers for both the current on-road study and the last simulator study (HF3.4: Creaser et al., 2008). For questions 2 and 10, higher scores indicated a *less* favorable rating; for the remaining questions a higher scores indicated a *more* favorable rating. Results indicated no statistically significant differences in ratings between the simulation study and the field test for all questions. This suggests that results reported from the field test were comparable to those reported during the simulation testing, therefore allowing us to be confident that the methodologies used during the other portions of both tests (e.g., driving performance measures) were also comparable.

Table 9. Comprehension and use questionnaire from both the current on-road study and a previous simulator-based experiment.

Question		Simulator HF3.4	Field Test HF4.2
1	I felt confident using this sign.	3.22	3.73
2	I felt it was confusing to use this sign.	2.80	2.42
3	Using this sign made me feel safer.	3.10	3.23
4	I trusted the information provided by the sign.	3.53	3.74
5	I like this sign.	3.14	3.51
6	The sign was reliable.	3.63	3.88
7	I felt this sign was easy to understand.	3.18	3.71
8	The sign's information was believable (credible).	3.70	4.00
9	This sign was useful.	3.35	3.87
10	I could complete the maneuver the same way without using the sign.	3.98	3.76

When asked if they used the information on the CICAS-SSA sign to help make crossing decisions, 66% of all drivers reported using the CICAS-SSA sign. When examined by age group (Figure 12), almost 85% of young drivers and almost two-thirds of the middle age drivers used the sign while half of the senior and less than half of the truck drivers reported using the signs.

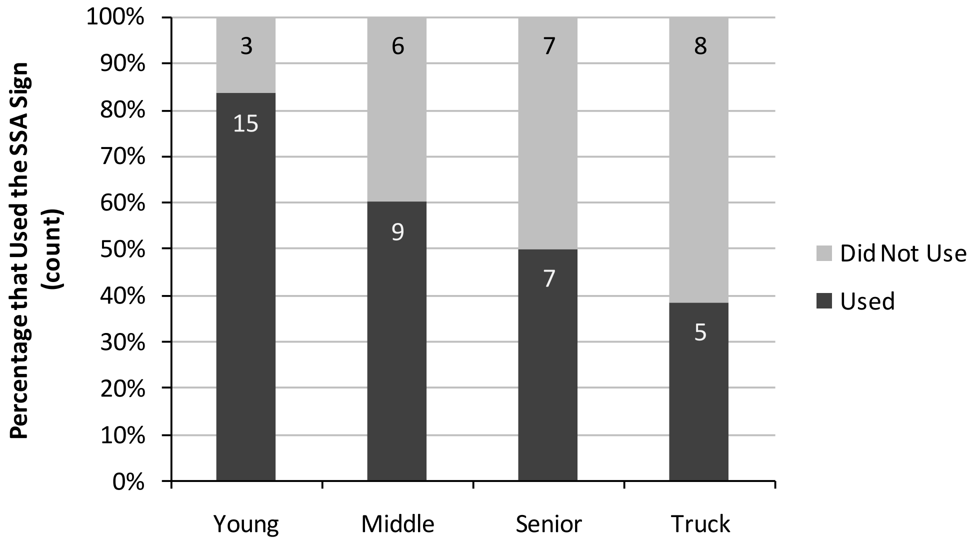


Figure 12. Percentage of participant responses by age group when queried if they used the CICAS-SSA sign (count presented in columns).

To better determine how well participants understood sign functioning, after each Sign On block of trials participants were asked to "Describe what you think this sign's function is and what information it provides to the driver (you)." Open-ended responses for this question were grouped into three main categories that represent common groupings of responses. For example, a significant number of responses were related to intersection entry safety and they were grouped together into a main category. Within each main category responses were grouped further by common topic. Within Table 10, main categories are identified by shaded sections, while sub-groupings appear immediately after. If a response contained information that applied to more than one main category that response contributed to the overall number of responses for the appropriate main categories. This situation explains why the percentage of responses was greater than 100% for the main categories. In addition, when a response was general and did not address a main or sub category that response was not included in the calculation of response percentages.

The majority of car driver participants (85%) reported that the function of the sign was to inform them when it was safe or unsafe to enter the intersection. It was also encouraging to see that 61% of these responses reported that the sign was meant to be assistive, rather than regulatory (i.e., mandatory) in nature. This is good because the CICAS-SSA sign was designed as an additional assistive cue for drivers to suggest when it is safe to enter the intersection and not meant as a regulatory device. It was also encouraging to see that over half of the car driver participants (56%) reported that the sign told them information about approaching vehicles. It is not necessarily important that drivers understand exactly what the sign was monitoring, however the sub categorical responses are presented to give an impression of how participants conceptualized the warning timing.

Table 10. Grouped responses and relevant second-level responses when car drivers were asked the function and information provided by the CICAS-SSA sign.

Percentage of all respondents (N = 48)	Percentage of responses in category	*"Describe what you think this sign's function is and what information it provides to the driver (you)"*
85%	Tells when it is safe or unsafe to enter the intersection	
	61%	Assists my decision by suggesting when to make a safe maneuver (informative)
	12%	Tells driver what they can or cannot do (regulatory)
56%	Presence of approaching vehicles near intersection, "traffic information"	
	33%	Traffic volume &/or direction, "traffic flow"
	26%	Distance from intersection; relative location to driver
	7%	Time to arrive at intersection
	4%	Gaps, "traffic intervals"
6%	Says that this is a divided highway with traffic in two directions	

The majority of car driver participants (85%) reported that the function of the sign was to inform them when it was safe or unsafe to enter the intersection. It was also encouraging to see that 61% of these responses reported that the sign was meant to be assistive, rather than regulatory in nature. This is a positive finding because the CICAS-SSA sign was designed as an additional assistive cue for drivers to suggest when it is unsafe to enter the intersection and not meant to control behaviors. It was also encouraging to see that over half of the car driver participants (56%) reported that the sign presented information about approaching vehicles. It is not necessarily important that drivers understand how the sign interpreted information from the approaching traffic stream; however the sub categorical responses are presented to give an impression of how participants conceptualized the warning timing.

Drivers were also asked to, "Explain what [CICAS-SSA sign] information you used or how you used the information to make your decision of when to cross?" The frequencies of responses from car drivers are presented in Table 11, with most followed by specific quotes from participants. Participant's responses sometimes covered multiple categories, which explains why the percentage of responses is greater than 100%. Just over half of the car driver respondents (52%) reported that they compared their own judgment to the information presented on the sign. Only a few participants actually remarked on sign design details, but fortunately their assessments agreed with the sign's intentions (e.g., red as prohibitive, yellow as warning). 27% of car driver participants reported that the sign warning timing was more cautious than their own judgment. This may suggest that some drivers would have selected gaps smaller than the 7.5 second warning threshold but did not do so because the sign prompted them do select larger gaps. It is promising that only 13% of car driver participants reported that they did not use the sign, and that only 10% thought it was confusing or were not comfortable with the sign (distracting, alarming, made them nervous).

Table 11. Grouped responses when car drivers were asked what information on the CICAS-SSA sign they used and how they used it.

Percentage of all respondents (N = 48)	***"Explain what information you used or how you used the information to make your decision of when to cross"***
52%	I compared my judgment to the sign; Sign was used as a confirmation of my own judgment
	- *I read the sign & took the info into consideration, but in the end relied on my own experience, intuition, & knowledge.*
	- *I sometimes went even when the sign said I shouldn't. I would look also to make sure myself regardless of the sign.*
	- *It gave me a feeling of confidence.*
	- *If the intersection was clear when I pulled up, I used the sign to make sure no one was coming.*
27%	Sign's timing was longer then my own, or that it would change late / after gap had arrived
	- *What it thought I wasn't capable of, I thought I was.*
13%	I made my decision prior to / without looking at the sign; trusted my own judgment more
	- *I feel "my judgment" would insure a safe passage through the intersection. I worry about malfunctions, [because] electronic devices regarding intersection safety can be compromised. I would only use the signs as advisory.*
	- *[The] Signs confused me, and sometimes told me it was unsafe to go when it was safe, so I stopped using them.*
	- *My judgment would have been the same without the signs.*
10%	Sign could be confusing, especially at first
	- *The sign seemed cluttered.*
10%	Distracting, alarming, intimidating, made me nervous
	- *At first it made me nervous. When I'd used it a few times I felt more confident about what it said, but I would not rely only on the sign.*
	- *I don't have time to figure out which sign I'm supposed to watch - could one be covered up better so I'm not distracted by watching both of them?*
8%	I examined symbols on the arrows to decide when it was safe to go
	- *If the car was red I wouldn't try to cross.*
	- *The red & yellow blocks determined how heavy & close the traffic was, or best case scenario, the sign would be clear to let me know I could proceed safely.*
	- *I waited till it was all black & yellow to cross.*
6%	When the sign indicated it was safe to go, I entered the intersection
4%	Gather information when view obstructed for lanes I couldn't see (far lanes)
4%	Reliable in telling me when it was appropriate to go
	- *When it showed "clear", there was plenty of time to cross, and it seemed quite safe.*

4.1.2.2 Usability Questionnaire

Results of the usability questionnaire indicated that car driver participants reported the CICAS-SSA sign to be moderately useful and somewhat satisfying to use. These positive results are comparable to previous CICAS-SSA project experiments (simulator study HF 3.4: Creaser et al., 2008) as shown in Figure 13.

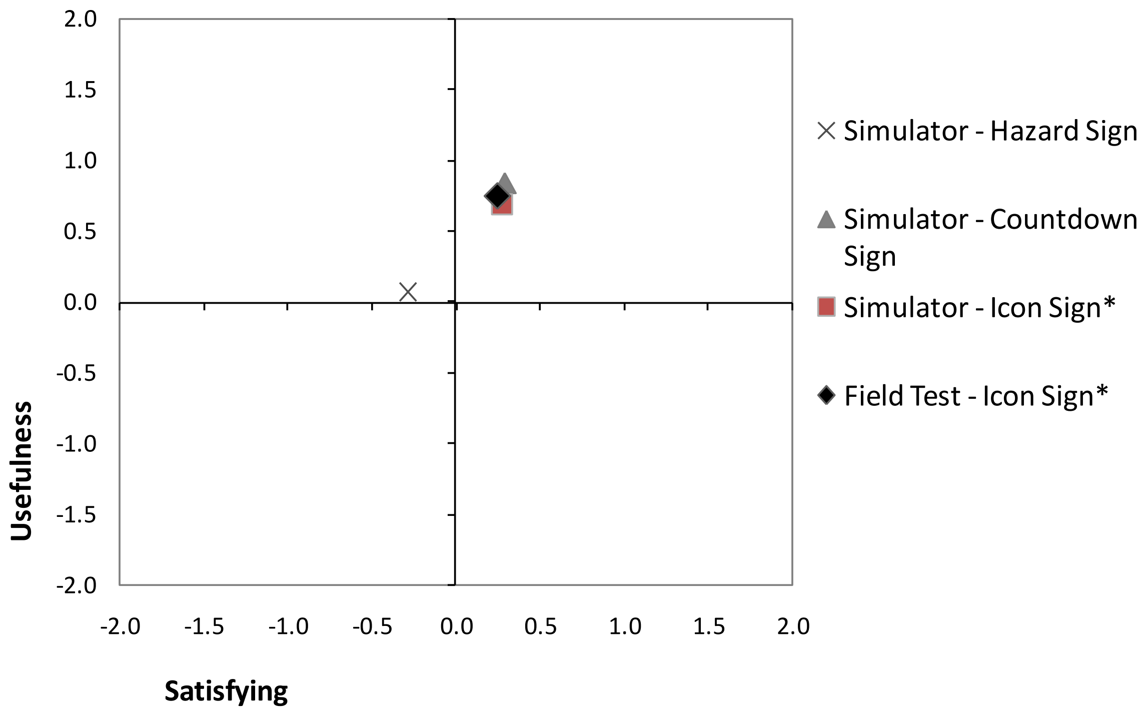


Figure 13. Usefulness and satisfying ratings for the CICAS-SSA sign during the field test plotted against results from three other CICAS-SSA signs from the CICAS Random Gap study. Icon sign headings are noted with * for comparison purposes.

5

5.1.1 Usability Summary

Younger drivers reported feeling less rushed to make their maneuver as compared to senior drivers.
Senior age reported selecting a safer gap when compared to younger drivers.
Drivers reported that they selected a safer gap and that they experienced less mental effort during right turn maneuvers than during left turn or crossing maneuvers.
Drivers in the field study gave similar responses to the comprehension and use questionnaire as did drivers in the Random Gap simulation study.
Two-thirds of all car drivers reported using the CICAS-SSA sign. Usage appeared to differ by age group where 85% of the young drivers, 60% of middle age drivers, and 50% of the senior drivers reported using the sign.
85% of drivers reported that the function of the sign was to inform them when it was safe or unsafe to enter the intersection. 61% of these responses said the sign was to be informative, while only 12% said the sign was to be regulatory.
56% of drivers reported that the function of the sign was to give traffic information.
52% of drivers reported they compared their own judgment to the information presented on the sign. 27% thought the sign's timing was longer than their own, while only 13% reported that they made their decision without also consulting the CICAS-SSA sign.
Drivers found the CICAS-SSA sign to be moderately useful and somewhat satisfying to use, which was comparable to ratings from the Random Gap simulation study.

These findings suggest the following primary conclusions related to the crossing behavior results.
A majority of drivers reported using the sign.
A majority of drivers reported the function of the sign was to inform when it was safe or unsafe to enter the intersection by giving them information on traffic conditions.
A majority of drivers reported comparing their own judgment to the warning given on the sign before crossing.
Drivers reported the sign to be useful while making gap acceptance decisions.

6 Discussion

The CICAS-SSA sign is an infrastructure-based driver support system that is intended to reduce the risk associated with gap acceptance decisions for drivers at rural stop-controlled intersections. The CICAS-SSA system tracks vehicle locations on a major road and then displays dynamic messages to a driver at an intersection on a minor road. The messages provide an indication of gaps that are unsafe and should be rejected and also provides an indication of vehicle presence that should be evaluated by the driver (meaning the decision to reject or accept rests with the driver). Drivers can then use the information contained in the messages to make more informed decisions. Driver-based techniques have been employed previously to design and evaluate the utility of the CICAS-SSA sign because of the significant interaction required between humans (i.e., drivers) and technology for this system to be successful. This work was conducted using previously validated system-evaluation questionnaires and methods employed during driving simulation experiments. While the results of previous work indicated a collective reduction in risk for drivers who used the CICAS-SSA sign to make a gap decision, a number of experimental constraints may have limited the ability to generalize these results to real-world settings. For example, even high-fidelity simulation environments are not able to replicate fully the perceived level of safety experienced in real-world settings due to the lack of crash risk. Because the results of the simulation-based studies support the utility of the selected CICAS-SSA Icon sign, the next necessary step was to perform an evaluation in a real-world setting to fully address these potential limitations.

The primary goal of the current work was to validate the use and functioning of the CICAS-SSA sign interface in a real-world setting under typical high-volume traffic conditions to identify if it could reduce risky crossing behavior while not resulting in any unintended consequences for drivers. This was accomplished by first recruiting a representative sample of drivers from rural areas in Minnesota across a range of ages. Drivers then drove an instrumented vehicle through a test intersection while performing typical maneuvers that included turning right, turning left, and crossing straight through. Drivers performed these maneuvers under two conditions: an experimental condition in which the CICAS-SSA sign presented gap information using the selected warning thresholds describe in this document and a baseline no-sign condition. In addition, the current work sought to evaluate the usability of the CICAS-SSA sign interface to better understand drivers' perceptions of workload, satisfaction, usefulness, and willingness to use the information presented by the sign.

A tertiary goal was to determine if both performance and usability relative to CICAS-SSA sign use was congruent with findings from the previous CICAS-SSA evaluations. Congruence of results across studies would support the notion that these findings are robust and that the behaviors associated with CICAS-SSA sign use observed in those studies may also be observed in both field operational tests and future real-world deployment. The results presented here focus on car drivers with results from the truck driver evaluation presented where they make a significant contribution to the discussion.

6.1 CICAS-SSA Sign Use

The "eightieth percentile rejected gap" refers to the 80^{th} percentile gap size of all gaps that were rejected by a driver. A larger rejected gap size indicates drivers are not accepting smaller gaps. Results indicated that during all crossing maneuvers (as opposed to left or right turns), drivers exhibited larger 80^{th} percentile rejected gaps when experiencing the Sign On condition as compared to the Sign Off condition. Notably, the 80^{th} percentile rejected gap size increased by more than 1.5 seconds when drivers crossed from the median location when using the sign information. This result is informative because it suggests that the CICAS-SSA sign helped drivers reject smaller gaps specific to the maneuver type associated with the highest rate of crashes at the test intersection (i.e. crossing from the median). It was previously suggested that, "If the CICAS-SSA can increase rejection thresholds when gap acceptance is 10 s or less, [we will also] likely decrease crash frequencies" (Gorjestani et al, 2008). In addition, during right and left turn maneuvers rejected gap decisions using the sign were not significantly different than those made while not using the sign. These findings lend initial support to the contention that the CICAS-SSA sign may have a positive impact on gap decision making by reducing risk while deployed in real-world settings.

A second measure of rejected gap was the percentage of rejected gaps smaller than the warning threshold. The assumption for using this metric was that drivers are generally good at rejecting unsafe gaps at intersections (gaps that are 6.5 seconds or smaller; Gorjestani et al., 2008), and this 7.5 second threshold was representative of a gap size that was perceived to be unacceptable for 80% of drivers under normal conditions with time considerations for information processing of the sign information taken into account in the threshold. If the percentage of gaps rejected under the alert threshold was lower while using the CICAS-SSA sign, this would signify that drivers are selecting a higher proportion of larger gaps, and would signify an increase in performance. Results of the current work indicated that during all crossing maneuvers (as opposed to left or right turns), drivers rejected a smaller percentage of gaps under 7.5 seconds when experiencing the Sign On condition as compared to the Sign Off condition. These results were consistent with those of the Random Gap simulator study (Creaser, et al., 2008) and the naturalistic (non-experimental) field observation (Gorjestani et al, 2008) studies. The similarity in behavior between the CICAS-SSA condition and the baseline condition was expected because the alert threshold was partially derived from the naturalistic gap rejection behavior at the intersection. Therefore, although this analysis agrees with our expectations, analysis of other safety-related behaviors must be taken into account to determine the safety of performance when using the CICAS-SSA signs.

Accepted gap size refers to the size of the gap between two vehicles, in seconds, when a driver began to cross the roadway. It is important to note that accepted gap is not the opposite of rejected gap, and is highly dependent upon the size of the gaps available to the driver in a traffic stream; in other words, the availability of a particular gap size will vary across traffic streams. In this study, the available gaps are potentially biased by the researchers' selection of traffic streams of similar size to which each driver was exposed, with the gap lengths in each stream being a subset of all the potential gap sizes that may appear on that roadway at different times and during different driving conditions. Drivers can choose to reject increasingly larger gaps, but ultimately can decide to accept very similar gaps across trials as they will accept the first gap that appears large enough to enter safely, whether it comes early or late in the traffic stream.

Results of the current work indicated that accepted gap size was not significantly different for drivers who were presented with the CICAS-SSA sign when compared with drivers in the baseline no-sign condition. This result was consistent with those of the simulator study that also found no significant differences between the sign conditions. These consistent findings do not detract from the utility of the CICAS-SSA sign. When paired with the findings from the rejected gap analysis, the results indicate that presentation of the CICAS-SSA sign was associated with the rejection of smaller, less safe gaps and the acceptance of consistently sized gaps. It should be noted that findings from the accepted gap size analyses should be viewed with caution due to variability in accepted gap results between studies. The average size of accepted gaps chosen by participants of all age groups was larger in this study (16.5 seconds) than in the random gap simulation study (10 seconds, Creaser et al., 2008) or in the naturalistic (non-experimental) field observation study (9.4 seconds, Gorjestani et al, 2008). This may be a result of drivers being more cautious due to: 1) a heightened perception of safety inherent in the field test compared to the relatively benign simulation study setting, and 2) being aware they were being observed (i.e., there was an experimenter in the back seat of the car they were driving). However, even in light of these observations, we expect that drivers who use the CICAS-SSA signs outside of an experimental context may exhibit similar reduction in crash risk due to increased 80th percentile rejected gap size.

Because of the variability in accepted gaps, the size of the gap remaining between the oncoming vehicle and the entering vehicle when it first enters the intersection and when it exits the lane of interest (time-to-contact (TTC) and safety margin, respectively), are more important than the accepted gap in regards to safety as entering a large gap too late can result in a collision or near-miss. Therefore, the original size of the gap, while potentially predictive of TTC, may not correlate directly to the actual gap available between an entering vehicle and the oncoming vehicle. For example, time to process the CICAS-SSA display information could result in a driver entering a large enough gap later than normal, thus resulting in a smaller TTC or safety margin and a higher potential for collision. The CICAS-SSA sign is a decision support system, therefore, it was important that comprehension and responses to the sign's information not affect drivers' ability to act quickly and enter the intersection once a gap decision was made. Because a majority of participants reported using the CICAS-SSA sign to help them with their crossing decisions, it was expected that TTCs and/or safety margins would be shorter due to increased processing time from using the sign given that the accepted gaps were similar in length. However, the results of the current work indicated no significant differences in TTCs or safety margins for the Sign On and Off conditions. This supports the findings when the same CICAS-SSA interface was used in the random gap study (Creaser, et al, 2008), further suggesting that using the CICAS-SSA sign did *not* delay drivers from entering the intersection after selecting an appropriate gap. This is also supported by the lack of differences observed in lead gap size between the Sign On and Off conditions.

Another indication of gap decision making at intersections occurs when drivers accept smaller gaps than they normally would in order to traverse the intersection more quickly (Pollatschek, Polus, & Livneh, 2002). Even though our analysis of naturalistic behavior at the test intersection suggested that drivers do not change their gap selection decision based on their wait time (Gorjestani et al., 2008), safe crossing decisions would be promoted by encouraging drivers to wait for a larger gap. On average, our participants waited 2.5 seconds longer at the stop sign before taking a gap when presented with the Sign On condition as compared to Sign Off condition. Because traffic streams were selected to include a group of vehicles for each trial that were similar in number of available gaps across trials, the longer wait times in the Sign On conditions suggest participants were responding to the information on the signs and may have delayed gap acceptance based on CICAS-SSA information. This finding was consistent with the trends found in the Random Gap simulation study. Truck drivers also exhibited longer wait times while using the CICAS-SSA sign to cross the intersection when they were positioned in the median. Increased wait times at the intersection while using the CICAS-SSA sign provide further support for the notion that the sign is associated with a shift towards reduced risk in gap acceptance behavior by drivers.

An example of an behavior that can lead to a crash is a one-stage crossing maneuver. In this situation a driver initiates a maneuver from the stop sign, fails to yield in the median, and in doing so does not re-assess the oncoming traffic arriving from the right (i.e., the "far lane gap"). Research at rural stop-controlled intersections has indicated that the majority of crashes are associated with drivers performing a one-stage crossing maneuver, regardless of other factors such as intersection geometry or sight lines (Preston et al., 2004; 2005; 2007). At the Minnesota test intersection most crashes occur in the far lanes (Preston et al., 2004). Evaluations of stop-controlled intersections in partner states, such as Wisconsin and Iowa, also found several intersections with significantly more far-lane crashes than near-lane crashes (e.g., Preston, Storm, Donath & Shankwitz, 2006; Preston, Storm, Donath & Shankwitz, 2007). Therefore, a goal of the CICAS-SSA sign was to encourage drivers to make a two-stage maneuver by providing information at the stop sign and separate information at the median. The design of the CICAS-SSA sign supports this goal by including information about the far lanes at the stop sign and again in the median. Although previous examinations of traffic at the test intersection observed a marked number of one-stage crossing maneuvers (Gorjestani, et al., 2008), all maneuvers in the current study (with the exception of one) were two-stage maneuvers. This finding suggests that drivers were either reluctant or unable to make one-stage maneuvers. The latter suggestion is supported by the fact that the experimental protocol was designed to provide drivers with a high volume of traffic at the intersection, therefore making it difficult for drivers to safely proceed through the near and far lanes of traffic without stopping. Drivers may also have been more cautious during this experiment due to increased wait times while in the median, as exhibited by increased wait times and 80th percentile rejected gap sizes at this location.

A factor that may influence the overall utility of the CICAS-SSA sign is usability. Usability refers to the degree to which drivers perceive that the sign is reliable, trustworthy, useful, satisfying, and the degree to which the sign promotes safety. If drivers consistently have negative usability perceptions they are likely not to use the sign, and subsequently, not enjoy the benefits offered by the sign's information. Results of the current work indicated that participants developed positive perceptions of the CICAA-SSA sign in terms of reliability, trust, usefulness, satisfying, and perception of safety. When comprehension, use, and usability ratings (sub-scales within the Usability factor) were compared between the current study and the simulator study (HF3.4: Creaser et al., 2008), no significant differences existed. This last point indicates that the results of our previous studies, which took place in a simulated driving environment and contributed to the current CICAS-SSA design, were truly suggestive of how drivers would perceive and use the sign in a real-world setting. In addition, we forward the notion that employing a simulated environment is a valid and cost-effective tool in evaluating the design of ITS technologies.

A second indication of usability can be garnered directly from drivers when they are asked whether or not they used the sign. Driver responses to this relatively simple question are important because they can reveal a number of underlying issues that support drivers use or non-use of the sign. Results indicated that the majority of drivers, 66%, reported using information from the sign during the experimental trials. A smaller percentage of drivers reported not using the sign (33%) or thought it was confusing. This affirmation of sign use was consistent with the positive changes in driving performance observed during the experiment. When these results were analyzed according to condition, differences in self-reported use emerged for driver age. Specifically, young and middle age drivers were more likely to report using the sign than senior age car drivers. Furthermore, a majority of all car driver participants reported that the main function of the sign was to assist them in making a safety judgment about approaching vehicles before they entered the intersection. Similarly, when asked to explain how they used the information on the sign, just over half of the participants reported that they compared their own judgment to the information presented on the CICAS-SSA sign.

Some drivers also recognized that the warning threshold of the CICAS-SSA sign was more cautious than their own gap selection tendencies. Perhaps this is why car drivers entering the intersection from the stop sign location took more time to cross when the CICAS-SSA sign was on. As confirmed by the usage questions, drivers had relatively high trust, acceptance, and confidence in the information presented on the CICAS-SSA sign. This also suggests that car drivers understood the functioning of the sign well enough to expect that the information it gave erred on the safe side; a positive conclusion when considering drivers only had a limited exposure to the sign.

Collectively, the findings from the usability analyses suggest that the majority of drivers perceived the sign as being useful for assisting their maneuvers at the intersection and perceived the sign as being satisfying. These findings suggest that if the CICAS-SSA is deployed into service, drivers will have a positive perception of the sign which will be associated with a high rate of sign use.

6.2 Effects of Maneuver Type

The independent variable of maneuver type describes the vehicle action that drivers implemented from either the stop sign or median locations. For drivers at the stop sign their actions included right turn, left turn, and crossing straight through with the latter two being performed once they passed over the lanes of traffic immediately in front of them. For drivers in the median their actions included left turn and crossing straight through (a right turn would have resulted in driving against the flow of traffic). Note, that none of the previous CICAS-SSA evaluations examined differences in performance or usability between maneuver types due to the extensive time required to perform these analyses. In light of the fact that the current work represents an initial examination of maneuver type and that no previous research can lend confirmatory evidence, readers are encouraged to be cautious when extrapolating these results to real-world applications. The effects for maneuver type are presented to initiate a conversation relative to the effect of CICAS-SSA on performance during these maneuver types and to serve as the basis for future research efforts that may investigate these effects.

Results indicated potential differences for performance depending on maneuver type and starting position (i.e., stop sign or median). When car and truck drivers initiated a crossing maneuver from the median, presentation of the CICAS-SSA sign was associated with greater 80^{th} percentile rejected gaps. Again, this is a beneficial effect due to sign use (see Figure 14b). When drivers initiated a left turn maneuver from the median, there were no differences between the Sign On and Off conditions. It should be emphasized that these findings suggest that the CICAS-SSA sign had a positive effect on 80^{th} percentile rejected gap when drivers performed a crossing maneuver and that the CICAS-SSA sign did not detract from participants' gap decisions when making a left turn. However differences did exist when drivers were presented with the Sign On condition (as compared to the Sign Off condition) while crossing from the stop sign to the median *in preparation* for a left turn or crossing maneuver (which they made after crossing to the median). Drivers making this preparatory crossing maneuver in preparation for a crossing maneuver from the median exhibited larger 80^{th} percentile rejected gaps with the Sign On condition. This finding lends support to the notion that drivers rejected smaller gaps as a result of CICAS-SSA sign use; a finding that supports the utility of the CICAS-SSA sign. In contrast, when drivers initiated a preparatory maneuver from the stop sign location and ultimately completed a left-turn maneuver they exhibited slightly smaller 80^{th} percentile rejected gaps when presented with the Sign On condition (see Figure 14a). A rationale to support this finding is not available at this time. In light of the fact that all crashes observed at the test intersection occurred when drivers were attempting a crossing maneuver, it is important to note the beneficial effect that the CICAS-SSA sign has on the final left turn maneuvers. In addition, although drivers' rejected gaps were shorter during the Sign On condition, they were still within the expected range as observed in the data presented by Gorjestani et al. (2008). Therefore, it is adequate to report that drivers may differ in their gap acceptance decisions while *preparing* for a turn from the median based on sign state although the relative risk does not increase.

These findings are interesting for several reasons. First, they suggest that the maneuver a driver ultimately wished to complete (i.e., left turn or crossing *after* crossing over to the median) impacted their gap rejection performance when crossing traffic from the stop sign location. Given that nearly all drivers completed a two-stage maneuver we expected them to break the total crossing maneuver into two halves (i.e., first half was initiating a movement from the stop sign location and the second half was initiating a movement from the median). If drivers did break the total crossing maneuver into two halves we would have expected identical performance in the first half because that portion of the total crossing maneuver was identical for conditions where the driver had to move from the stop sign to the median location. Essentially, performance should be identical during this half regardless of what goal the driver has for the second half. Second, in light of the differences in the 80^{th} percentile rejected gap findings when drivers initiated a movement from the stop sign as compared to the median, it is clear that once drivers stop in the median they reassess the situation and change their gap decision criteria. Evidence of this can be found in the significant differences observed when drivers cross traffic from the stop sign and ultimately make a left turn as compared to the lack of differences for those drivers that perform the same maneuver type from the median. Collectively, when these two findings are combined they suggest that, 1) the CICAS-SSA sign benefited drivers' gap decision making when they performed a crossing maneuver regardless of whether they crossed traffic from either the stop sign or median locations, and that 2) once drivers reached the median, the CICAS-SSA sign did not detract from performance as compared to the baseline no-sign condition. However, the results relative to movements initiated from the median should be accepted with caution due to the fact that participants did not experience experimentally controlled traffic densities, as they were for drivers initiating a maneuver from the stop sign location.

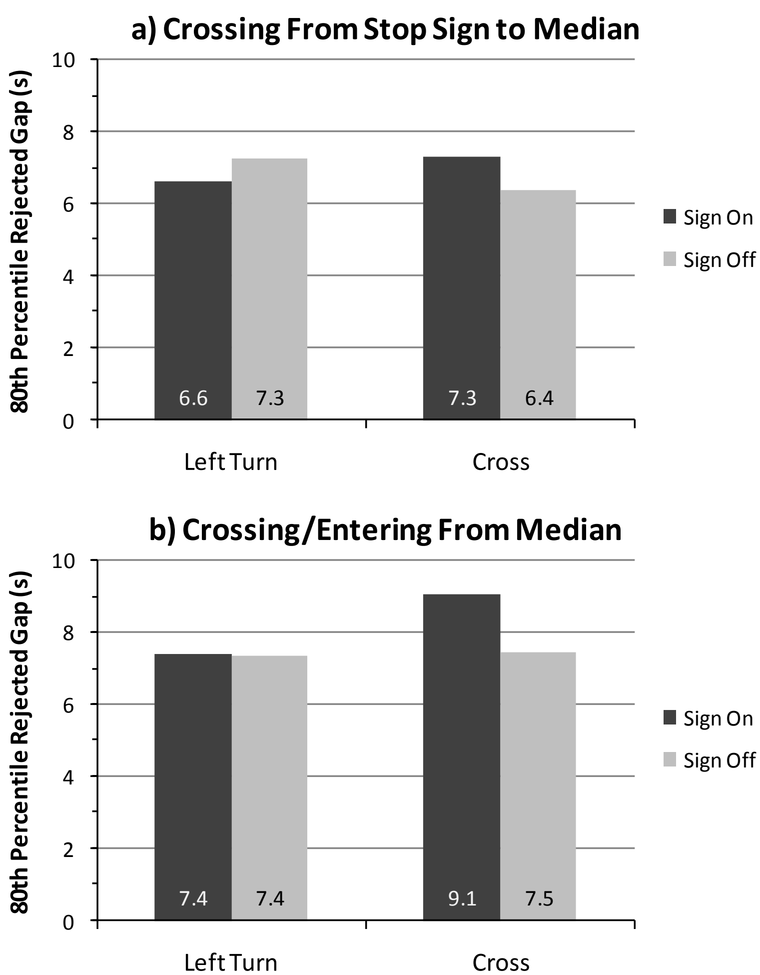


Figure 14. 80th percentile rejected gap size for car drivers making left turns or crossing maneuvers for both sign conditions while, a) crossing from the stop sign, and b) crossing/entering from the median.

In terms of subjective responses, all drivers indicated that making a right turn, as compared to crossing, required less mental effort and that during this maneuver type they felt they selected safer gaps. This finding confirms our expectations given that right turns involve only merging with traffic while left turn and crossing maneuvers involve crossing traffic ("preparing for the maneuver"), stopping in the median, and then initiating a second maneuver. Collectively, the findings from the maneuver type analysis suggest that drivers positioned at the stop sign are most likely planning their entire maneuver and that their plans, and subsequent behaviors, are influenced by the type of maneuver they would like to execute.

Recall that the majority of crashes observed at the test intersection involved one-stage maneuvers. It may be that planning an entire maneuver may result in a higher propensity to complete the maneuver as a whole. In addition, a challenge drivers may experience with this approach is that the information used to plan the entire maneuver (e.g., gap information) may become outdated quite quickly as the driver moves across the first lanes of traffic into the median. Relying on outdated information would result in gap decision making errors that could contribute to crashes. Use of the CICAS-SSA sign in this case would capture drivers' attention and thus would promote a fresh analysis of the situation, whether they decide to stop in the median or not, by providing drivers with information indicating whether it is unsafe to execute a maneuver. Both of these actions could contribute to a potential reduction in the rate of crashes. Finally, although these findings are interesting from a driver-behavior perspective, it is unclear how they will impact the final sign design because the CICAS-SSA interface was not designed to detect or react to the maneuver that the driver intends to take.

6.3 Effects of Age Group and Sex

A strength of future ITS systems is the ability to detect a variety of driver related variables that may influence performance and perceptions of usability. In light of this ability, a purpose of the current work was to determine if two common driver-related variables, driver age and sex, influenced performance during the Sign On and Off conditions. Results of the analyses on driver age indicated that senior drivers had significantly larger accepted gaps (almost 6 seconds larger) than did middle age group drivers. The significant difference between age groups for this variable was in contrast to the lack of significant differences found in the Random Gap simulator study. This difference in findings between the studies was most likely due to the range of ages selected for each study. In the current work, participants were recruited from three age groups (i.e., young, middle age, & senior) whereas in the Random Gap simulation study, only younger and senior drivers were recruited. This suggests that future work should include three age groups to understand fully the influence of age on performance when using the CICAS-SSA sign.

The senior drivers exhibited longer TTC and safety margins when entering from the stop sign position compared to both young and middle age drivers while making right turns and crossing maneuvers. Although this finding was consistent with those of the Random Gap simulation study (Creaser et al., 2008, which only examined crossing maneuvers), only half of the senior drivers in the current study reported using the system to help with their maneuvers. Therefore, their longer TTC and safety margins may be due in part to the cautiousness of these drivers under study conditions. Additionally, older drivers are often aware of their perceptual and reactive limitations, and when they performed the maneuvers in this study they may have compensated for their limitations by creating a larger safety window. This sense of cautiousness may also be responsible for the significantly larger wait times of senior drivers during right turn and crossing maneuvers. However, these interpretations should be considered tentative until additional studies are conducted that might provide confirmatory evidence.

Results also indicated an interesting age by sex interaction for perception of safe gap selection. Younger females thought they selected larger gaps than did younger males while, in contrast, middle age females thought they selected smaller gaps than did middle age males. In light of the fact that actual performance did not differ between younger males and females this finding may suggest that younger males have accepted the popular notion that they tend be less safe behind the wheel as their young female counterparts. The apparent switch in perception of gap selection for males and females in the middle age group cannot be explained fully at this time. Perhaps the middle age female drivers selected for this study were more apt to take risks or the middle age males were apt to take fewer risks. Alternatively, older women may simple be less confident drivers so they may be assessing their performance to be poor when it is truly not poor. Regardless, the extent of any practical sex and age group effects listed above are minimal and perhaps most likely limited to our current driver sample.

6.4 Truck Driver Summary

Overall, the behavior of the truck drivers was similar to that of the car drivers. During the Sign On condition, both car and truck drivers exhibited shorter 80th percentile rejected gaps while crossing from the stop sign and when crossing from the median. They also exhibited larger rejected gap values when making left-turn maneuvers from the stop sign. Both car and truck drivers made safer gap judgments (i.e., larger 80th percentile rejected gaps) during the crossing maneuvers when compared to left turn maneuvers when entering the intersection from the stop sign. Truck drivers also had longer wait times during the Sign On condition and they did not attempt to make one-stage maneuvers during the experiment. These similarities suggest that both car and truck drivers are making gap decisions in similar ways. It also suggests that they are similarly using the CICAS-SSA sign information to reduce the crash risk of their maneuver through the intersection.

The size of the 80th percentile rejected gaps that truck drivers took were slightly larger (greater than 8.5 seconds) than those of the car drivers (less than 7 seconds) in both sign conditions. In addition, although both driver types waited longer during the Sign On condition, the additional time that truck drivers waited was much greater (7.9 second difference) than the time waited by car drivers (2.4 seconds). These differences may stem from the difference in vehicle type and familiarity with the truck due to training and experience (a situation not afforded to car drivers because they were using a vehicle unfamiliar to them) and, perhaps, an understanding by the truck drivers that they would need to be more cautious and accept a larger gap size in order to accommodate the acceleration characteristics and additional size of the heavy truck.

Finally, only 38% of the truck drivers reported using the sign. This is in contrast to the approximately 66% of the car drivers (in all age groups) who reported using the sign. Confirmation of this finding is provided by the lack of significant differences observed for accepted gap and movement time performance metrics. This may suggest that truck driver performance is more dependent upon how the driver perceives the gap at the intersection and not due to the information presented on the CICAS-SSA sign.

7 Conclusions

Overall the behavioral measures indicated that a majority of participants used the sign to reduce their risk level at the intersection while subjective measures indicated they had a positive opinion of the CICAS-SSA sign. Using the CICAS-SSA sign appeared to assist both car and truck drivers in rejecting small gaps as shown by increased 80^{th} percentile rejected gap lengths in the Sign On condition. However, because only 66% of the car drivers and only 38% of the truck drivers reported using the sign, some of the differences in the rejected gap patterns for the Sign On condition are likely due to other factors, such as typical bias among participants to perform accordingly in the test condition. The 7.5 second critical gap threshold used by the CICAS-SSA sign was shown to be in agreement with drivers' gap selection performance in this study and in previous studies (Gorjestani, et al., 2008). These findings were especially noticeable while crossing from the median location. For this reason, the CICAS-SSA sign may assist drivers in reducing the risk in making gap decisions during the more taxing maneuver through the far lanes, which is associated with more crashes at this (Preston et al., 2004) and other (Preston, Storm, Donath & Shankwitz, 2006; Preston, Storm, Donath & Shankwitz, 2007) intersections.

There were no effects of sign condition for accepted gap length, lead gap length, time-to-contact, or safety margin measures for car drivers. This collective lack of effect during the Sign On condition suggests that using the sign does not significantly change the way drivers maneuver through the intersection, but instead, as indicated earlier, the sign potentially influences the gaps that are rejected by drivers. The CICAS-SSA sign appeared to reduce the safety risk (increased 80^{th} percentile rejected gap selection) while not noticeably changing how drivers moved their vehicles through the intersection. This conclusion is important as it supports the notion that the CICAS-SSA sign has a primary impact on gap decision making; the very performance element that has been cited in previous research as the source of crashes at the test intersection. However, because the field researcher was pre-selecting streams of traffic to which each driver would be exposed, it is likely that the gaps may not have been normally distributed, which may also have an effect on the availability of gap sizes for selection by drivers, thus influencing these measures.

In addition to finding the CICAS-SSA sign usable and positive overall, drivers also reported that the sign was to be used in an advisory role. This is promising because it was the intent of this design to confirm the driver's own perceptions of safety before entering the intersection, rather than control drivers' actions by employing a regulatory traffic control device. Overall, two-thirds of drivers self-reported that they used the CICAS-SSA sign, with a negative relationship between age and usage (i.e., the younger the driver, the more likely they reported using it). Even so, half of the senior drivers did report that they used the sign. This was a positive finding given that senior drivers are over-represented in rural intersection collisions (Staplin & Lyles, 1991; Preusser et al., 1998) and may also have more difficulty understanding traffic signs and signals (Shinar et al., 2003; Dewar, Kline, & Swanson, 1994). This suggests that previous research and design efforts to create a CICAS-SSA sign that was useful to senior drivers was accomplished. Convincing the remainder of senior drivers that the sign can provide a benefit for them may require the deployment of an information-advertising campaign targeted at these individuals

It was encouraging to observe that performance and subjective opinions of the CICAS-SSA sign were consistent with previous observations within the simulation-based experiments (especially Creaser, et al., 2008). The Random Gap study indicated that similar to the real-world, drivers in the simulator were good at rejecting unsafe gaps at rural stop-controlled intersections in both the CICAS-SSA and baseline conditions. Likewise, the results from this field test reaffirmed many of the findings from the Random Gap study; primarily those relating to rejecting gaps shorter than the critical threshold of 7.5 seconds. The consistency of results suggests researchers can make valid inferences from data gained in the simulator about behaviors and perceptions that may be observed in the real-world. The consistency of results between the simulation-based studies also suggests that the driving simulator is a valid tool that can be employed to perform preliminary design and evaluation tasks for CICAS-SSA devices and for ITS technology in general.

This study also exposed a potential novel finding relating to how drivers interact with traffic based on the maneuver they are *preparing to execute*. Both car and truck drivers' rejected gap sizes while crossing from the stop sign to the median were notably shorter when they were preparing to make a left turn as compared to when they were preparing to make a crossing maneuver. This may suggest that all drivers conceptualize these two maneuvers differently even *while crossing from the stop sign to the median before actually performing either maneuver*. Specifically, drivers may be more cautious while preparing for a left turn without support from the CICAS-SSA sign, as evidenced by the longer 80th percentile rejected gap size during the Sign Off condition (Tables 4 and 5). In addition, the truck drivers had reduced TTC and safety margins while preparing for a left turn maneuver as compared to preparing for a crossing maneuver. Further exploration is needed to see if this potential interaction between vehicle type and crossing behavior has practical significance for drivers maneuvering through the intersection. Repetition of this finding would help to show whether this finding is due to gap selection behavior or due to natural variability in the sample of gaps that our participants encountered during this study.

Collectively, all of these results suggest that the use of the CICAS-SSA sign may assist drivers' performance, that the use of the sign did not add undue stress, and that the CICAS-SSA sign was found to be usable. In addition, for those types of maneuvers that are associated with crashes at the actual test intersection, results from the current work suggest that the CICAS-SSA sign could facilitate the reduction of the risk in gap decision making. Based on the consistent positive results displayed across multiple studies it is expected that use of the CICAS-SSA sign in a field operational test or in actual deployment may result in similar positive results.

8 References

Alexander, L, Cheng, P., Donath, M., Gorjestani, A., Menon, A., Newstrom, B., & Shankwitz, C., (2006). "The Minnesota Mobile Intersection Surveillance System", *Proceedings of the 9th International IEEE Conference on Intelligent Transportation Systems*, Toronto, Ontario, CA.

AASHTO Strategic Highway Safety Plan. American Association of State Highway and Transportation Officials. Washington, D.C., 1998.

Campbell, J.L., Richman, J.B., Carney, C., & Lee, J.D. (2004a). *In-vehicle display icons and other information elements volume 1: Guidelines* (Rep. No. FHWA-RD-03-065). McLean, VA: Federal Highway Administration.

Campbell, J.L., Hoffmeister, D.H., Keifer, R.J., Selke, D.J., Green, P.A., & Richman, J.B. (2004b). "Comprehension Testing of Active Safety Symbols" (2004-01-0450). *2004 SAE World Congress and Exhibition Technical Papers*, Detroit, MI, March 8-11, 2004.

Chrysler, S.T., Wright, J., & Williams, A. (2004). *3D Visualization as a Tool to Evaluate Sign Comprehension* (Rep. No. SWUTC/04/167721-1). College Station, TX: Southwest University Transportation Center.

Creaser, J., Manser, M., Rakauskas, M., & Donath, M. (2010). Sign Comprehension, Considering Rotation and Location, Using Random Gap Simulation for Cooperative Intersection Collision Avoidance System – Stop Sign Assist: CICAS-SSA Report #4. Intelligent Transportation Systems Institute Center for Transportation Studies, August.

Creaser, J.I., Rakauskas, M.E., Ward, N.J., Laberge, J.C., & Donath, M. (2007). "Concept evaluation of intersection decision support (IDS) system interfaces to support drivers' gap acceptance decisions at rural stop-controlled intersections". *Transportation Research Part F, 10*, 208-228.

Dewar, R.E., Kline, D.W., & Swanson, H.A. (1994). Age differences in comprehension of traffic sign symbols. *Transportation Research Record 1456*, 1-10.

Federal Highway Administration (2004). Intersection safety facts and statistics. US Department of Transportation: FHWA. http://safety.fhwa.dot.gov/intersections/inter_facts.htm (accessed January 23, 2008).

Godley, S.T., Triggs, T.J., & Fildes, B.N. (2002). "Driving simulator validation for speed research." *Accident Analysis and Prevention*, 34, 589-600.

Gorjestani, A., Menon, A., Cheng, P., Shankwitz, C., & Donath, M. (2010). Determination of the Alert and Warning Timing for the Cooperative Intersection Collision Avoidance System – Stop Sign Assist Using Macroscopic and Microscopic Data: CICAS-SSA Report #1, Intelligent Transportation Systems Institute Center for Transportation Studies, August.

Laberge, J.C., Creaser, J.I., Rakauskas, M.E., & Ward, N.J. (2006). "Design of an intersection decision support (IDS) interface to reduce crashes at rural stop-controlled intersections." *Transportation Research Part C: Emerging Technologies*, 14, 39–56.

Neuman, T., Pfefer, R., Slack, K., Harwood, D., Potts, I., Torbic, D., & Rabbani, E. *NCHRP Report 500 (Volume 5): A Guide for Addressing Unsignalized Intersection Collisions*, TRB, National Research Council, Washington, D.C., 2003.

Preston, H. & Storm, R. (2003). "Review of Minnesota's rural crash data." Draft-Technical Memorandum, 112003. Eagan, MN: CH2M HILL, October.

Preston, H., Storm, R., Donath, M., & Shankwitz, C. (2004). *Review of Minnesota's rural crash data: Methodology for identifying intersections for intersection decision support (IDS).* (Rep No. MN/RC-2004-31) St. Paul, MN: Minnesota Department of Transportation.

Shinar, D., Dewar, R.E., Summala, H., & Zakowska, L. (2003). "Traffic sign symbol comprehension: a cross-cultural study". *Ergonomics, 46*(15), 1549-1565.

Stemler, S.E. (2004). “A comparison of consensus, consistency, and measurement approaches to estimating interrater reliability”. *Practical Assessment, Research & Evaluation, 9*, Retrieved May 24, 2007 from http://PAREonline.net/.

Tornros, J. (1998). “Driving behaviour in a real and a simulated road tunnel- a validation study”. *Accident Analysis and Prevention*, 30(4), 497-503.

Wierwille, W.W. & Casali, J.G. (1983). “A validated rating scale for global mental workload measurement applications”, *Proceedings of the 27ths Annual Meeting of the Human Factors and Ergonomics Society.* 129-133. Santa Monica, CA: Human Factors Society.

Witmer, B. & Sadowski, W.J. Jr. (1988). “Nonvisually guided locomotion to a previously viewed target in real and virtual environments”. *Human Factors* 40, 478–488.

APPENDIX A. CONSENT FORM

Consent Form
Cooperative Intersection Collision Avoidance Systems: Validation Study

You are invited to be in a research study on driver behavior at intersections in rural environments. You were selected as a possible participant because you responded to our call for participation, are familiar with the types of roads in this area, and were found to have a safe driving history. We ask that you read this form and ask any questions you may have before agreeing to be in the study. This study is being conducted by Michael Manser, Michael Rakauskas, and Janet Creaser who are all research staff at the University of Minnesota HumanFIRST program.

Background Information
The purpose of this study is to investigate how people drive at intersections in rural environments both with and without assistance from Intelligent Transportation System (ITS) assistive signs.

Procedures:
If you agree to be in this study, we would ask you to perform a number directed drives through an intersection on HWY52 in Minnesota. We will also need your consent to review your license history (DVS records). You will drive a vehicle that has been instrumented to collect data about your driving behavior. You will also wear a light-weight device to track and make a video recording of your eye gaze. You will also be asked about your driving experience. The duration of the entire study will be about 3 hours.

Risks and Benefits of being in the Study
We have tried to create a study with no high risks. However, driving naturally has some level of risk. You are responsible for driving safely in this study. There are no direct benefits to you for participating in this study other than compensation.

Compensation:
$250 for completion of the study.

Confidentiality:
The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify a subject. Research records will be stored securely and only researchers will have access to the records. Video recordings of your drive and eye behavior will only be available to researchers on the project.

Voluntary Nature of the Study:
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Minnesota. If you decide to participate, you are free to not answer any question or withdraw at any time with out affecting those relationships or compensation.

Contacts and Questions:
You may ask any questions you have now. If you have questions later, **you are encouraged** to contact the lead researcher Michael Rakauskas at 612-624-4614 or mickr@me.umn.edu.
If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Research Subjects' Advocate Line, D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455; (612) 625-1650.

Statement of Consent:
I have read the above information. I have asked questions and have received answers. I understand that I may request a copy of the consent form. I give permission for the researchers to review my DVS records. I consent to participate in the study.

Signature:_______________________________________ Date: __________________

MN Drivers License #: ______________________________________

Signature of Investigator:___________________________ Date: __________________

APPENDIX B. M45 DRIVER IDENTIFICATION FORM

University of Minnesota
Identification of Approved M45 Drivers Form

Name: ____

Affiliation: ____

Address: Street:_________________________________
City: _________________________________
Zip Code _____________________________

Phone: ____

Driver's license number: ____________________________

State in which license is held: ________________________

Current Date: _____________________________________

Signature: ____

Program Director or Operations Manager shall fax this form to:

Toshiro Muramatsu
Manager, Technology Planning
Nissan Technical Center North America, Inc.
39001 Sunrise Drive
Farmington Hills, MI 48331, U.S.A.

Phone: 248-488-4443
Fax: 248-488-3914
E-mail: MuramT2@ntcna.nissan-usa.com

Phone: 248.488.4443
Fax: 248.488.3905
Email: mitamut@nrd.nissan-usa.com

Date Faxed:____________________

APPENDIX C. DRIVING HISTORY QUESTIONNAIRE

DRIVING HISTORY QUESTIONNAIRE

This questionnaire asks you to indicate some details about your driving history and related information. Please tick one box for each question.

1. Your age: ____________ years

2. Your sex:
   - ☐ Male
   - ☐ Female

3. What is your highest educational level completed?
   - ☐ High School / Vocational School
   - ☐ Associates Degree
   - ☐ Bachelor of Arts / Bachelor of Science
   - ☐ Masters
   - ☐ PhD

4. Are you currently taking any college level classes?
   - ☐ Yes
   - ☐ No

5. Please state your occupation:____

6. Please state the **year** when you obtained your full driving license: __________

7. About how often do you drive nowadays?

   ☐ ======= ☐ ======= ☐ ======= ☐ ======= ☐

   Never — Hardly Ever — Sometimes — Most Days — Every Day

8. Estimate roughly how many miles you personally have driven in the past year:
   - ☐ Less than 5000 miles
   - ☐ 5000-10,000 miles
   - ☐ 10,000-15,000 miles
   - ☐ 15,000-20,000 miles
   - ☐ Over 20,000 miles

9. About how often do you drive to and from your place of work?

   ☐ ======= ☐ ======= ☐ ======= ☐ ======= ☐

   Never — Hardly Ever — Sometimes — Most Days — Every Day

Do you drive frequently on…

	Yes	No
10. Highways?:	☐	☐
11. Main Roads other than Highways?:	☐	☐
12. Urban Roads?:	☐	☐
13. Country Roads?:	☐	☐

14. During the last three years, how many minor road accidents have you been involved in where you were at fault? A minor accident is one in which no-one required medical treatment, AND costs of damage to vehicles and property were less than $1000.

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

15. During the last three years, how many major road accidents have you been involved in where you were at fault? A major accident is one in which EITHER someone required medical treatment, OR costs of damage to vehicles and property were greater than $1000, or both.

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

16. During the last three years, have you ever been convicted for:

	Yes	No
a. Speeding	☐	☐
b. Careless or dangerous driving	☐	☐
c. Driving under the influence of alcohol/drugs	☐	☐

17. What type of vehicle do you drive most often?

☐ Motorcycle
☐ Passenger Car
☐ Pick-Up Truck
☐ Sport utility vehicle
☐ Van or Minivan
☐ Other, briefly describe: ______________________________

18. How frequently to do drive on Highway 52?

Never ☐—☐—☐—☐—☐ *Every Day*

19. How frequently to do drive on County Road 9?

Never ☐—☐—☐—☐—☐ *Every Day*

20. How frequently to do cross or enter Highway 52 from County Road 9?

Never ☐—☐—☐—☐—☐ *Every Day*

21. Approximately how many times have driven through this intersection from the minor road (County Road 9) in the past 6 months? ____________

APPENDIX D. EXPERIMENT INSTRUCTIONS

EXPERIMENT INSTRUCTIONS

Thank you for taking part in our study. We would first like to give you an overview of what you will be doing during the experiment. This experimental session will involve three sections:
Instructions & Setup
Driving 1
Driving 2
Debrief

Setup
You will first be asked to put on a head tracking device. This consists of a headband you will wear while driving. Once you have put it on and it is comfortable, the experimenter will guide you through the calibration process by asking you to make several movements in order to make sure it is secure.

Driving 1 & 2
After the calibration and instructions, you will be performing a number directed drives through the intersection of Highway 52 and County Road 9.

Please drive as you normally would. An experimenter will be riding with you in the backseat in order to let you know what direction to turn at the intersection and when you are to begin each drive. You may communicate with him before each drive begins and after you have negotiated the intersection, but not during the maneuver through the intersection itself (except in the event of an emergency).

While driving, your primary goal will be to cross the intersection as directed. Your secondary goal will be to maintain safe driving behavior at all times during this study, as you normally would. After each maneuver, you will return to the starting location. At that time, the experimenter will give you some questions to answer about your last experience at the intersection.

During the experiment, please follow all directions given to you by the experimenter.

Debrief
After both drives, you will be debriefed on the experiment and paid for your participation.

We ask that if you know any other people scheduled to participate in this study that you do not reveal to them any specific details about what you were required to do.

If you have any questions, please feel free to ask the experimenter now or at any time during the experiment.

DRIVING INSTRUCTIONS

In a moment, you will be performing a number directed drives through the intersection of Highway 52 and County Road 9. The experimenter will first ride with you along the planned routes so that you get a feel for where you are to go.

While driving, your primary goal will be to cross the intersection and make a safe left turn, right turn, or intersection-crossing maneuver.

The experimenter will tell you when to begin each drive. Before each drive, you will be instructed on which of these maneuvers to make, and given a map showing you the route you are to take. These are the same routes that were shown to you during the practice drive with the experimenter. Please remember to follow any instructions given to you by the experimenter before and during the drives.

During these drives an additional smart-sign may be present at the intersection. This means the information on the smart sign changes in real time depending on the current traffic conditions near the intersection. This system presents information that helps you, the driver, make decisions about when to cross or turn at the intersection based on current traffic conditions. Your goal is to cross the intersection as you would normally if you encountered these traffic signs in the real world. Examine these signs to see if you understand the information they provide and use the information if you think it is useful.

Your secondary goal will be to maintain safe driving behavior at all times during this study, as you normally would.

After each maneuver, you will return to the starting location. At that time, the experimenter will give you some questionnaires to answer about your last experience at the intersection.

You will be given the opportunity to take a break halfway through the experiment, if you so choose. The experimenter will let you know when you have completed all of the drives.

Practice Drive Instructions

The purpose of this practice drive is to help you get used to the car and the driving routes. You will drive according to the practice drive route maps and our experimenter's instruction. These practice routes cover all the routes you will drive during this study.

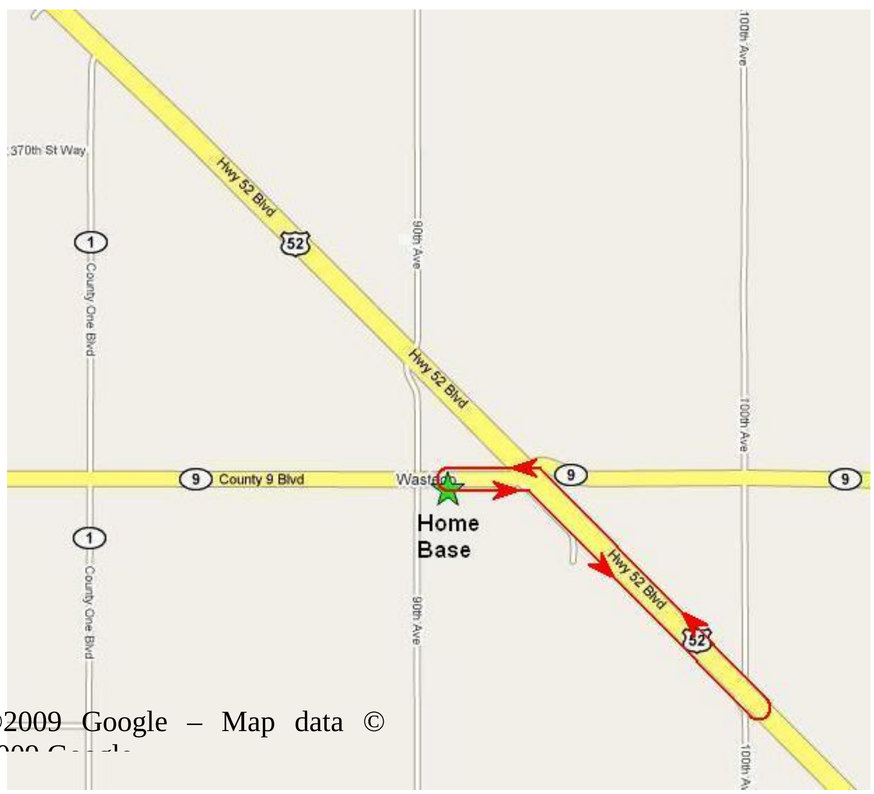
Route Maps:

Left Turn:

©2009 Google – Map data © 2009 Google

Straight Driving Maneuver:

Right Turn:



APPENDIX E. RUN ASSIGNMENT CONDITION ORDERS

Maneuvers
"R" = Right Turn
"L" = Left Turn
"C" = Crossing

Direction
"e" = Eastbound
"w" = Westbound

		Block 1									Block 2								
P#	Group	Sign	1	2	3	4	5	6	7	8	Sign	9	10	11	12	13	14	15	16
1	Young	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re
2	Young	On	Re	Ce	Cw	Le	Le	Re	Ce	Cw	Off	Le	Ce	Cw	Re	Ce	Cw	Re	Le
3	Young	On	Le	Re	Ce	Cw	Le	Ce	Cw	Re	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re
4	Young	Off	Le	Ce	Cw	Re	Ce	Cw	Re	Le	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw
5	Young	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le
6	Young	Off	Ce	Cw	Le	Re	Re	Le	Ce	Cw	On	Re	Ce	Cw	Le	Le	Re	Ce	Cw
7	Young	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le
8	Young	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw
9	Young	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re
10	Young	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le
11	Young	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re
12	Young	Off	Le	Ce	Cw	Re	Ce	Cw	Re	Le	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw
13	Young	On	Le	Re	Ce	Cw	Le	Ce	Cw	Re	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re
14	Young	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le	Off	Ce	Cw	Le	Re	Re	Le	Ce	Cw
15	Young	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le
16	Young	Off	Ce	Cw	Le	Re	Re	Le	Ce	Cw	On	Re	Ce	Cw	Le	Le	Re	Ce	Cw
17	Young	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le	On	Le	Re	Ce	Cw	Le	Ce	Cw	Re
18	Young	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le
19	Young	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le
20	Young	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re
26	Middle	Off	Le	Ce	Cw	Re	Ce	Cw	Re	Le	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw
27	Middle	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le
28	Middle	Off	Ce	Cw	Le	Re	Re	Le	Ce	Cw	On	Re	Ce	Cw	Le	Le	Re	Ce	Cw
29	Middle	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le
30	Middle	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw
31	Middle	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re
32	Middle	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le
33	Middle	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re
34	Middle	Off	Le	Ce	Cw	Re	Ce	Cw	Re	Le	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw
35	Middle	On	Le	Re	Ce	Cw	Le	Ce	Cw	Re	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re
36	Middle	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le	Off	Ce	Cw	Le	Re	Re	Le	Ce	Cw
37	Middle	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le
38	Middle	Off	Ce	Cw	Le	Re	Re	Le	Ce	Cw	On	Re	Ce	Cw	Le	Le	Re	Ce	Cw
39	Middle	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le	On	Le	Re	Ce	Cw	Le	Ce	Cw	Re
40	Middle	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le
41	Middle	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re
42	Middle	On	Re	Ce	Cw	Le	Le	Re	Ce	Cw	Off	Le	Ce	Cw	Re	Ce	Cw	Re	Le
43	Middle	On	Le	Re	Ce	Cw	Le	Ce	Cw	Re	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re
44	Middle	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le
45	Middle	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le

Maneuvers
"R" = Right Turn
"L" = Left Turn
"C" = Crossing

Direction
"e" = Eastbound
"w" = Westbound

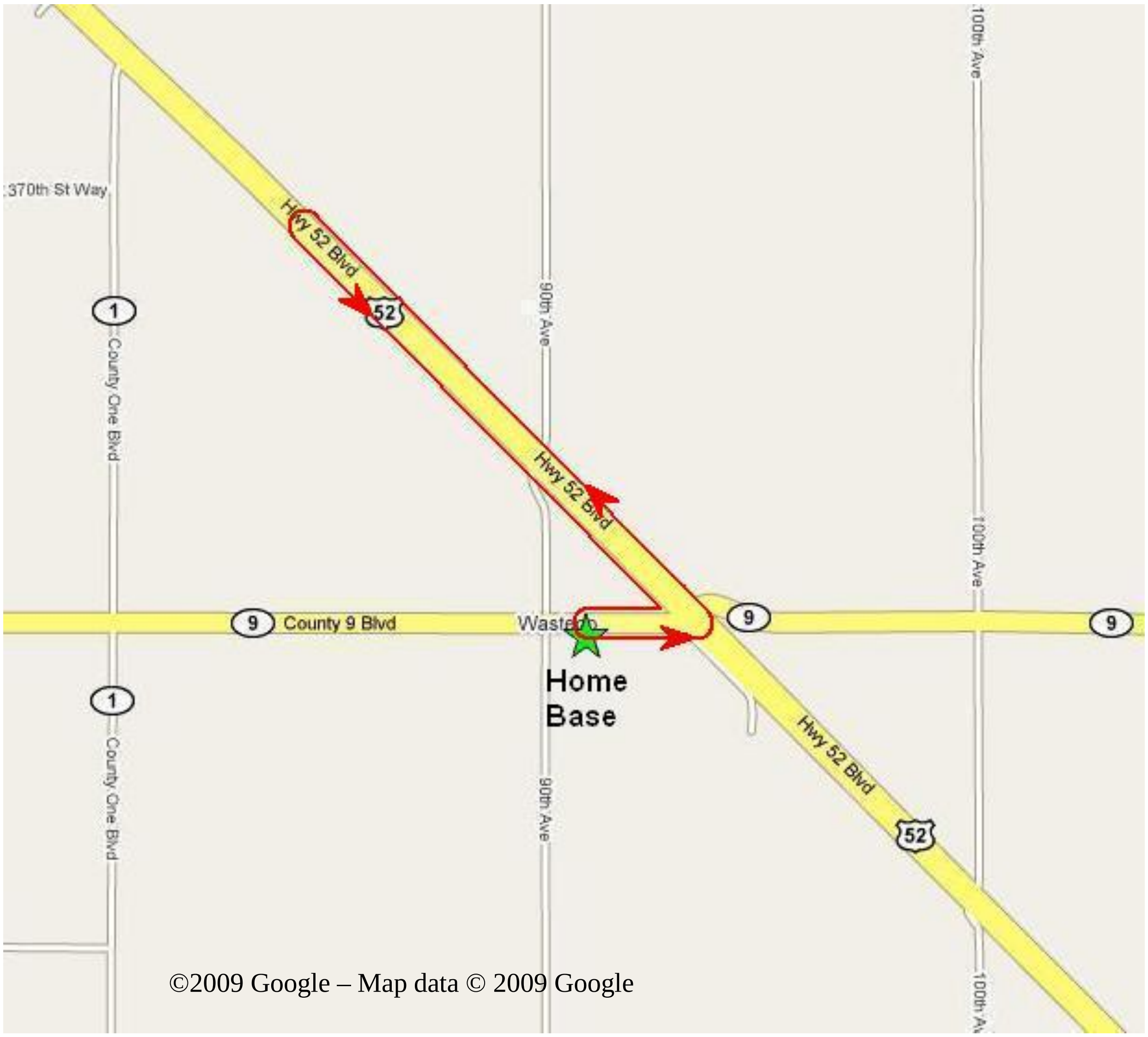
		Block 1									Block 2								
P#	Group	Sign	1	2	3	4	5	6	7	8	Sign	9	10	11	12	13	14	15	16
51	Older	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le
52	Older	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw
53	Older	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re
54	Older	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le
55	Older	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re
56	Older	Off	Le	Ce	Cw	Re	Ce	Cw	Re	Le	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw
57	Older	On	Le	Re	Ce	Cw	Le	Ce	Cw	Re	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re
58	Older	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le	Off	Ce	Cw	Le	Re	Re	Le	Ce	Cw
59	Older	On	Ce	Cw	Re	Le	Ce	Cw	Le	Re	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le
60	Older	Off	Ce	Cw	Le	Re	Re	Le	Ce	Cw	On	Re	Ce	Cw	Le	Le	Re	Ce	Cw
61	Older	Off	Re	Le	Ce	Cw	Re	Ce	Cw	Le	On	Le	Re	Ce	Cw	Le	Ce	Cw	Re
62	Older	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw	On	Le	Ce	Cw	Re	Ce	Cw	Re	Le
63	Older	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le	Off	Le	Re	Ce	Cw	Le	Ce	Cw	Re
64	Older	On	Re	Ce	Cw	Le	Le	Re	Ce	Cw	Off	Le	Ce	Cw	Re	Ce	Cw	Re	Le
65	Older	On	Le	Re	Ce	Cw	Le	Ce	Cw	Re	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re
66	Older	Off	Le	Ce	Cw	Re	Ce	Cw	Re	Le	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw
67	Older	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le
68	Older	Off	Ce	Cw	Le	Re	Re	Le	Ce	Cw	On	Re	Ce	Cw	Le	Le	Re	Ce	Cw
69	Older	Off	Ce	Cw	Re	Le	Ce	Cw	Le	Re	On	Re	Le	Ce	Cw	Re	Ce	Cw	Le
70	Older	On	Ce	Cw	Le	Re	Re	Le	Ce	Cw	Off	Re	Ce	Cw	Le	Le	Re	Ce	Cw
76	Truck	Off		Ce	Cw	Le	Le		Ce	Cw	On	Le	Ce	Cw		Ce	Cw		Le
77	Truck	Off	Le		Ce	Cw	Le	Ce	Cw		On	Ce	Cw		Le	Ce	Cw	Le	
78	Truck	Off	Le	Ce	Cw		Ce	Cw		Le	On	Ce	Cw	Le			Le	Ce	Cw
79	Truck	On	Le		Ce	Cw	Le	Ce	Cw		Off	Ce	Cw		Le	Ce	Cw	Le	
80	Truck	On	Le	Ce	Cw		Ce	Cw		Le	Off	Ce	Cw	Le			Le	Ce	Cw
81	Truck	On	Ce	Cw		Le	Ce	Cw	Le		Off		Le	Ce	Cw		Ce	Cw	Le
82	Truck	Off	Ce	Cw	Le			Le	Ce	Cw	On		Ce	Cw	Le	Le		Ce	Cw
83	Truck	Off		Le	Ce	Cw		Ce	Cw	Le	On	Le		Ce	Cw	Le	Ce	Cw	
84	Truck	Off		Ce	Cw	Le	Le		Ce	Cw	On	Le	Ce	Cw		Ce	Cw		Le
85	Truck	On		Le	Ce	Cw		Ce	Cw	Le	Off	Le		Ce	Cw	Le	Ce	Cw	
86	Truck	On		Ce	Cw	Le	Le		Ce	Cw	Off	Le	Ce	Cw		Ce	Cw		Le
87	Truck	On	Le		Ce	Cw	Le	Ce	Cw		Off	Ce	Cw		Le	Ce	Cw	Le	
88	Truck	Off	Le	Ce	Cw		Ce	Cw		Le	On	Ce	Cw	Le			Le	Ce	Cw
89	Truck	Off	Ce	Cw		Le	Ce	Cw	Le		On		Le	Ce	Cw		Ce	Cw	Le
90	Truck	Off	Ce	Cw	Le			Le	Ce	Cw	On		Ce	Cw	Le	Le		Ce	Cw
91	Truck	On	Ce	Cw		Le	Ce	Cw	Le		Off		Le	Ce	Cw		Ce	Cw	Le
92	Truck	On	Ce	Cw	Le			Le	Ce	Cw	Off		Ce	Cw	Le	Le		Ce	Cw
93	Truck	On		Le	Ce	Cw		Ce	Cw	Le	Off	Le		Ce	Cw	Le	Ce	Cw	
94	Truck	Off		Ce	Cw	Le	Le		Ce	Cw	On	Le	Ce	Cw		Ce	Cw		Le
95	Tuck	On		Le	Ce	Cw		Ce	Cw	Le	Off	Le		Ce	Cw	Le	Ce	Cw	

APPENDIX F. TRIAL INSTRUCTIONS & QUESTIONNAIRES

Left Turn Maneuver Instructions

In this drive, you will make a left turn onto Highway 52 from County 9. After making the left turn, stay in the left lane and drive ahead for about 1 mile. The experimenter will show you where to make a U-turn to return to Home Base.

Route Map:



Post Condition Questionnaire

Answer the following questions in regards to the last time you crossed US 52 by placing a mark (**X**) in the appropriate box.

Did you feel you had enough time before making your maneuver (turn or cross) through the intersection?

Not enough time ☐—☐—☐—☐—☐ More than enough time

Did you feel you had enough time to make your maneuver (turn or cross) through the intersection?

Not enough time ☐—☐—☐—☐—☐ More than enough time

How safe was the gap in traffic that you chose while driving through the intersection?

Not safe ☐—☐—☐—☐—☐ Extremely safe

How <u>frustrating</u> was your entire experience at the intersection?

Not frustrating ☐—☐—☐—☐—☐ Extremely frustrating

How much <u>mental effort</u> was needed to drive through the intersection?

Small amount of effort ☐—☐—☐—☐—☐ Large amount of effort

How much <u>physical effort</u> was needed to drive through the intersection?

Small amount of effort ☐—☐—☐—☐—☐ Large amount of effort

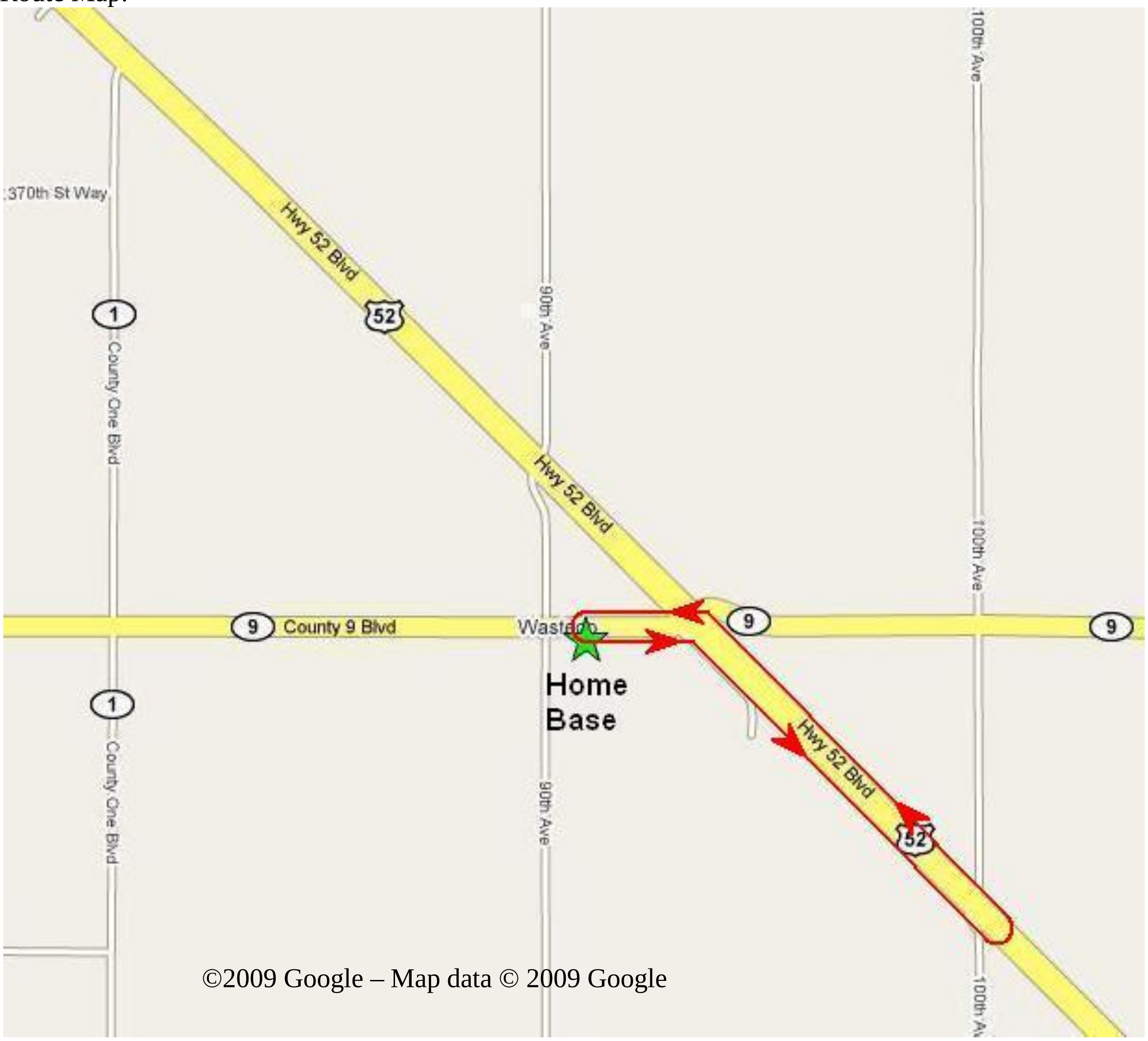
How would you rate your overall performance while driving through the intersection?

Worse than normal ☐—☐—☐—☐—☐ Better than normal

Right Turn Maneuver Instructions

In this drive, you will make a right turn onto Highway 52 from County 9. After making the right turn, drive ahead to 100th Ave and make a U-turn. Then, drive back to Home Base.

Route Map:



Post Condition Questionnaire

Answer the following questions in regards to the last time you crossed US 52 by placing a mark (**X**) in the appropriate box.

Did you feel you had enough time before making your maneuver (turn or cross) through the intersection?

Not enough time ☐—☐—☐—☐—☐ More than enough time

Did you feel you had enough time to make your maneuver (turn or cross) through the intersection?

Not enough time ☐—☐—☐—☐—☐ More than enough time

How safe was the gap in traffic that you chose while driving through the intersection?

Not safe ☐—☐—☐—☐—☐ Extremely safe

How frustrating was your entire experience at the intersection?

Not frustrating ☐—☐—☐—☐—☐ Extremely frustrating

How much mental effort was needed to drive through the intersection?

Small amount of effort ☐—☐—☐—☐—☐ Large amount of effort

How much physical effort was needed to drive through the intersection?

Small amount of effort ☐—☐—☐—☐—☐ Large amount of effort

How would you rate your overall performance while driving through the intersection?

Worse than normal ☐—☐—☐—☐—☐ Better than normal

Straight Driving Maneuver Instructions

In this drive, you drive straight across Highway 52. After crossing the intersection, drive ahead and make a U-turn at the intersection of County 9 and 100th Ave. Then, return to Home Base.

Route Map:

Post Condition Questionnaire

Answer the following questions in regards to the last time you crossed US 52 by placing a mark (**X**) in the appropriate box.

Did you feel you had enough time before making your maneuver (turn or cross) through the intersection?

Not enough time ☐—☐—☐—☐—☐ More than enough time

Did you feel you had enough time to make your maneuver (turn or cross) through the intersection?

Not enough time ☐—☐—☐—☐—☐ More than enough time

How safe was the gap in traffic that you chose while driving through the intersection?

Not safe ☐—☐—☐—☐—☐ Extremely safe

How <u>frustrating</u> was your entire experience at the intersection?

Not frustrating ☐—☐—☐—☐—☐ Extremely frustrating

How much <u>mental effort</u> was needed to drive through the intersection?

Small amount of effort ☐—☐—☐—☐—☐ Large amount of effort

How much <u>physical effort</u> was needed to drive through the intersection?

Small amount of effort ☐—☐—☐—☐—☐ Large amount of effort

How would you rate your overall performance while driving through the intersection?

Worse than normal ☐—☐—☐—☐—☐ Better than normal

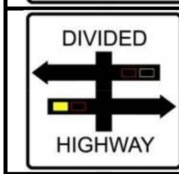
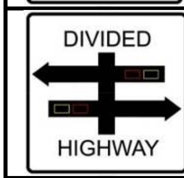
APPENDIX G. POST SIGN ON QUESTIONNAIRES

You just viewed this sign at the intersection.

Remember that, although multiple pictures are shown, this set of pictures represents only ONE sign that is capable of displaying several messages

Sign with Different Messages



Please answer the question on this page and the questions on the following pages based on your experience driving through the intersection with this sign present in addition to the stop sign.

Please describe in your own words what you think this sign's function is and what information it provides to the driver (you).

Continued on Next Page

Please indicate how strongly you agree or disagree with the following statements. Answer these questions in relation to the smart sign you just viewed at the intersection while driving.

I felt confident using this sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I felt it was confusing to use this sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

Using this sign made me feel safer.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I trusted the information provided by the sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I like this sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

The sign was reliable.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I felt this sign was easy to understand.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

The sign's information was believable (credible).

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

This sign was useful.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I could complete the maneuver the same way without using the sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

Continued on Next Page

11. Did you use the information on this sign to help you make your crossing decisions?

☐Yes ☐No

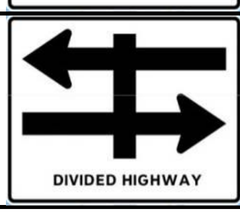
If "yes", please explain what information you used or how you used the information to make your decision of when to cross.

If **"no"**, please explain why you did not use the information presented on the sign.

Only move onto the next questionnaire once you have completed this section.

Sign Description

You just viewed this sign at the intersection.
This sign shows an overview of the highway and the direction of travel of vehicles on the highway. This sign uses icons to indicate when traffic is detected near the intersection in each set of lanes (near and far lanes). When traffic is detected too close to the intersection in a set of lanes, a red block (indicating a vehicle) is lit up. At the same time, an icon indicates that it is unsafe to enter the intersection and which maneuvers might be dangerous. When a vehicle is detected approaching the intersection but is not considered too close, a yellow icon lights up (indicating the presence of a vehicle). This icon is yellow to indicate that it may be OK to cross, but that the driver should still proceed cautiously. If no vehicles are detected near the intersection, none of the icons are lit up. In this case, it may be ok to enter the intersection to cross over or turn right/left.

Sign with Different Messages	What Each Message Means
	Do not enter the intersection; a vehicle is detected too close to the intersection in the near lanes (approaching from the left).
	Do not enter the intersection; vehicles are detected too close to the intersection in both the near (approaching from left) and far lanes (approaching from right).
	You may turn right; no vehicles detected approaching from the left in the near lanes. Vehicles are detected approaching from the right and are too close to the intersection; do not cross or turn left into the far lanes.
	A vehicle is detected approaching from the left in the near lanes. You may be able to cross or turn, but proceed with caution.
	No vehicles are detected approaching in the near (from the left) or far lanes (from the right). You may be able to cross or turn.

Please rate your opinion of the “smart” sign shown using all the items listed below.

Please refer to the “Sign Description” on the previous page if you need a reminder of how the sign works and the types of messages it presents. Remember that although multiple pictures are shown, this set of pictures represents only ONE sign that is capable of displaying several messages.

Example: If you thought the sign was very easy to use but required a lot of effort you might respond as follows:

Easy	☒	☐	☐	☐	☐	Difficult
Simple	☐	☐	☐	☒	☐	Confusing

Useful	☐	☐	☐	☐	☐	Useless
Pleasant	☐	☐	☐	☐	☐	Unpleasant
Bad	☐	☐	☐	☐	☐	Good
Nice	☐	☐	☐	☐	☐	Annoying
Effective	☐	☐	☐	☐	☐	Superfluous
Irritating	☐	☐	☐	☐	☐	Likeable
Assisting						☐ ☐ ☐ ☐ ☐
Undesirable	☐	☐	☐	☐	☐	Desirable
Raising Alertness	☐	☐	☐	☐	☐	Sleep-inducing

Please let the researcher know you have finished this section.

APPENDIX H. POST SIGN OFF QUESTIONNAIRES

You just viewed this sign at the intersection.

Stop Sign

Please answer the question on this page and the questions on the following pages based on your experience driving through the intersection with the stop sign.

Please describe in your own words what you think this sign's function is and what information it provides to the driver (you).

____
____
____

Continued on Next Page

Please indicate how strongly you agree or disagree with the following statements. Answer these questions in relation to the smart sign you just viewed at the intersection while driving.

I felt confident using this sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I felt it was confusing to use this sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

Using this sign made me feel safer.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I trusted the information provided by the sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I like this sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

The sign was reliable.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I felt this sign was easy to understand.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

The sign's information was believable (credible).

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

This sign was useful.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

I could complete the maneuver the same way without using the sign.

☐ Strongly Disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly Agree

Continued on Next Page

11. Did you use the information on this sign to help you make your crossing decisions?

☐Yes ☐No

If "yes", please explain what information you used or how you used the information to make your decision of when to cross?

If **"no"**, please explain why you did not use the information presented on the sign.

Only move onto the next questionnaire once you have completed this section.

Sign Description

You just viewed this sign at the intersection.
This sign is the standard stop sign found at this type of intersection. It does not provide any information about the traffic at the intersection. It simply tells the driver that they must stop at the intersection before crossing. The crossing decision rests entirely upon the driver.

Sign with Both Messages	What the Sign Means
	Stop at the intersection.

Please rate your opinion of the stop sign shown using all the items listed below.

Please refer to the “Sign Description” on the previous page if you need a reminder of how the sign works and the messages it presents to the driver.

Example: If you thought the sign was very easy to use but required a lot of effort you might respond as follows:

Easy	☒ ☐ ☐ ☐ ☐	Difficult
Simple	☐ ☐ ☐ ☒ ☐	Confusing

Useful	☐ ☐ ☐ ☐ ☐	Useless
Pleasant	☐ ☐ ☐ ☐ ☐	Unpleasant
Bad	☐ ☐ ☐ ☐ ☐	Good
Nice	☐ ☐ ☐ ☐ ☐	Annoying
Effective	☐ ☐ ☐ ☐ ☐	Superfluous
Irritating	☐ ☐ ☐ ☐ ☐	Likeable
Assisting		☐ ☐ ☐ ☐ ☐
Undesirable	☐ ☐ ☐ ☐ ☐	Desirable
Raising Alertness	☐ ☐ ☐ ☐ ☐	Sleep-inducing

Please let the researcher know you have finished this section.

.

U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free "Help Line" 866-367-7487
www.its.dot.gov

U.S. Department of Transportation

Research and Innovative Technology Administration