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The Effects of Motor Vehicle Fleet Daytime Running Lights (DRL) on Motorcycle Conspicuity

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16. Abstract

As a group, motorcyclists experience a high fatality rate, a significant number of which are attributable to right-of-way violations by other drivers. One factor behind the high crash rate is insufficient conspicuity of motorcycles, which is now of greater concern because of the increasing use of Daytime Running Lights (DRL) in the vehicle fleet. The hypothesis is that the additional lights on all vehicles will degrade the conspicuity of the previously unique DRL signal used by motorcycles. The main goal of the current study was to evaluate the effects of motorcycle conspicuity treatments on other drivers' left turn gap acceptance. This study was comprised of three phases. In Phase 1, a test track study measured participants' left turn gap judgment as a function of motorcycle DRL treatments. This study was designed to determine which treatments yielded the largest gaps, thereby making that treatment a good candidate for the on-road portion. No treatment was clearly better, so lighting systems currently in use on motorcycles were selected for the on-road study. In Phase 2, an on-road study measured gap acceptance, then followed up with intercept surveys of observed drivers. This phase included data collection in the United States (low fleet DRL use) and Canada (high fleet DRL use) in order to evaluate the effect of DRL use in the vehicle fleet. However, due to concerns about the comparability of the U.S. and Canadian data, the results are inconclusive, and additional research is suggested. In Phase 3, motorcycle side conspicuity treatments (retro-reflectors and marker lamp) were compared. Results indicated that there were no differences in detection distance between the treatments.

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1 Executive Summary

In 2007 motorcyclists experienced a fatality rate per vehicle mile traveled that was much higher than that for occupants of passenger vehicles (National Center for Statistics and Analysis, 2009). In 2008, just under half (47%) of all motorcycles involved in fatal crashes were involved in a conflict with another vehicle, and in two-vehicle crashes, 77% of the motorcycles were struck from the front. One analysis of fatal two-vehicle crashes involving a motorcycle and a passenger vehicle showed that 57% of these crashes occurred during the daytime (Longthorne, Varghese, & Shankar, 2007).

Researchers have hypothesized that the majority of frontal crashes are attributable to either car drivers having poor speed spacing judgment of approaching motorcycles or insufficient front motorcycle conspicuity (e.g., Olson, 1989; Olson, Halstead-Nussloch, & Sivak, 1979). Speed-spacing judgment (referred to as "left turn gap judgment" for the remainder of this document) refers to the accuracy with which a driver can estimate the distance at which it is safe to turn left at an intersection in front of an oncoming motorcycle. Conspicuity can be defined as follows: "…the degree to which an object can be distinguished from an environmental display, that is its visual prominence due to its physical characteristics" (Hancock, Wulf, Thom, & Fassnacht, 1990). While motorcycles have operated with front headlamps during the daytime for many years, many vehicle manufacturers have recently chosen to voluntarily equip passenger vehicles with daytime running lights (DRL) to increase their conspicuity. Thus, a new concern about motorcycles is whether DRL on passenger vehicles affects the conspicuity of motorcycles if other vehicles have similar lights. In particular, the concern is that motorcycles may become less noticeable because they have lost their unique identifying signature as the only vehicles with DRL. In addition, there is a possibility that drivers may become accustomed to searching for two headlamps (i.e., another passenger vehicle), and thus inadvertently "overlook" motorcycles with only one headlamp lit. Although research has shown that headlamps increase motorcycle conspicuity (e.g., Waller & Griffin, 1977), no on-road research has been conducted to determine whether increased DRL use among passenger vehicles would degrade this benefit.

This project explored the effects of different motorcycle conspicuity treatments on driver left turn gap judgment. These treatments included a modulating low beam headlamp that varies the intensity to create a flashing effect and auxiliary driving lights that are mounted on the front of the motorcycle to increase the amount of light and give a unique appearance to the motorcycle. In the United States and Canada modulating headlamps are permissible on motorcycles and are typically installed as aftermarket equipment. The objective was to determine which, if any, alternative DRL treatments might improve motorcycle conspicuity and reduce the number of unsafe gaps accepted by unalerted motorists turning left in front of an approaching motorcycle. Initial conspicuity tests were conducted on a test track, with the goal of identifying treatments that showed promise in lengthening drivers' judgments of the smallest distance at which they would feel safe to turn in front of an oncoming motorcycle. These treatments would then be tested using an on-road evaluation protocol. The results of this evaluation did not find any statistically significant differences among the conspicuity treatments. Thus, treatments for the on-road study were selected based on their prevalence in the current motorcycle fleet and the possibility that these treatments provide motorcycles with a unique signature. It was hypothesized that a unique signature would increase safety because it would help drivers to immediately identify the vehicle as a motorcycle, and therefore would allow them to make more accurate assumptions about that vehicle's behavior. These treatments were: Lower Beam (baseline), Reduced Intensity Upper Beam, Driving Lights with Lower Beam, and Modulating Lower Beam.

The project also explored whether relative prevalence of daytime running lights (DRL) on passenger vehicles would affect driver left turn gap judgment relative to oncoming motorcycles. Driver responses to an oncoming motorcycle were compared in two locations: Canada, to represent higher motor vehicle fleet DRL use, and the United States, to represent lower fleet DRL use. Canada, which has required fleet DRL since December 1, 1989, experienced a rate of DRL use of about 90 percent in the locations where the study was conducted. The United States, which has no such requirement, had a DRL use rate of about 30-50 percent measured at the study site when data were collected in 2004.

The on-road study evaluated the effects of fleet DRL use and different motorcycle conspicuity treatments on car drivers' left turn gap behaviors. This scenario attempted to replicate a common crash scenario where motorcycles have the right of way but collide with a vehicle turning left across their path at an intersection. One measure recorded the distance at which motorists turned left in front of an oncoming motorcycle (i.e., gap acceptance). A second measure was the response of the left turning drivers who were questioned after they parked to determine if they noticed the motorcycle at the intersection. This dual-prong approach was used to try to establish a relationship between the behaviors (gap acceptance) and the perceptions (interview questions) of drivers. In addition, to provide a baseline for comparison of driving patterns for the two countries, these same measurements were obtained for left turn gap acceptances for vehicles other than motorcycles.

The on-road evaluation showed that the vast majority of gaps to motorcycles are more than adequate (greater than two seconds). There were no significant differences between the accepted gaps for passenger vehicles and for motorcycles in either condition. Additional research is necessary to verify these trends because of the lack of statistical significance as well as the possibility that there may be some confounding factors between the two countries other than fleet DRL use that affected the gap differences.

2 Introduction

Motorcycle fatalities have been on the rise since 1998. In 2008, 47 percent of all motorcycle fatalities included a collision with another moving vehicle, and in two-vehicle crashes, 77 percent of the motorcycles were stuck from the front (National Center for Statistics and Analysis, 2009). In 41 percent of these crashes the other vehicle was turning left while the motorcycle was going straight, passing, or overtaking the vehicle. One analysis of fatal two-vehicle crashes involving a motorcycle and a passenger vehicle suggested that 57 percent of these crashes occurred during the daytime (Longthorne, Varghese, & Shankar, 2007). Motorcyclists have the highest fatality rate of all vehicle occupants (NCSA, 2009).

Researchers have hypothesized that the majority of frontal crashes are attributable to either poor left turn gap judgment of other motorists or insufficient front motorcycle conspicuity (e.g., Olson, 1989; Olson, Halstead-Nussloch, & Sivak, 1979; Hurt & DuPont, 1977). Conspicuity can be defined as, "…the degree to which an object can be distinguished from an environmental display, that is its visual prominence due to its physical characteristics" (Hancock, Wulf, Thom, & Fassnacht, 1991). Motorcycles by nature are less conspicuous than other motor vehicles. They are smaller in size and generally don't have large, flat surfaces that might make them more noticeable to drivers.

The recommendations from Hurt and Dupont (1977) and other researchers include using headlamps functioning as daytime running lights (DRL) during the daylight hours to increase motorcycle conspicuity. Waller and Griffin (1977) found a decrease in daytime multi-vehicle crashes immediately following the implementation of a motorcycle headlamp law in North Carolina. This reduction was seen despite an increase in overall crashes. A subsequent analysis of states with and without motorcycle headlamp laws showed 13 percent fewer daytime motorcycle crashes in states with laws (Zador, 1985).

With the increased use of DRL in the passenger vehicle fleet, however, concern has been raised about the possible unintended consequence of reduced motorcycle conspicuity. While motorcycles have operated with front headlamps during the daytime for many years, passenger vehicle manufacturers have recently chosen to voluntarily equip their vehicles with daytime running lights (DRL). Thus, a new concern about motorcycles is whether DRL on passenger vehicles would affect the conspicuity of motorcycles if other vehicles have similar lights. In part, this concern is based on the possibility that drivers may become accustomed to searching for two headlamps (i.e., another passenger vehicle), and thus inadvertently "overlook" motorcycles with only one headlamp lit. Another possibility is that motorcycles may become less noticeable because they have lost their unique identifying signature as the only vehicle type with DRL. Several organizations (e.g., the Federation of European Motorcyclists Associations, 2006) have used this hypothesis to argue against the implementation of fleet DRL use. If fleet DRL use has an impact on motorcycle conspicuity, the effect may be reduced through enhanced DRL, such as modulating headlamps and driving lights, the latter of which provide additional light output on the front of the vehicle.

Besides poor conspicuity, researchers have discussed an alternative explanation for motorcycle crashes at intersections: car drivers making left turn gap judgment errors (e.g., Mortimer & Schuldt, 1980). This error occurs when the driver sees the motorcycle, but misjudges the closing rate. Both vehicle speed and distance judgment errors could contribute to the inaccurate estimation of the appropriate gap size in which it is safe for vehicles to cross in front of oncoming motorcycles. Little research has been conducted to determine the effects of different conspicuity treatments on gap acceptance.

The goals of this effort were to:

- Determine which conspicuity treatments (of those tested) improved left turn gap judgments of other motorists.
- Determine if motorcycle conspicuity can be maintained with increased use of DRL in motor vehicle fleets.
- Determine the effects of motorcycle side conspicuity treatments on detection distance by other motorists.

3 Method

3.1 Literature Review

A literature review on conspicuity was conducted. The findings suggested that motorcycle conspicuity is significantly affected by luminance, background clutter, vehicle speed, vehicle offset, distance between vehicles, and vehicle size. These variables were considered during the design of all test series. In addition, vehicle fleet characteristics (e.g., how many motorcycles are registered in the United States and in Canada by State and Province), basic perception research on conspicuity and visual memory, and technology bulletins were reviewed for information relevant to the selection of conspicuity treatments to be evaluated. A set of conspicuity treatments (described below) was selected based on this analysis.

3.2 Apparatus: Motorcycle

In selecting a test motorcycle, motorcycle type, and its relative involvement in crashes, was considered. To determine the relative crash involvement of different motorcycle types, an internal, ad hoc NHTSA analysis was completed looking at crash rates for the different makes and models (as identified by listed displacement). This analysis found that of those motorcycles that could be identified, sport bikes constituted a relatively high proportion of fatalities. The higher rate of fatalities for sport bikes is of great concern, especially since they only represented 21% of the market share at the time of this study (Motorcycle Industry Council, 2003). Sport bikes have a smaller visual profile than other types of motorcycles. When considering the front profile, the small front fairing and windscreen are designed to be streamlined, and therefore provide minimal conspicuity. In addition, the rider's "tucked" riding position can contribute to the reduced conspicuity of sport bikes. This eliminates an important visual cue of human shape on top of the motorcycle. Because of these considerations, a sport bike was selected for use in this study.

A 2003 Honda CBR 600 F4i was selected because this motorcycle is popular in its class, shown by sales figures, and because it had sufficient electrical capacity to run the anticipated lighting components. Figure 1 shows the Honda CBR 600 F4i motorcycle selected for this program.

Figure 1. Test motorcycle: 2003 Honda CBR 600 F4i

3.3 Apparatus: Conspicuity Treatments

Seven treatments were selected for further testing:

- Modulating Lower Beam
- Dual Lower Beam
- Lower Beam + Auxiliary Parking Lamps
- Reduced Intensity Upper Beam
- Lower Beam + Fork Lights
- Lower Beam + Two White Driving Lights
- Lower Beam (Baseline Condition)

Three of these treatments – Lower Beam, Modulating Lower Beam, and Lower Beam + Two White Driving Lights – were selected because of their prevalence on the roadways. Reduced Intensity Upper Beam was modified from the stock Upper Beam, which is also widely used by motorcyclists, to reduce glare. The other treatments were selected as more progressive alternatives to what is typically used. Researchers examined treatments for compliance with

Federal Motor Vehicle Safety Standard 108 (FMVSS 108) and, if applicable, SAE standards. Researchers also explored feasibility of implementation, cost, and user acceptance.

Table 1 below describes details of each of the conspicuity treatments, including the aftermarket component price at the time of the testing. Figures 2 through 8 provide illustrations of the treatments implemented on the motorcycle. Details of the luminous intensity measurements of each treatment are shown in Appendix A.

Table 1. Conspicuity treatments details

Conspicuity Treatment	Modification Specification	Treatment Cost	Reference (SAE or FMVSS)
Modulating Lower Beam	55W sealed beam halogen upper /lower beam headlamp in center position at stock height. Modulator unit cycles headlamp 4 cycles per second from 70% to 100% intensity.	$90	FMVSS 108 S7.9.4.1
Dual Lower Beam	Dual 55W sealed beamed halogen upper/lower beam headlamps horizontally disposed 5.75 inches about vertical centerline. Lamps comprise two outer lamps of three-lamp system.	$37	SAE J584 FMVSS 108 S7.9.6.2
Lower Beam with Auxiliary Parking Lamps	Center mounted lamp used as lower beam. Each of the two Enhanced Parking Lamps consists of a 23W incandescent bulb with a 71 cm^2 projected area amber lens. Enhanced parking lamps horizontally disposed 11.5 inches about vertical centerline.	$10	SAE J584 FMVSS 108 S7.9.6.2
Reduced Intensity Upper Beam	Center mounted lamp used as upper beam. A variable voltage regulator restricts light output of upper beam at its brightest point to no more than 3000cd.	$15	No reference
Lower Beam with Fork Lights	Center mounted lamp used as lower beam. Mounted vertically on each fork tube, 29 amber color LEDs were evenly distributed over a 220mm long strip, 5mm diameter (19.625 mm^2 projected luminous area per LED. Lights horizontally opposed 4 inches about the vertical centerline of motorcycle. Total of 58 LEDs used.	$120	SAE J1889
Lower Beam with Driving Lights	Center mounted lamp used as lower beam. Two 50W white halogen upper beam auxiliary lamps added, horizontally disposed 10.75 inches about vertical centerline, close to horizontal centerline of headlamp.	$50	SAE J582
Lower Beam (Baseline)	Center mounted lower beam used.	$0	SAE J131

Figure 2. Modulating lower beam

Figure 3. Dual lower beam

Figure 4. Lower beam with auxiliary parking lamps

Figure 5. Reduced intensity upper beam

Figure 6. Lower beam with fork lights **Figure 7. Lower beam with driving lights**

Figure 8. Lower beam (baseline configuration)

The treatment concept development included a measurement of the luminous intensity for each configuration. This step was critical in that FMVSS 108 specifies the luminous intensity for various lights on motor vehicles. The concepts developed and tested in this program were similar to what was described in FMVSS No. 108. Each of the treatments developed in this task were tested to the applicable FMVSS or Society of Automotive Engineers (SAE) standards. For comparison, the reference vehicle (a sedan) was also measured. The value and location of the maximum luminous intensity for each treatment is shown in Table 2.

Table 2. Maximum luminous intensity of conspicuity treatments

Conspicuity Treatment		Maximum Luminous Intensity (cd)	Location of Maximum Luminous Intensity	
			Angle (Deg) Left/Right	Angle (Deg) Up/Down
Lower Beam – Reference Vehicle (sedan)		31,680	0	1D
Lower Beam – Motorcycle		5,043	5R	1D
Reduced Intensity Upper Beam		2,881	5R	0
Modulating Lower Beam	Maximum	1,441	5R	1D
	Minimum	360	5R	1D
Dual Lower Beam		5,407	0	2D
Lower Beam with Driving Lights		7,562	0	1D
Lower Beam w/Auxiliary Parking Lamps		3,602	5R	1D
Lower Beam w/ Fork Lights		4,683	5R	1D

4 Test Track Evaluation of Conspicuity Treatments on Left Turn Gap Acceptance

The test hypothesis was as follows: one or more of the test treatments would result in participants accepting a significantly larger gap than the others. That treatment would then be selected for the on-road evaluation.

4.1 Procedure

The tests in this series were performed on a test track. The full experimenter protocol is shown in Appendix B. Three experimental vehicles were used in this evaluation. The first was the motorcycle, instrumented with the treatments described above. The second was a reference vehicle, a sedan, which was used as a baseline condition. The third was the vehicle for the participant to sit in.

The test area was configured as a four lane (two lanes in each direction) four-way intersection. The instrumented participant vehicle was placed at the intersection in an opposing traffic lane adjacent to the path of the motorcycle. The test subject was placed in the participant vehicle to observe the approaching motorcycle or sedan. During these tests the same motorcycle and rider were used for all subjects.

The speed (either 25 or 45 mph) and position of the motorcycle/reference vehicle on the test track were monitored and recorded using two radar systems. The radars were placed in the adjacent travel lane to the motorcycle to permit tracking of the motorcycle from the start of the test to the point where the motorcycle passed the subject seated in the participant vehicle. The test subject could clearly see the motorcycle throughout the approach. Ambient lighting condition at the time of the tests was measured and recorded. Illuminance levels during this testing ranged from 2,300 to 10,500 foot-candles.

Subjects for this program task were 25 volunteers who were recruited through their workplace. Subject selection criteria included: current driver's license, never having ridden a motorcycle, minimum 20/40 natural or corrected vision (as determined using a Snellen Eye Chart), and not color blind (as determined from Ishihara Test for Color Blindness). The complete list of screening questions is shown in Appendix C. The subjects' age range was 25 to 64 years with a mean of 39.2 years. Participants read and signed an informed consent form (shown in Appendix D). After the subject screening was completed, subjects were driven to the test track to participate in the test program.

Subjects were seated in the driver's seat of the participant vehicle. The test engineer in the vehicle asked subjects to fasten the seat belt. The test engineer reviewed the test instructions and addressed any concerns the subject had.

To initiate the test, the motorcyclist/driver took a position in the opposing travel lane 700 feet (213.3 meters) away from the subject. The test engineer signaled the rider/driver that the data acquisition system was active. The motorcyclist/driver accelerated to the test condition speed – either 25 or 45 mph – and proceeded toward the test vehicle. The subject pressed a button mounted on the steering wheel when they estimated that the vehicle was at the "last safe distance" at which the subject would be able to begin a left turn in front of the motorcycle.

The data from the two radars and the subject input were recorded and stored on a data acquisition system in the instrumented automobile. Typical data from a test is shown in Figure 9. Note that once it attained the target speed, the vehicle velocity was constant. The subject input is superimposed on the distance and speed data.

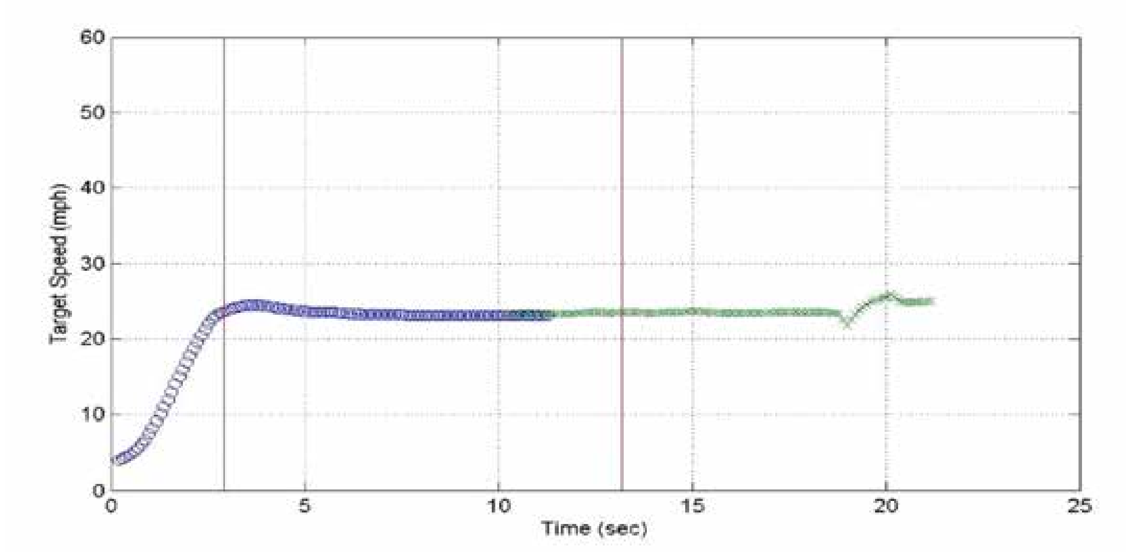

Figure 9. Typical range and velocity data from speed-gap test series

Video of the approaching vehicle was digitally recorded to document any discrepancies during the tests. For each subject, each of the seven motorcycle lighting treatments and the reference car (without DRL) were repeated twice at both of the test speeds, yielding a total of 32 tests per subject. The order of the conspicuity treatments and speed was partially counterbalanced across subjects. After testing, subjects ranked the seven conspicuity treatments and the baseline from highest to lowest conspicuity. This methodology was an adaptation of a method used in other research efforts (e.g., Stroud, Kirkby, & Fulton, 1980; and Nagayama, Morita, Miura, Watanabe, & Murakami, 1980). At the end of the session, participants completed an exit interview about their experience (shown in Appendix E).

4.2 Results

The distance that the driver indicated was the last safe point to make a left turn in front of the motorcycle was used as an estimate of collision risk, with greater distances indicating lower risk. Given the effects of speed on driver perception, time at which the driver indicated was the last safe point at which to turn in front of the motorcycle was also used as an estimate of collision risk, with longer times indicating lower risk. Time to collision is a common estimate of collision risk (e.g., Skarr, Rizzo, & Stierman, 2002). In addition, speed estimate errors (and by inference time to arrival estimates) increase with speed (Fildes, Leening, & Corrigan, 2005).

Examination of the dataset revealed several issues. The first was an incomplete counterbalancing for presentation order. The second was unequal cell size for the gap acceptance – as many as 7% of the observations were missing for any one condition. While this was adjusted for in the analyses, it still implies some potential deficiencies in the data quality. The interpretation of the results must be conservative because of these issues. The results are presented below.

In addition to speed and headlight treatment, replication was used as a third independent measure. Replication referred to the time (first or second) the participant was exposed to the exact treatment/speed combination. Because the participant saw each combination twice, but in a randomized order, this variable was recorded. Table 3 below shows the results of the ANOVA.

Table 3. ANOVA of test track data

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Replication	1	3778.5495	3778.5495	0.94	0.3334
Speed	1	403281.7436	403281.7436	99.98	<.0001
Treatment	7	191618.9066	27374.1295	6.79	<.0001
Replication *Speed	1	7496.2360	7496.2360	1.86	0.1732
Replication *Treatment	7	5703.8806	814.8401	0.20	0.9850
Speed*Treatment	7	11549.1303	1649.8758	0.41	0.8970

Two effects – Speed and Treatment – were significant (p <.0001). Figure 10 below shows the relationship for speed (p <.0001). As expected, the higher speed (45 mph) yielded larger gap distances.

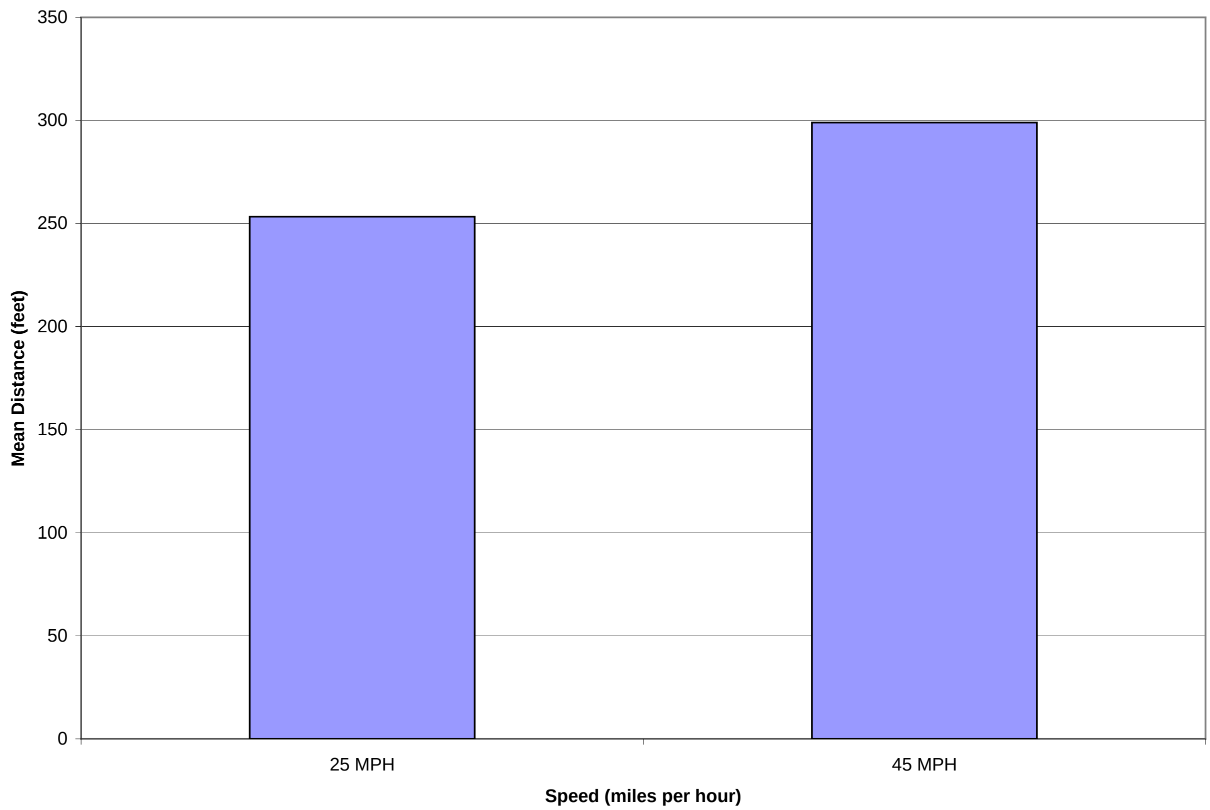

Figure 10. Mean gaps by reference vehicle speed

A post-hoc test (Scheffe's) determined the statistically significant gap between the Reference Vehicle (mean gap 314.8 feet) and all motorcycle treatments. Figure 11 below shows the relationship for the conspicuity treatments (p < .0001). On average, shorter gap distances were given to all of the motorcycle treatments than to the reference vehicle, but there were no significant differences between the motorcycle treatments.

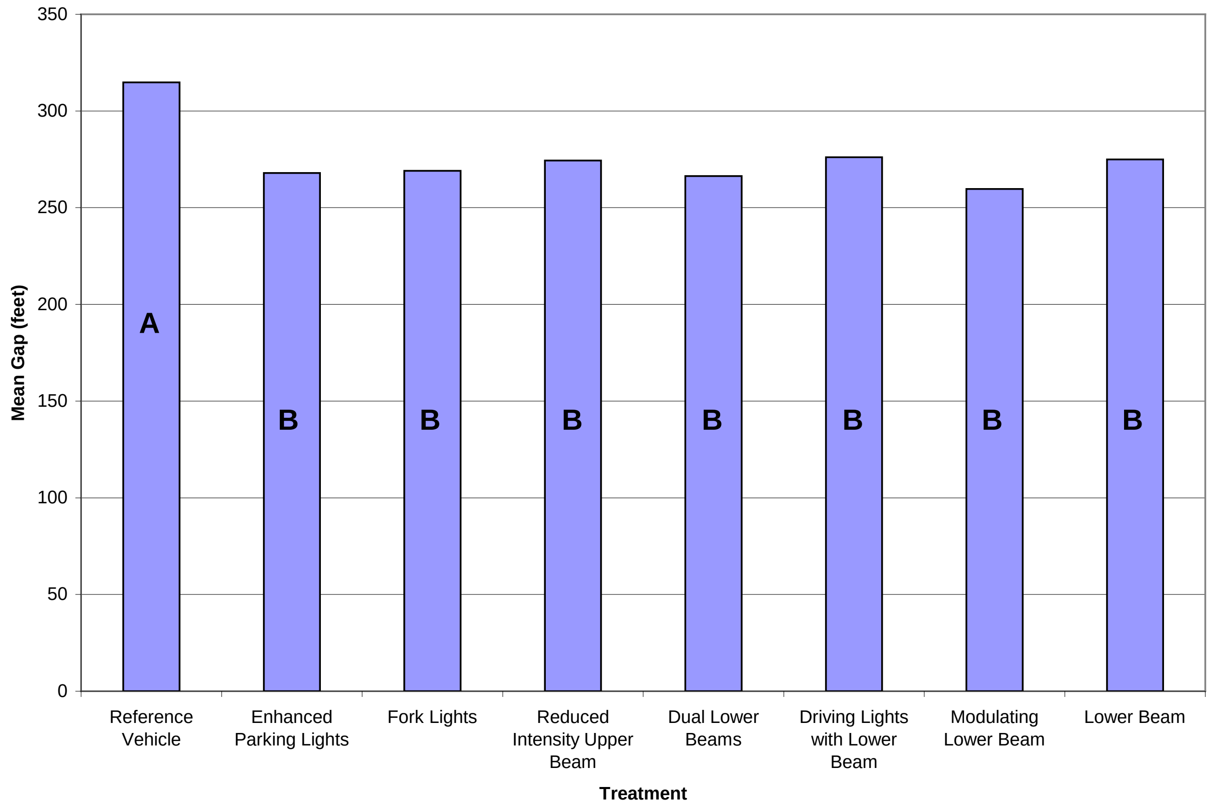

Figure 11. Mean gap by conspicuity treatment for the test track study

4.3 Conclusions

The main purpose of this portion of the research was to determine relative differences between conspicuity treatments. It was thought that if one clearly performed better (i.e., facilitated larger gaps) it would be selected for the on-road portion of the study. In fact, no one motorcycle treatment performed consistently better than the others.

It should be noted that the gap distances were very large. Several factors may explain this finding. First, the participants were fully alert and focused on the primary task, whereas in the driving environment they would be sharing their attention among many stimuli. It is reasonable to expect larger distances than what would be seen in the real world. Second, the participants were indicating when they would initiate the turn, whereas other evaluations (including the on-road evaluation that follows) measured the distance once the participant was "committed" (had actually initiated the turn). The latter would be a much shorter time completing the turn. Third, there may have been some visual cues in the background that participants learned to use as landmarks to estimate distances.

Because no treatments were clearly better, three treatments were selected for the on-road portion based on the frequency with which riders voluntarily implement the treatments on their motorcycles. The treatments were: Reduced Intensity Upper Beam, Driving Lights with Lower Beam, and Modulating Lower Beam. Lower Beam was selected as the baseline condition.

5 On-Road Evaluation of Driver Reactions to Motorcycle Conspicuity Treatments in the United States and Canada

In this on-road test series, four of the previously developed and evaluated conspicuity treatments were used to study driver gap acceptance when making left turns in front of oncoming motorcycles. The first research question was which conspicuity treatment resulted in the longest gap. The second research question was whether the treatment would be effective across two levels of fleet DRL. To assess this issue, this test series was performed in the United States and Canada during 2005. This methodology permitted an evaluation of the drivers' responses to motorcycle conspicuity treatments in an environment with a high penetration of passenger fleet DRL (Canada) and with a relatively low penetration of DRL (United States). This evaluation consisted of two parts – a gap acceptance of unalerted drivers, and a follow-up interview of the same drivers.

One test hypothesis was that one or more of the enhanced conspicuity treatments would induce motorists to turn left in front of the oncoming motorcycle at longer distances compared to the standard low beam. The other test hypothesis was that all conspicuity treatments would maintain effectiveness (as measured by gap acceptance) in both levels of fleet DRL concentration. In the previously described test track study none of the enhanced conspicuity treatments was associated with significantly different gap acceptance as compared to the baseline (low beam) condition. However, the greater visual complexity provided by an active roadway and the potential for a crash in the real driving situation may influence drivers gap acceptance behavior.

5.1 Method

The gap assessment method was similar to that used by Olson et al. (1979): data were collected in real traffic, where the instrumented motorcycle drove through an intersection where unalerted drivers could turn left across its path. The gap size was then recorded. Proponents of this methodology cite the fidelity of attaining a behavioral measure: because the data are collected in the driving environment the safety implications are more directly measured.

An observation of gap acceptance does not provide insight to the variables that influenced the driver's gap acceptance. To address this issue, researchers conducted interviews with the drivers who turned left in front of the experimental motorcycle. This interview was designed to determine what elements drivers detected from the traffic scene. This method is similar to that used by Janoff, Cassel, Fertner, and Smierciak (1970). Critics of this methodology cite the potential for errant reporting because the task requires not only detection of the motorcycle but also storage to and retrieval from memory of this detection. Previous research results showed that recall was reduced in poorer visibility and more dense traffic scenarios, which is representative of real-world conspicuity.

The testing locations used in this series were two shopping malls located in suburban Buffalo, New York and London, Ontario. During this test series, automobiles with Canadian license plates were excluded from data analysis at the United States site; conversely, automobiles with U.S. plates were excluded from data collected in Canada.

5.1.1 United States Site Design

Unalerted drivers were observed making a left turn in front of the test vehicle. To record the gap that each driver accepted, recording equipment was set in a parking lot with an unobstructed view of the roadway, including the section of road leading up to the intersection. A controlled area (the parking lot) was used to interview the drivers who had made the left turns in front of the test vehicles.

Measurement of the motorcycle-to-subject vehicle gap distance in the United States was accomplished using a MiniDV digital camcorder to record the approach of the motorcycle to the intersection. The camcorder was mounted on a tripod and was placed perpendicular to the roadway. The camera was set up at a fixed location, such that the entire intersection and length of the subject vehicle approach were captured on the right side of the field of view. The left extent of the field of view captured approximately 235 feet downrange of the intersection. Two red reflective 10 inch diameter barrels were placed 10 feet apart as close to the center of the field of view as possible and approximately 4 feet from the road. These barrels served as targets to mark off a known distance in the field of view.

The use of a confederate "background" vehicle protected the motorcycle rider from other motorists and provided a controlled, consistent background to the test subjects. In the United States, the background vehicle did not have DRL – this was consistent with the majority of vehicles on the road at the time of data collection. The camera operator began taping before the motorcycle entered the field of view and stopped taping when the background vehicle exited the right side of the field of view. A photograph of the test intersection along with the motorcycle and background vehicle is shown in Figure 12.

Figure 12. Side view of test scene – U.S. test site

The test site was a junction left intersection, as observed by the uninformed driver, controlled by a phased signal with protected phase green arrow. The signal phase went from red to protected (green arrow) to green in both directions. Measurements were taken only during the phase when the signal was green in both directions. The roadway leading to the intersection was a four-lane road (two lanes in each direction). The motorcycle traveled straight in the left lane toward the unalerted driver, providing an opportunity for the driver to execute a left turn in front of the motorcycle. The posted speed limit is 35 mph, but the motorcycle traveled an average speed of 30 mph.

The motorcycle and background vehicle approached the test site giving the test subject (i.e., unalerted driver) 235 feet of unobstructed viewing distance of the vehicles. Figure 13 shows the view of the roadway, the approaching motorcycle, and background vehicle as they would be seen by the driver.

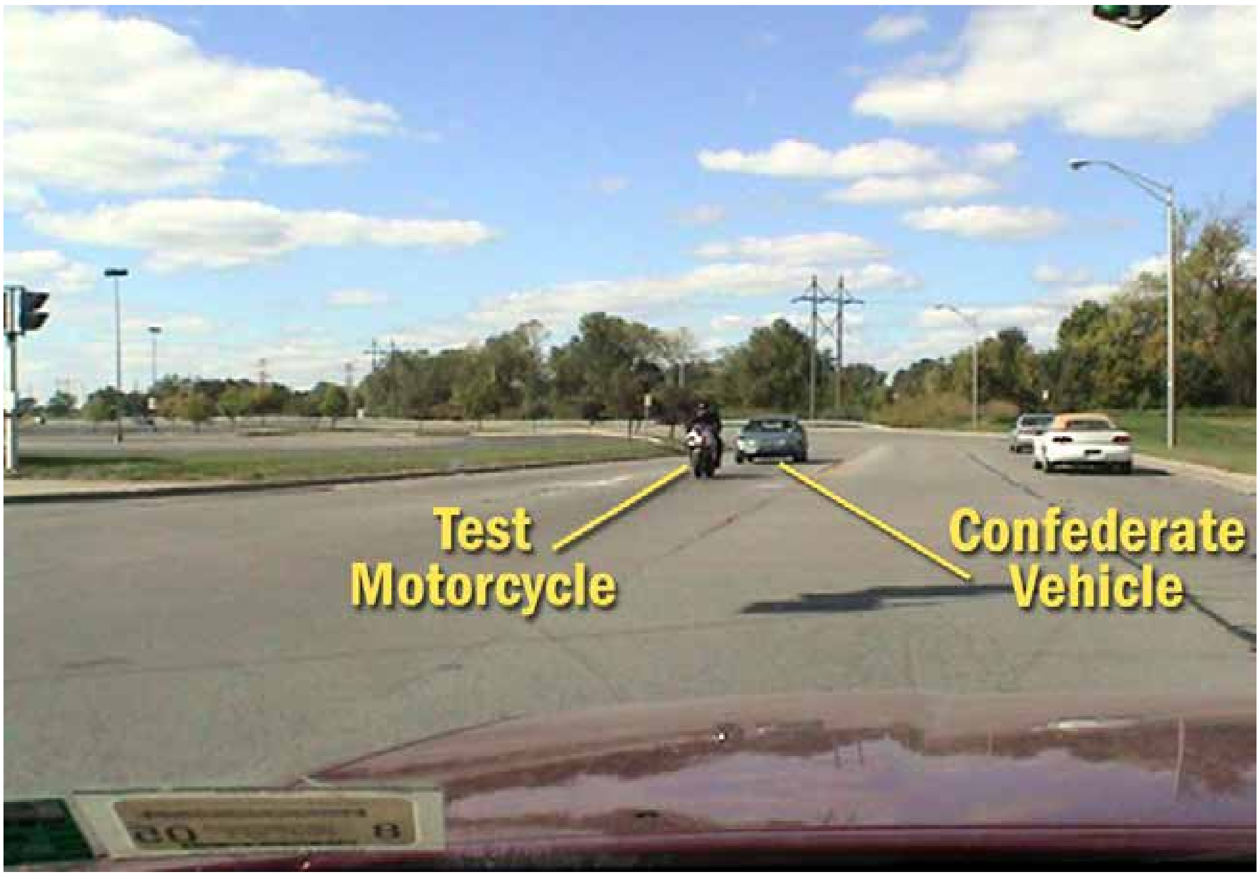

Figure 13. Test subject's (i.e., unalerted driver's) perspective – U.S. test site

5.1.2 Canada Site Design

A mall in London, Ontario was used as a comparison site. This intersection was very similar in design to the U.S. location. Consistent with the U.S. site, the contractor team obtained the cooperation of the mall security force to approach and interview the test participants.

The test site was a junction left intersection (as observed by the uninformed driver) controlled by a signal with protected phase (green arrow) followed by a permitted phase. The roadway leading to the intersection was a four-lane road (two lanes in each direction). The speed limit in this area is 50 kph (~ 31 mph); however the motorcycle traveled at an average speed of 30 mph. Figure 14 shows the view of the roadway, approaching motorcycle and background vehicle as they would be seen by the driver. The background vehicle used DRL at the Canadian site.

Figure 14. Test subject's (i.e., unalerted driver's) perspective – Canadian test site

Because of roadside obstructions at the Canadian site, data collection was conducted using an on-board camera system on the motorcycle. This system consisted of forward and side looking cameras and video recording equipment. Testing of the system for gap measurements indicated that this system was capable of accuracies equal to that in the U.S. tests.

Two pencil cameras were mounted on the test motorcycle: one facing forward on the front of the motorcycle and the other facing 90 degrees to the right on the rear of the motorcycle. The camera images were fed into a multiplexer that displayed the two images on one screen. The output of the multiplexer was fed into a digital MiniDV camcorder. Similar to the U.S. testing, videotaped encounters were matched up to the corresponding interviews. The videotape was reviewed and a digital video still was captured at the moment at which the driver making the left turn committed to the turn and their vehicle grill made a 45-degree angle to the roadway. Photos of the cameras mounted on the motorcycle are shown in Figures 15 and 16.

Figure 15. Side looking camera - Canadian test site

Figure 16. Forward looking camera - Canadian test site

5.1.3 Procedure

The test motorcycle, configured with one of four conspicuity treatments (Lower Beam, Driving Lights with Lower Beam, Reduced Intensity Upper Beam, or Modulating Lower Beam) traveled in the left travel lane, followed by the confederate vehicle. A mall security vehicle was stationed near the camera.

The following procedures were followed to collect data during this road study:

- The motorcycle rider and background vehicle driver positioned themselves in a safe area in the mall parking lot with easy access to the roadway.
- The observer and the mall security guard positioned themselves with a clear view of the intersection and traffic signal. They were also positioned so they could follow the driver to their parking spot.
- When the test crew was ready, the motorcycle and background vehicle driver entered the roadway, based on the timing of the light and travel time of the motorcycle and background vehicle from their staging position. They usually entered the roadway when the signal had phased beyond the protected turn phase. This created a condition of free flowing traffic where the driver would need to exercise a judgment of gap distance and speed.
- After leaving the staging area, the motorcycle and background vehicle were positioned in the left lane and traveled between 25 and 30 mph. The background vehicle followed the motorcycle, maintaining a distance between two and five car lengths.
- As the motorcycle and background vehicle left the staging area, the camera operator began video recording. Recording was stopped after the motorcycle and background vehicle cleared the intersection.
- The observer and security guard waited until a vehicle completed its left turn in front of the motorcycle. When a vehicle performed the turn, the type and color of the vehicle were noted and the security guard and the researcher followed the vehicle to a parking spot. When the driver had safely pulled into a parking spot and before they walked away from the vehicle, the guard and the researcher approached the driver and used a standard dialogue (see Appendix F). The drivers who participated in the interview were given a $5 gift certificate to use at the mall.

In the passenger vehicle gap acceptance series the same video set-up was used. No interview of the turning drivers was performed. Vehicle type and gap were recorded for each maneuver.

5.1.4 Gap Data Reduction

5.1.4.1 United States site

Gap measurements (n = 237) were post-processed using the interview form as an indicator of the motorcycle-car encounter time. When an encounter of interest was identified on the tape, a 640 x 480 digital snapshot of the encounter was recorded using a built-in feature of the camcorder. This snapshot was taken when the driver had committed to taking the turn and the nose of the vehicle roughly made a 45-degree angle to the roadway.

The snapshot was then loaded into Microsoft® Photo Editor. Photo Editor shows the pixel position of the cursor as it hovers over the image. Four horizontal pixel positions were recorded:

the center of each red barrel target, the center of the driver's vehicle grill and the headlight on the motorcycle. Each of these measurements was recorded into a spreadsheet. By dividing 10 feet by the number of pixels between the targets, a foot per pixel value was generated. Multiplying this value by the pixel difference between the motorcycle and the turning vehicle yielded the distance between the vehicles in feet. This process was repeated for every video capture to control for incidental camera movement.

Prior to the on-road testing, the image-processing technique was tested using known distances at the extents of the field of view as well as comparing the actual and computed distances across the entire field of view. The image processing technique was found to be accurate to approximately 3 feet.

5.1.4.2 Canada site

The methodology for the Canadian testing differed in that the test site did not have a clear line of sight from the parking lot to the roadway and intersection, so the technique used in the U.S. could not be implemented. Instead, the Canadian site had a mass row planting of trees between the sidewalk and parking lot. The locations of each of these trees and other permanent stationary objects were measured from the intersection center.

The data reductionist determined the measurement plane for the right-looking camera by studying the relation of the expansion joints in the sidewalk to the camera image. If an expansion joint was vertical in the video still image, this position was considered to be the plane perpendicular to the motorcycle. This horizontal pixel position was used as the point of measurement for the motorcycle's roadway location. If this measurement plane lined up with one of the trees or landmarks on the roadside, the distance of the tree from the intersection was known and thus the distance of the motorcycle from the intersection was known. If the measurement plane fell between two landmarks then their pixel distance in view divided the actual distance between the two landmarks, and this value was used to determine the motorcycle's offset distance from one of the landmark actual distances.

This method was used for all gap measurements for the motorcycle (n = 187) during the main data collection. For the passenger vehicle data collection, access to the mall roof was granted and a remote camera was positioned to record intersection encounters. Gap measurements for passenger vehicles (n = 170) were determined using the technique identical to the one used in the U.S. gap measurements.

5.2 Vehicle, Daytime Running Light (DRL) Populations in Both Countries

Left turn gaps to oncoming passenger vehicles were used as a baseline condition to compare to left turn gaps to motorcycles. To determine the gaps afforded to non-motorcycle traffic – including type of vehicle and gap size – data were collected for passenger vehicles (i.e., sedans, minivans, and SUVs) making left turns in front of other (non-experimental) vehicles. The population of oncoming vehicles in that data is shown in Table 4.

Table 4. Country by oncoming traffic vehicle population (for baseline data)

	Oncoming Traffic			
Country	**SUV**	**Sedan**	**Minivan**	**Total**
Canada	33 (19.41%)	116 (68.24%)	21 (12.35%)	170 (100%)
US	32 (18.39%)	113 (64.94%)	29 (16.67%)	174 (100%)
Total	65	229	50	344

A Chi-square analysis did not yield a significant difference between the populations (χ^2 (2) = 1.28, p = 0.52). Thus the mix of vehicle types in the oncoming traffic was comparable between data collection venues.

To assess the effect of fleet DRL on motorcycle conspicuity, an observational study was performed at both test locations to determine the percentage of vehicles operating with DRL in each site. Since DRL have been standard equipment on vehicles in Canada since 1987, it was expected that there would be a very high prevalence there. In the United States implementing DRL is optional, and only some of the manufacturers have elected to do so; therefore, the rate of DRL use in the US sample was expected to be relatively low.

The observational studies were performed at the same locations as the motorcycle tests – shopping malls in Buffalo, NY and London, OT. Because this was only to sample the level of DRL use in each country, no effort was made to control for vehicle type or other demographic information such as driver age or gender. Two types of DRL were observed in the U.S. One configuration of DRL illuminated the turn signals, and is termed “amber DRL.” The other configuration illuminates the headlamps, and is termed “white DRL.” The latter is standard equipment on vehicles sold in Canada. The results of the observation study are shown in Table 5.

Table 5. Observed use of DRL in Canada and United States

Country	All Vehicles	DRL Type	DRL Equipped Vehicles	Percentage of Total
Canada	267	White DRL	250	93.6%
United States	240	White DRL	93	38.7%
		Amber DRL	21	8.7%

Note that in Canada the prevalence of DRL at the test location was 93.6 percent. Those vehicles not equipped with DRL were generally older vehicles manufactured prior to the requirement. In the United States the sample of white DRL (similar to those in Canada) was 38.7 percent. An additional 8.7 percent of the US vehicles had amber DRL.

5.3 Results

5.3.1 Which Treatment Yields the Safest Gap?

To determine the most effective treatment in eliciting larger gaps, an analysis of variance (ANOVA) was performed for the motorcycle gaps observed by country. The independent variables were conspicuity treatment (four levels) and country (two levels). The results are presented in Table 6. The effect of country was significant (p = 0.0001), but the effects of conspicuity treatment and conspicuity treatment by country were not. Figures 17 and 18 below show the mean, maximum, and minimum gap distance for each conspicuity treatment in the United States and Canada, respectively.

Table 6. ANOVA for gap by conspicuity treatment

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Country	1	17310.01	17310.01	15.03	0.0001
Conspicuity treatment	3	2018.33	672.78	0.58	0.6256
Conspicuity treatment * Country	3	7149.08	2383.03	2.07	0.1036

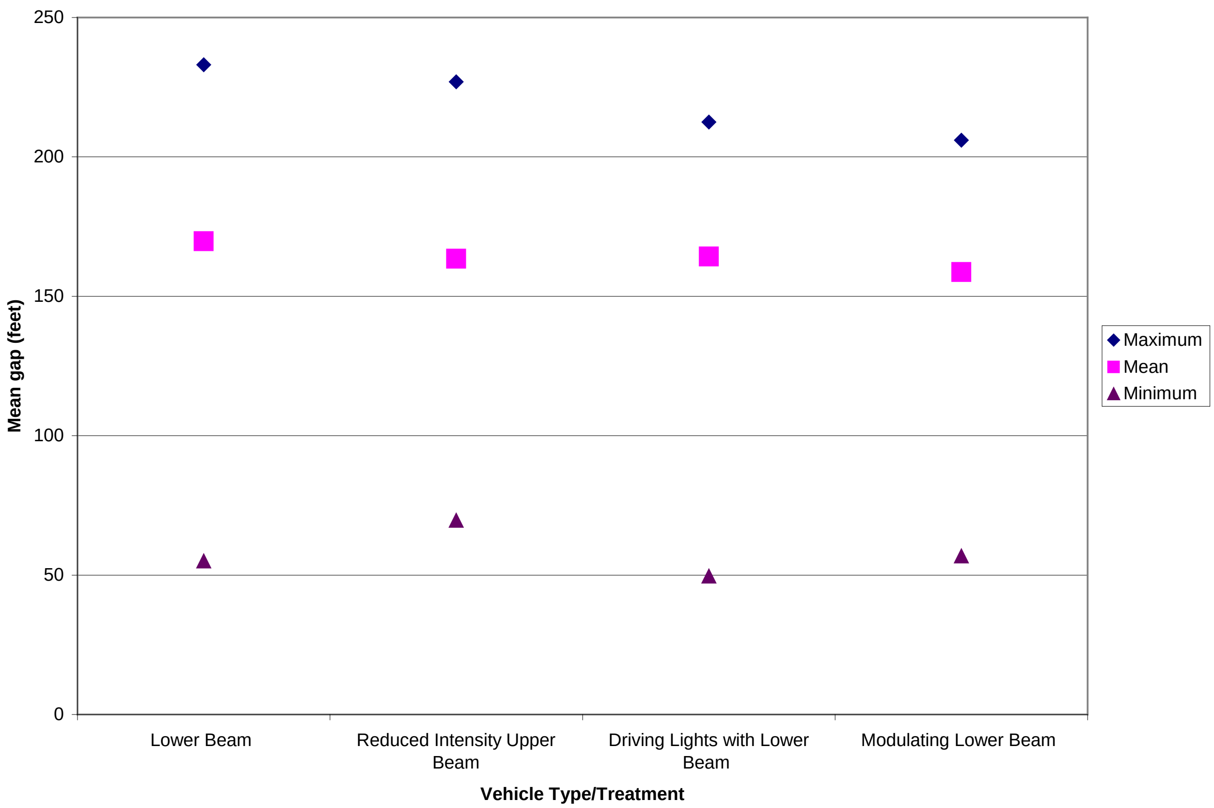

Figure 17. Mean, maximum, and minimum gap (in feet) for all traffic by motorcycle treatment – United States

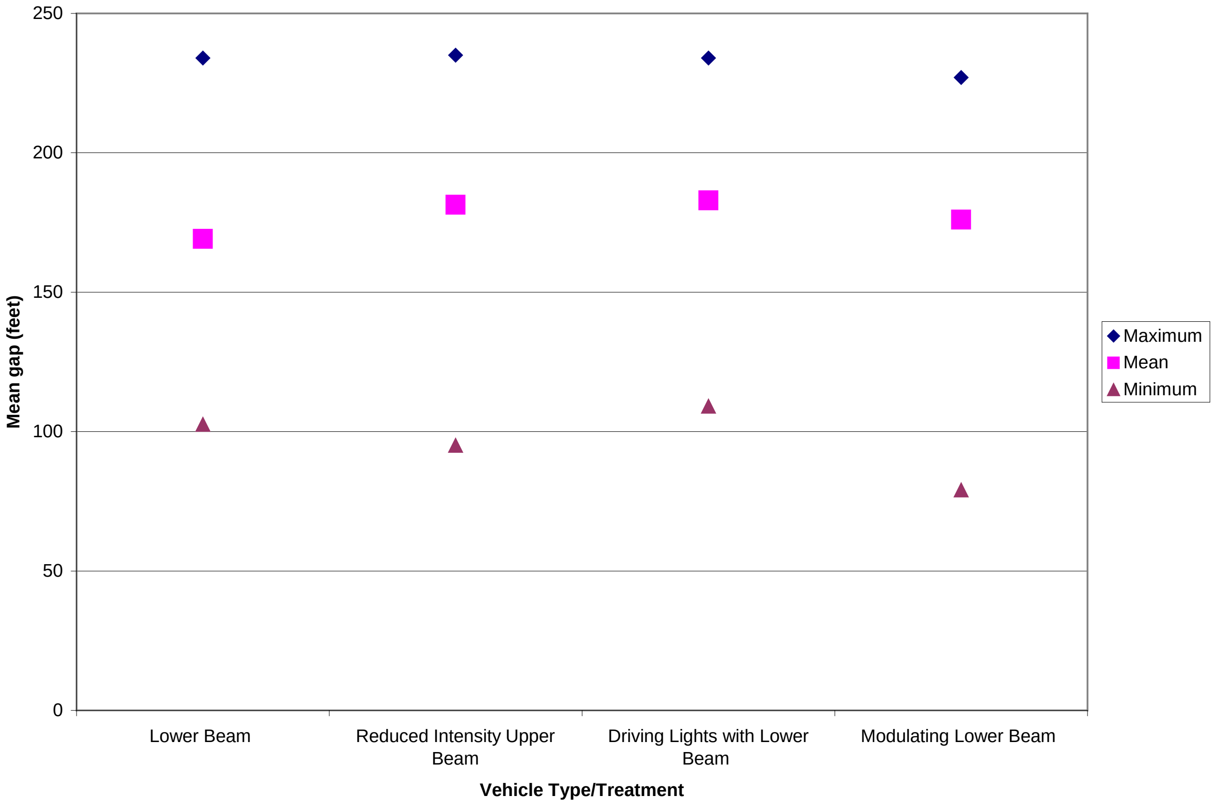

Figure 18. Mean, maximum, and minimum gap (in feet) for all traffic by motorcycle treatment - Canada

Based on previous research, crashes with traffic were not anticipated (e.g., Olson et al., 1979). Therefore, the Traffic Conflicts Technique (TCT) was implemented to evaluate the shortest gaps for relative crash risk. As summarized by Campbell, Joksch, and Green (1996), this method, originally adopted to monitor intersections, uses the rate of conflicts to estimate the overall crash risk. This effort is concerned with gaps less than two seconds, which provides a conservative estimate. Table 7 depicts the percentage (and number) of gaps in seconds for each treatment in the United States. It should be noted that short gaps (i.e., 2 seconds or shorter) were infrequent with a maximum of 3 observations for only one condition with that gap size. It is important to note that the differences between treatments are not statistically reliable.

Table 7. Percentage of gaps by treatment and gap size in seconds – United States

	Gap (seconds)		
Treatment	**0-1 s**	**1-2 s**	**>2 s**
Lower Beam	0% (n=0)	3.0% (n=2)	97.0% (n=64)
Reduced Intensity Upper Beam	0% (n=0)	3.0% (n=2)	97.0% (n=63)
Driving Lights with Lower Beam	0% (n=0)	1.8% (n=1)	98.2% (n=55)
Modulating Lower Beam	0% (n=0)	6.0% (n=3)	94.0% (n=47)

Table 8 depicts the percentage (and number) of gaps in seconds for each treatment in Canada. Short gaps (i.e., 2 seconds or shorter) were observed only one time.

Table 8. Percentage (number) of gaps by treatment, gap size in seconds – Canada

	Gap (seconds)		
Treatment	**0-1 s**	**1-2 s**	**>2 s**
Lower Beam	0% (n=0)	0% (n=0)	100% (n=49)
Reduced Intensity Upper Beam	0% (n=0)	0% (n=0)	100% (n=50)
Driving Lights with Lower Beam	0% (n=0)	0% (n=0)	100% (n=44)
Modulating Lower Beam	0% (n=0)	2.3% (n=1)	97.7% (n=43)

Based on the analyses above, no treatment was clearly better than the others. The brief interviews conducted with drivers after they parked revealed that approximately 80% of drivers in both countries remembered seeing a motorcycle as the vehicle they turned in front of. This suggests that the differences in respective prevailing conditions (including different previous exposure to DRL and presence/absence of DRL on background vehicle) had no significant effect on drivers' recollection of the type of vehicle encountered. There were no differences between individual conspicuity treatments in terms of the likelihood that the driver correctly identified the type of vehicle of which they turned in front. The interview data are described further in Appendix G.

5.3.2 Are the Treatments Effective Across Different Levels of Fleet DRL?

To attain a better understanding of the typical driving behaviors for each country and to have a common basis for comparing U.S. and Canadian drivers' responses to oncoming motorcycles, gap measurements were collected for passenger vehicles (i.e., sedans, minivans, and SUVs) making left turns in front of other (non-experimental) vehicles. An ANOVA was run to determine whether there was a difference between the gaps for passenger vehicles and the four motorcycle treatments, and the ambient light level. Table 9 below shows the results of the ANOVA. The variable Traffic/Treatment Type represents the data from the different conspicuity treatments and the passenger vehicles.

Table 9. ANOVA of gaps afforded to other traffic, test motorcycle

	DF	**Type I SS**	**Mean Square**	**F Value**	**Pr > F**
Country	1	84847.22	84847.22	68.41	<.0001
Traffic/Treatment Type	4	20614.76	5153.69	4.16	0.0025
Country* Traffic/Treatment Type	4	26355.90	6588.97	5.31	0.0003

The main effect of Country ($p<0.0001$) was significant, that is the measured gaps in Canada were different than those measured in the U.S. For the test conditions provided in this study, Canadians on average provided larger gaps than their American counterparts regardless of the traffic/treatment type (178 feet and 156 feet, respectively).

The effect of Traffic/Treatment Type was also significant ($p=0.0025$), meaning that the average gap measured for some of the treatments were different. The means are represented in Figure 19 below.

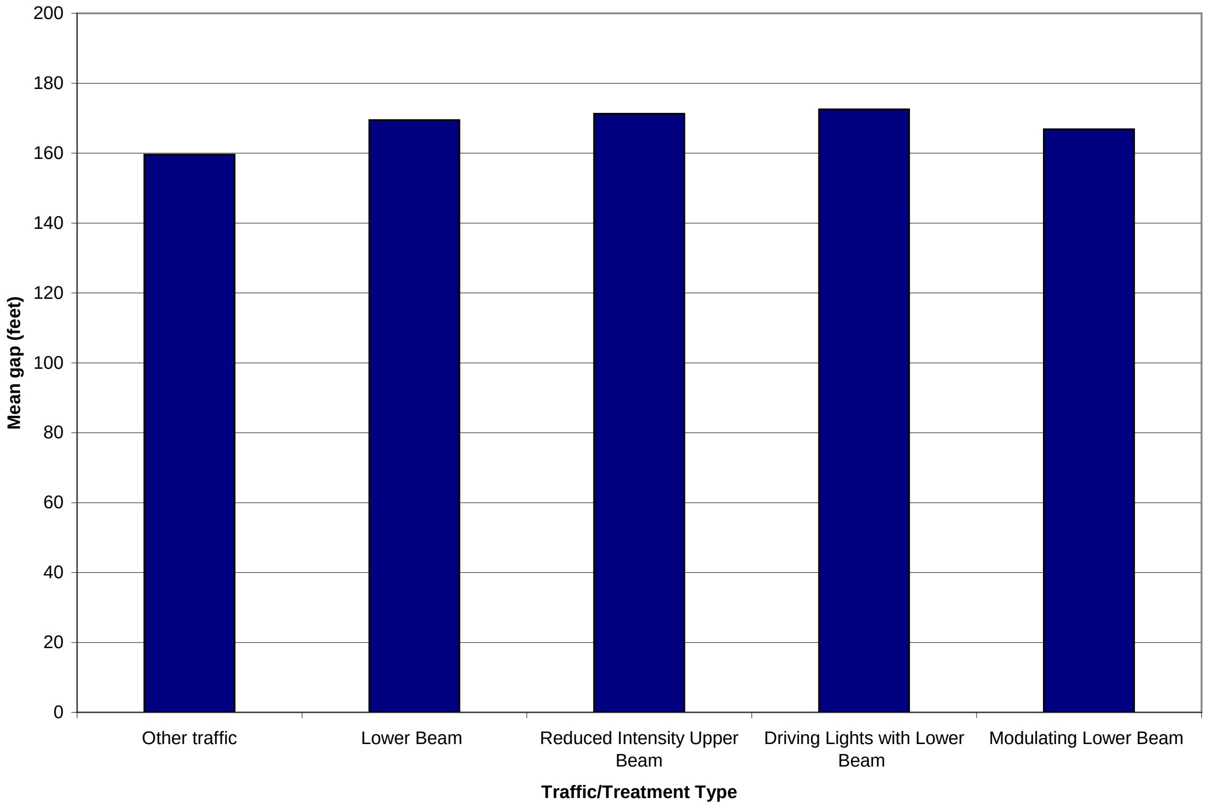

Figure 19. Mean gap (in feet) for all traffic and conspicuity treatments

The interaction of Country and Traffic/Treatment was also significant ($p = 0.0003$), meaning the measured gaps in each country were affected by the treatment. Figure 20 represents this interaction. Note that the "Other Traffic" category includes the observations of normal traffic. The category includes left turns in front of sedans, minivans, and SUVs (other types of vehicles, including commercial vehicles, were excluded due to small number of observations). Across all vehicle types, Canadians provided larger gaps, and the largest divergence was for the Other Traffic type (average gap of 145.1 feet for American drivers and 179.1 feet for Canadian drivers). Canadians typically provided apparently comparable average gaps for motorcycles when compared to other traffic, whereas Americans consistently provided slightly longer gaps for motorcycles.

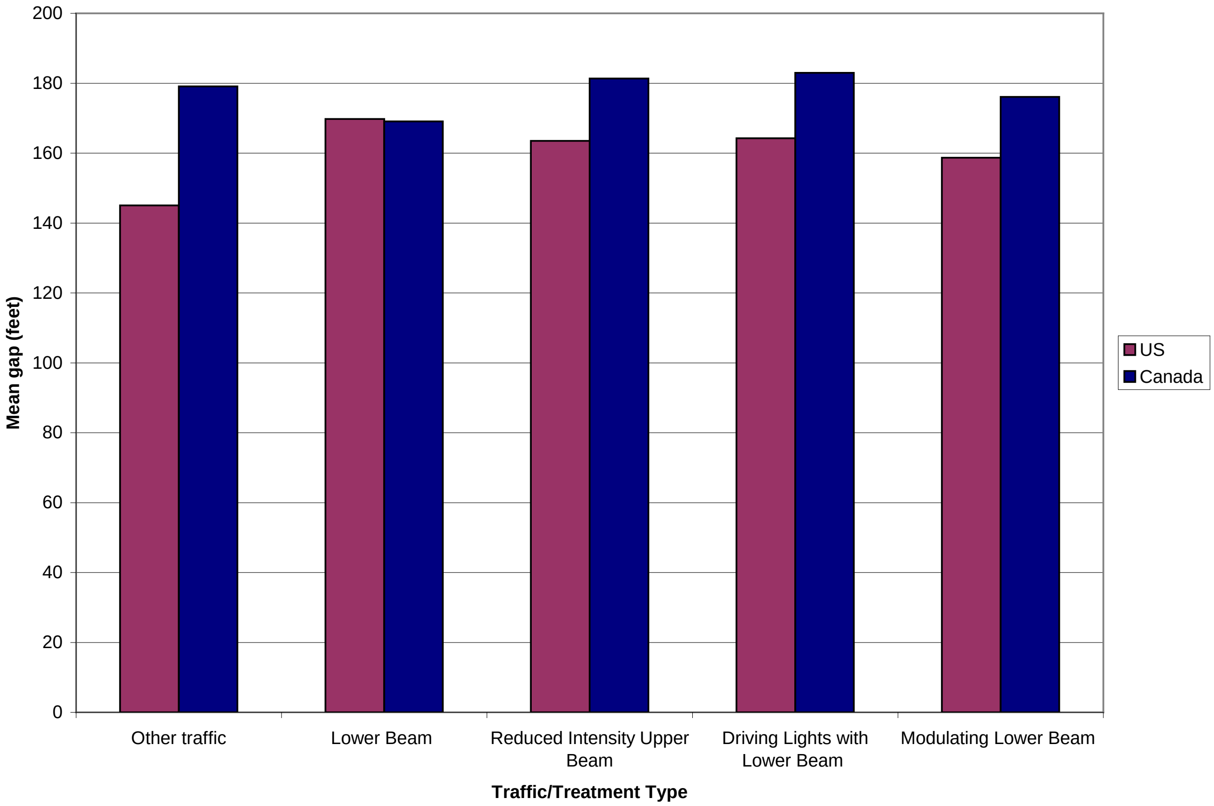

Figure 20. Mean gap (in feet) by traffic/treatment type, country

Table 10 below shows the post hoc analyses (t-tests). Because of the number of analyses, this analysis was more complex than other evaluations in this report, in part because the number of comparisons that were compiled, therefore increasing the risk of Type I error (i.e., a false positive). To ensure adequate statistical rigor an alpha of .002 (i.e., .05/25) was selected to control the family-wise error rate.

Table 10. Post-hoc analyses by Country, Conspicuity Treatment

		Canada					United States				
		1. Lower Beam	2. Driving Lights	3. Modulating Lower Beam	4. Reduced Intensity Upper Beam	5. Passenger vehicles	6. Lower Beam	7. Driving Lights	8. Modulating Lower Beam	9. Reduced Intensity Upper Beam	10. Passenger vehicles
Canada	1. Lower Beam		1.89386 0.0586	-0.95083 0.342	-1.73149 0.0838	-1.68713 0.092	-0.09767 0.9222	0.69916 0.4847	1.47079 0.1418	0.84342 0.3993	4.22121 <.0001
	2. Driving Lights			0.91866 0.3586	0.21904 0.8267	0.63134 0.528	1.92638 0.0545	2.63137 0.0087	3.33321 0.0009	2.83217 0.0048	6.37664 <.0001
	3. Modulating Lower Beam				-0.72849 0.4666	-0.49052 0.6239	0.92004 0.3579	1.65915 0.0975	2.38568 0.0173	1.82891 0.0678	5.21595 <.0001
	4. Reduced Intensity Upper Beam					0.38985 0.6968	1.75822 0.0791	2.4918 0.0129	3.21858 0.0013	2.69859 0.0071	6.4237 <.0001
	5. Passenger vehicles						1.74905 0.0807	2.6238 0.0089	3.47425 0.0005	2.91033 0.0037	8.31253 <.0001
United States	6. Lower Beam							-0.85414 0.3933	1.67517 0.0943	1.01852 0.3088	4.84974 <.0001
	7. Driving Lights								0.81662 0.4144	0.12505 0.9005	3.55327 0.0004
	8. Modulating Lower Beam									-0.72347 0.4696	2.41198 0.0161
	9. Reduced Intensity Upper Beam										-3.59856 0.0003
	10. Passenger vehicles										

The post hoc tests addressed the following questions:

1. Were there any differences between treatments for the Canadian data?
2. Were there any differences between treatments for the U.S. data?
3. Were there any differences between the Canadian and U.S. data?

Table 11 describes the comparisons required to address each question and the results from each comparison. The Comparisons references the conspicuity treatments by the number included in Table 10 above (e.g., 1 is Lower Beam in Canada).

Table 11. Results of post-hoc comparisons between treatments, countries

Question	Comparisons	Differences Found
1	1v2, 1v3, 1v4, 1v5, 2v3, 2v4, 2v5, 3v4, 3v5, 4v5	No differences
2	6v7, 6v8, 6v9, 6v10, 7v8, 7v9, 7v10, 8v9, 8v10, 9v10	7v10, 6v10, 9v10
3	1v6, 2v7, 3v8, 4v9, 5v10	5v10

The results of the post-hoc did not reveal a statistically significant difference between any of the conditions – including passenger vehicles – in Canada. For the U.S. data, the comparisons of Lower Beam and Passenger Vehicles (mean gaps of 169.8 and 145.1 feet, respectively), Driving Lights with Lower Beam and Passenger Vehicles (164.3 and 145.1 feet, respectively), and Reduced Intensity Upper Beam with Passenger Vehicles (163.5 and 145.1 feet, respectively) revealed statistically significant differences). When comparing differences between Canada and the United States, only the difference between the passenger vehicle baseline was found to be significant (mean gaps of 179.1 and 145.1 feet, respectively).

The previous TCT analysis was expanded to include passenger vehicles. Table 12 depicts the percentage of gaps in seconds for each treatment.

Table 12. Percentage, number of gaps by treatment, gap size in seconds – United States

	Gap (seconds)		
Treatment	**0-1**	**1-2**	**>2**
Lower Beam	0% (n=0)	3.0% (n=2)	97.0% (n=64)
Reduced Intensity Upper Beam	0% (n=0)	3.0% (n=2)	97.0% (n=63)
Driving Lights with Lower Beam	0% (n=0)	1.8% (n=1)	98.2% (n=55)
Modulating Lower Beam	0% (n=0)	6.0% (n=3)	94.0% (n=47)
Passenger Vehicles	0% (n=0)	7.5% (n=8)	92.5% (n=98)

Drivers of turning vehicles accepted short gaps for passenger vehicles more frequently than for motorcycles, but the differences were not statistically reliable.

Table 13 depicts the percentage of gaps in seconds for each treatment. It should be noted that short gaps, i.e., 2 seconds or shorter, were infrequent with only 2 observations at that length.

Table 13. Percentage, number of gaps by treatment, gap size in seconds – Canada

	Gap (seconds)		
Treatment	**0-1**	**1-2**	**>2**
Lower Beam	0% (n=0)	0% (n=0)	100% (n=49)
Reduced Intensity Upper Beam	0% (n=0)	0% (n=0)	100% (n=50)
Driving Lights with Lower Beam	0% (n=0)	0% (n=0)	100% (n=44)
Modulating Lower Beam	0% (n=0)	2.3% (n=1)	97.7% (n=43)
Passenger vehicles	0% (n=0)	0.8% (n=1)	99.2% (n=128)

5.4 Conclusions

The primary study objective was to determine whether DRL on passenger vehicles affected drivers' responses to oncoming motorcycles. Specifically, the study was to address the possibility that drivers may become accustomed to searching for two headlamps (i.e., another passenger vehicle), and thus inadvertently "overlook" motorcycles with only one headlamp lit. In addition to this possibility, when many motor vehicles have DRL, motorcycles may become less noticeable because they have lost their unique identifying signature as the only vehicle type with DRL. This was evaluated by comparing observed on-road gap sizes afforded by passenger car drivers to motorcycles both in Canada (where DRL are mandatory) and in the U.S., where DRL are less frequently used. Gap sizes were observed for motorists turning left at intersections in front of an oncoming motorcycle. In Canada the motorcycle was followed by an experimenter in a passenger vehicle with DRL. In the U.S., the following passenger vehicle did not have DRL. These passenger vehicles were used to present a similar background behind the motorcycle for the two test sites and to prevent other motorists from passing the motorcycle during its approach to the intersection.

In addition to the motorcycle trials, baseline data were collected in each setting. For these data, drivers were observed making left turns in front of different types of passenger vehicles. The analysis focused on the respective differences between the gaps to passenger vehicles and those to motorcycles. The American drivers selected longer gaps when turning in front of motorcycles than they did when turning in front of other passenger vehicles. This effect was not found in the

Canadian data where there were no reliable differences in gap size for passenger vehicles versus motorcycles.

In the U.S. data, the main difference between the baseline and motorcycle trials was the level of conspicuity treatments. All of the motorcycle trials had some form of conspicuity enhancement. In contrast, approximately half (47%) of the passenger vehicles had some kind of DRL. In the Canadian data, both sets of trials had high implementation of conspicuity treatments (100% for motorcycle trials and 94% of the baseline trials). It is possible that this difference, namely the absence of conspicuity treatment on 53% of the American baseline trials, contributed to the respective differences between baseline and motorcycle trials. If the increased gap sizes to motorcycles relative to cars in the U.S. are due to the lower fleet use of DRL, there may be a small detrimental effect on motorcycle conspicuity if all vehicles have DRL, though this cannot be determined from the data collected in this project. It is equally possible that there are differences in driving behavior among drivers from New York and Ontario, where the data were collected. Another possibility is that the prevalence of motorcycles differs at the two sites and that this affects drivers' gap acceptance. A recommendation for future research is to collect new data comparing gaps to passenger cars with and without DRL in the U.S. In addition, analyses of crash data in countries that have mandated DRL may provide further information about any effects of fleet use of DRL on motorcycle safety.

The second objective was to assess differences between specific lighting technologies in terms of conspicuity, inferred from differences in gap size. Here the results were generally straightforward: there were no differences between the individual conspicuity treatments. Moreover, this pattern was observed both for U.S. and Canadian sites. Although none of these conspicuity treatments elicited longer turning gaps than the others, it is possible that future research may identify more effective conspicuity measures.

Most encouraging was the finding that the vast majority (less than 1 percent overall) of gaps accepted by drivers in both countries were adequate (i.e., greater than 2 seconds). This suggests that for this type of scenario the safety problem is relatively small, independent of conspicuity treatment.

5.5 Caveats

As discussed previously, the selected methodologies had some limitations. The gap assessment provides a direct measurement of real world behaviors, although the behavior observed in drivers turning into shopping mall parking lots may not generalize to all real world situations. Furthermore, the motorcycle traveled at a steady, low speed (25-30 mph) and below the speed limit, and therefore it is unknown how driver gap acceptance may be affected at higher speeds. The method does not provide insight as to what variables influenced the driver to accept the gap. Therefore, it does not provide detailed information on how conspicuity treatments influence the driver's behavior. Do they help attract the attention of an inattentive driver, do they help even attentive drivers detect a motorcycle against a background, or do they provide drivers with better cues of the motorcycle relative velocity and distance?

Another limitation to the study was sample size. Although approximately 400 left turns were collected for the motorcycle treatments, the sample size was not large enough to collect an adequate sample of the shorter gaps – those less than two seconds – for any in-depth interpretation. Because of the infrequency with which short gaps are observed, a much larger sample size would be required to collect enough of these traffic conflicts and determine which of the treatments ultimately increased safety.

Finally, this data represents a narrow geographic region. The effect of DRL might be different in areas where ambient light levels are higher. Future research should consider different geographic regions and a sample size large enough to provide significant findings to the traffic conflicts.

6 Side Conspicuity Testing

This side conspicuity test series was conducted to investigate the effect of side conspicuity treatments on motorcycles. Motorcycle conspicuity treatments were developed using side mounted retro-reflectors at two mounting heights and a side marker lamp. Note that FMVSS 108 currently does not require manufacturers to equip motorcycles with side marker lamps. This section will describe the side treatments, the test design, and the results of the testing. This test was initiated by a request from NHTSA's Rulemaking office to better understand the side marker evaluation. Enhanced side conspicuity treatments possibly may enable drivers of other vehicles to more quickly and accurately detect and identify motorcycles.

6.1 Motorcycle Side Conspicuity Treatments

The stock conspicuity treatments on the Test Motorcycle consist of the following:

A front amber reflector with a size of 2.25" x 1.325" with the center mounted approximately:

- 18.25" above the ground
- 17.125" aft of the leading vertical plane of the front tire
- 10 degrees from longitudinal centerline to vertical

The stock rear red reflector is 3.175" x 1.050" in size and the center is mounted approximately:

- 29.25" above the ground
- 9.25" forward of the trailing vertical plane of the rear tire
- 21 degrees from longitudinal centerline to horizontal

The measurements were made with the rider in place. A mechanism was installed on the front forks to allow for the mounting of multiple reflectors positioned at 12" and 15" above the ground. A similar mechanism was implemented for the rear except the reflectors followed a vertical positioning centerline with détentes at 12" and 15." These mounting mechanisms are illustrated in Figures 21 through 23.


Figure 21. Side retro-reflectors, all potential configurations


Figure 22. Side retro-reflectors, standard configuration


Figure 23. Side retro-reflectors, 12” mounting location

A single amber marker light was placed on the side fairing of the motorcycle, forward of the rider’s legs yet behind the forks. As noted previously FMVSS 108 does not require motorcycles to have side marker lights. However, SAE Surface Vehicle Standard J592 “Side Marker Lamps for Use on Road Vehicles Less than 2032 mm in Overall Width” has the following installation requirements:

§ 6.5.2 Side marker lamps shall be mounted on the permanent structure of the vehicle not less than 380 mm (~15”) above the road surface measured from the center of the device at the vehicle curb weight.

§ 6.5.3 Side marker lamps shall be mounted as near as practicable to the front and rear edges of the vehicles to indicate the overall length of the vehicle.

The desired configuration for this experiment consists of a single amber marker light without the rear red marker as stated in SAE J592. Furthermore, the motorcycle has such a short wheelbase (~4.5 feet) that length is not a problem. Since the only obstacle to the side marker lamp is the rider’s leg, and any marker occlusion would occur after the motorcycle has passed the observer, the side marker lamp was mounted not less than 15” above the ground and as close to the vertical center of wheelbase while staying forward of the rider’s legs. The experiment examined the effect of lowering the reflectors to twelve inches; three inches lower than what FMVSS 108 requires for motorcycle retro-reflector placement. The side marker lamp is shown in Figure 24.

Figure 24. Side marker lamp

6.2 Methodology

The following equipment was utilized to perform the side conspicuity tests:

- Participant vehicle – The participants rode in a 1993 Ford Taurus station wagon. The vehicle was outfitted with two dash-mounted video cameras aimed at the intersecting legs of roadway intersections. The cameras recorded video at intersections to help identify intersecting traffic. Also, verbal comments of the test subject and test engineer were recorded.
- Background car – This vehicle is a 1995 Ford Crown Victoria. It also served as a command and observation post for orchestrating the test. No modifications were made to the car.
- Radios – Contact was maintained amongst the participant vehicle, motorcycle, and background vehicle using two-way radios. The motorcycle rider had a speaker and microphone embedded in the helmet for hands-free radio operation. The background vehicle driver used the radio as a handheld device. The test engineer in the participant vehicle had a headset to monitor the radio so that the test subject would not be able to hear any inter-vehicle communication, yet the test engineer would be able to transmit voice.
- Trimble Crosscheck GPS Radios – These compact radios utilize a GPS receiver and a cellular transceiver to report the position of the unit. Although this test series did not use cellular communication, the Crosschecks were used as GPS data logging devices. A Crosscheck was mounted on each of the three vehicles. The Crosscheck onboard the IV was equipped with a pushbutton switch that placed an electronic mark on the GPS data every time the button is depressed. The Crosscheck is shown in Figure 25. The unit mounted on the motorcycle is shown in Figure 26.

Figure 25. Trimble Crosscheck GPS unit

Figure 26. Trimble Crosscheck, installed on motorcycle

6.3 Test Procedure

All subjects were Calspan employees in the Buffalo, NY area. They were given a pretest interview to eliminate motorcycle riders and unlicensed drivers. Test subjects had to pass visual acuity and colorblindness tests.

Test subjects were asked to drive the vehicle through a predetermined course where they encountered random, unpredictable traffic as well as the NHTSA test motorcycle and the background vehicle. The test area was configured with six different test routes within the same neighborhood in Clarence, New York. Six routes were chosen to minimize order effects. The routes were based on the first six test orders as defined by an 8x8 orthogonal Latin Square. The test subject was accompanied by a Calspan test engineer who administered instructions to the subject. As the test subject approached a given intersection, either the background vehicle or test motorcycle was stationary on the left or right or would be approaching from the left or right.

The test subjects were informed, prior to entering the test area, that they would encounter traffic coming at them from the left and right inside the test area. Whenever the test subjects saw one of these vehicles they were asked to press the test button. They are also asked to identify the type of vehicle and the direction from which it is coming. For instance, as soon as they saw the motorcycle they would press the button and say, “Motorcycle on the right.”

After the vehicle presentations were complete the subject was returned to Calspan. They were given an exit interview and thanked for their participation.

6.4 Results

A within-subjects ANOVA was calculated on the detection distance. The independent variables were conspicuity treatment (reflector at 12 inches, reflector at 15 inches, side marker lamp, and reference car) and direction (left or right). The effect of conspicuity treatment was not significant ($F(1, 28)$ – 0.130, $p = 0.721$, power = 0.064. However, the effect of side was significant ($F(1, 28) = 9.469$, $p = 0.005$, power = 0.844). Specifically, vehicles on the left were detected at a mean distance of 236 feet and vehicles on the right at 204 feet. The results are illustrated in Figure 27 below.

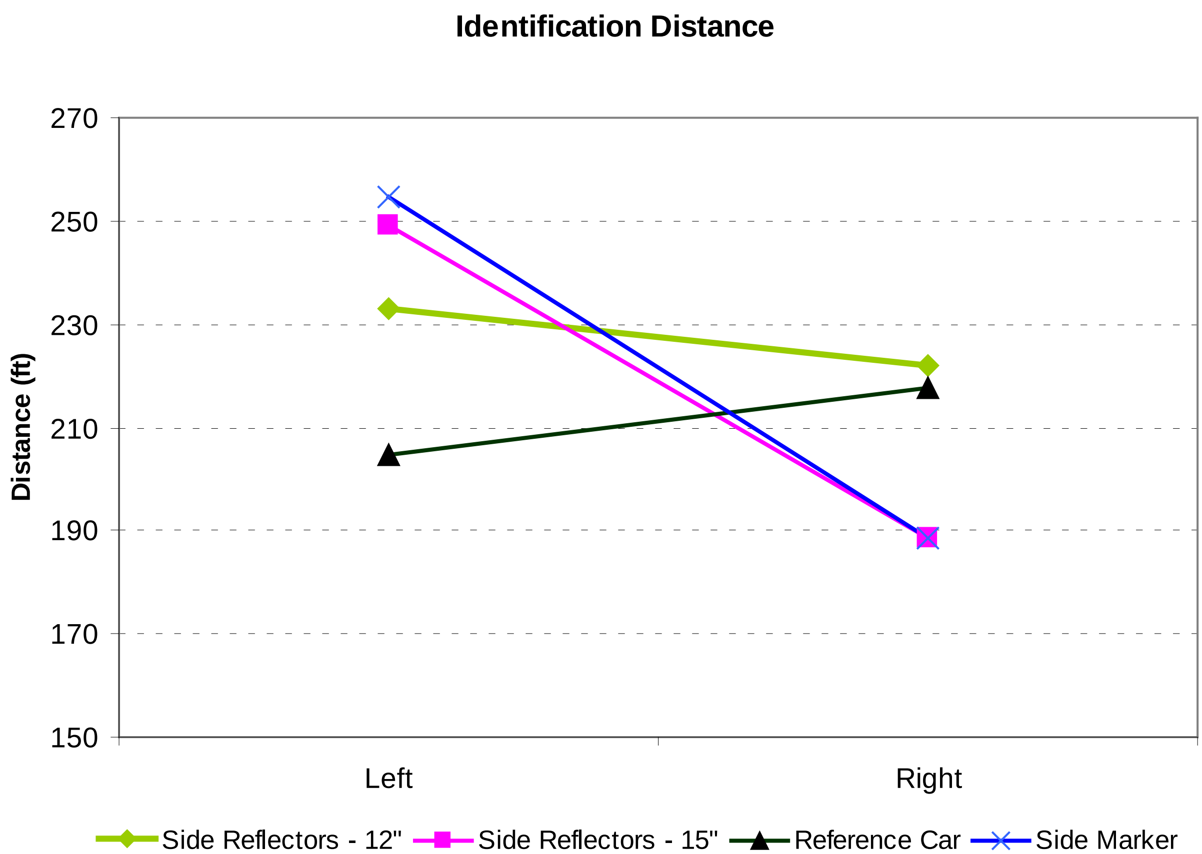

Figure 27. Mean identification distance (feet) by direction, vehicle type

7 Summary and Discussion

This program included three test series to investigate the issue of motorcycle conspicuity treatments. Three tests were conducted: speed gap on a test track, the on-road gap acceptance evaluation, and the side conspicuity evaluation. The test track results were all used to select treatments for the on-road gap acceptance evaluation. The side conspicuity evaluation was a standalone effort.

7.1 Test Track Evaluation

The main goal of the test track evaluation was to determine relative differences between conspicuity treatments. It was thought that if one clearly performed better (i.e., facilitated larger gaps) it would be selected for the on-road evaluation. In fact, no one motorcycle treatment performed consistently better; as a result, three treatments were selected for the on-road portion based on the frequency with which riders voluntarily implement the treatments on their motorcycles. The treatments were: Reduced Intensity Upper Beam, Driving Lights with Lower Beam, and Modulating Lower Beam. Lower Beam was selected as the baseline condition.

7.2 On-road Evaluation

The primary goal of the on-road evaluation was to determine whether fleet use of DRL would impact the effectiveness of motorcycle daytime conspicuity treatments. To determine this, data were collected in the United States (low DRL use) and Canada (high DRL use). Data collection included a naturalistic gap acceptance and a follow-up interview of observed drivers. In addition, gap size was recorded for LTAPs for other traffic (i.e., sedans, minivans, and SUVs) for comparison.

The vast majority of gaps were large – all but one condition (non-motorcycle traffic in the United States) yielded an average gap of three seconds or greater. Gaps of two seconds or less were measured for at most 9% of all observations. This finding was expected, as traffic conflicts are rare events.

The results revealed some differences between the two countries. Canadian drivers provided longer gaps than American drivers in the baseline conditions. Trends in this direction were observed for three of the four treatment conditions, but these differences did not reach statistical significance due to the conservative criterion ($p \leq .002$) set to control for false positive effects. Among Canadian drivers, there were no differences between gaps provided to motorcycles and those provided to other traffic; American drivers provided larger gaps to motorcycles than to other vehicles in three of the four motorcycle treatment conditions. This trend may indicate a disadvantage to motorcyclists in high-DRL environments. However, the data also indicate that higher intensity conspicuity treatments – Reduced Intensity Upper Beam and Lower Beam with Driving Lights – can compensate for this disadvantage, as those treatments yielded similar gaps to those of passenger vehicles in Canada.

The results did not identify any treatment as better than the others. More traffic conflict data (i.e., very short gaps) would need to be collected to determine whether any of the treatments result in fewer short gaps.

After looking at these data, one question remains: in the United States, is there a difference in gaps afforded to passenger vehicles with and without DRL? (The current data did not allow this determination.) This information would allow for clearer interpretation of these results; by having data of the same vehicle type (passenger vehicle) with and without DRL, a more definite distinction could be made regarding the extent to which different variables affected the results.

One test hypothesis was that one or more of the motorcycle conspicuity treatments would result in drivers providing longer gaps for motorcycles. Another hypothesis was that the same treatment that yielded larger gaps would also be subjectively rated as more conspicuous during the interviews. The final hypothesis was that the most effective treatment would maintain effectiveness in both levels of fleet DRL concentration. None of these hypotheses was supported by the data.

7.3 Side Marker Evaluation

In regards to the side marker evaluation, conspicuity treatments did not appear to affect motorcycle detection; therefore, the data do not support a need for side marker lamps.

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Appendix A – Luminous Intensity Measurements

MEMORANDUM

TO: John A. Pierowicz

FROM: Evan Tibbetts

DATE: June 16, 2004

RE: Motorcycle Conspicuity Luminous Intensity Mapping

CC: Glenn Wilson

Introduction

Prior to frontal conspicuity testing, the light beam intensity patterns of each conspicuity treatment must be obtained. Towards this objective, members of the Motorcycle Research team measured the luminous intensity of each treatment within a defined plane in front of the motorcycle. This memo provides a description of the tests and results.

Luminous Intensity Mapping Tests

The irradiance measurements, expressed in foot-candles (Fc), were made using an Extech Instruments Heavy Duty Light Meter Model 407026. For the measurement range of 0-186 Fc used in this testing, the meter has a resolution of 0.1 Fc and an accuracy of ± (4% + 2 digits of full scale). All measurements were taken with the sensor face perpendicular to the light source, and with the light meter properly zeroed and in tungsten/daylight mode.

Luminous intensity mapping tests were conducted in Building 8. Following the procedures from LM Test Procedures.doc, the enhanced parking lights and LED fork lights were tested with the low beam headlamp disconnected and the motorcycle engine idling. The light meter sensor was placed 10 feet away from the center point of the enhanced parking lamps. This distance was determined from SAE Surface Vehicle Standard *J222 Parking Lamps (Front Position Lamps)*. Measurements were taken for horizontal angles from 0° to 90°, in 5° increments, on both the left and right sides of the motorcycle. The vertical measurement points varied from -8° to 10° in 2° increments with respect to the horizontal plane through the center of each conspicuity treatment. Luminous intensity at -10° was not measured because the measurement point was below ground level. Since the sensor was longitudinally stationary, any geometric differences between the enhanced parking lamps and LED fork lights were compensated for in later calculations.

Since Building 8 could not accommodate motorcycle-light meter distances of more than 40 feet, the luminous intensity mapping tests continued with the remaining conspicuity treatments, excluding side marker lights, in the more spacious Crash Test Facility. Following similar procedures from LM Test Procedures.doc, the headlamps and driving lights were tested at a distance of 60 feet from the light meter sensor, per SAE Surface Vehicle Standards *J584 Motorcycle Headlamps* and *J581 Auxiliary High Beam Lamps*. In addition, 60 foot tests were repeated on the enhanced parking lights and LED fork lights with the low beam headlamp operational. Similarly, measurements were taken at horizontal positions from 0°to 90° in 5°

increments, on both sides of the motorcycle. Vertical measurement points occurred from -3° to 3° in 1° increments, with respect to the horizontal plane through the center of each conspicuity treatment.

Figures 1 and 2 show diagrams of the test setup for both 10 foot and 60 foot measurement points.

Figure A1. Overhead schematic of test layouts

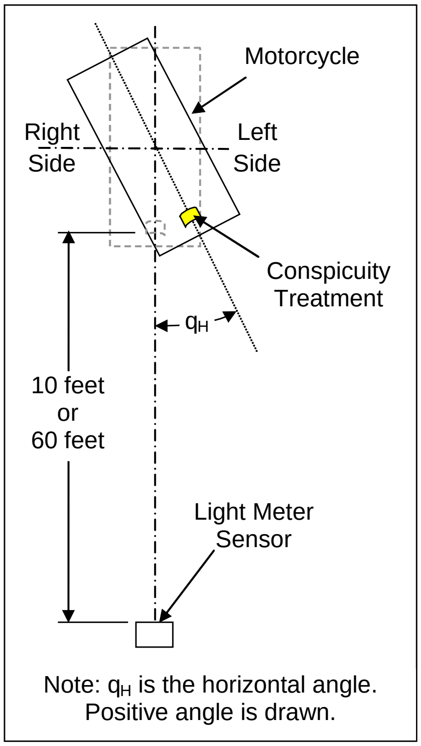
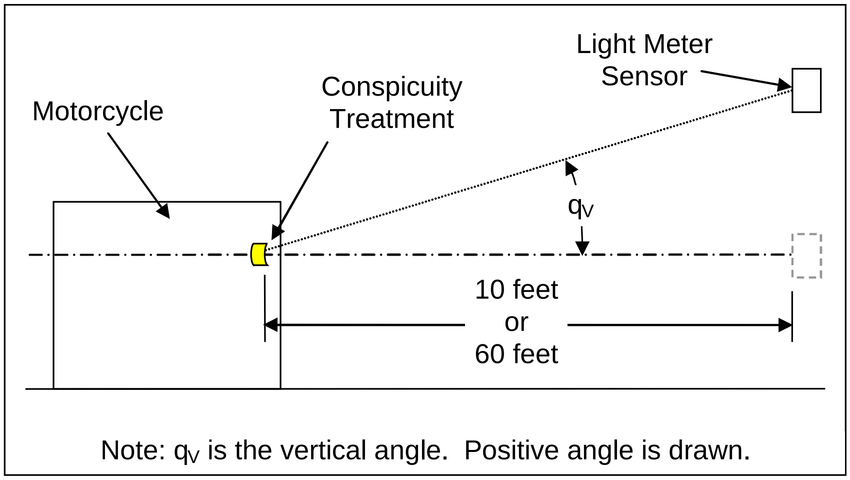


Figure A2. Side schematic of test layouts



Luminous Intensity Mapping Data and Results

The raw data from both tests can be found in Luminous Intensity Mapping Worksheet Raw.xls.

Likewise, the final calculated results are contained in a spreadsheet called Luminous Intensity Mapping Worksheet.xls. The true distances from the light meter sensor to each light source were calculated, taking both horizontal and vertical angles into account. The raw irradiance data, measured in foot-candles, was multiplied by the square of the distance in feet to obtain the luminous intensity in units of candela (cd).

A MATLAB program entitled lumplot.m was created to plot the luminous intensity data as .fig and .jpg files (stored in \\Nybf01-file01\projects\Motorcycle Research\Luminous Intensity Mapping). The luminous intensity plots are reproduced below. These plots detail the beam pattern of each conspicuity treatment. Negative horizontal angles refer to the left side of the motorcycle. Both the z-axis (out of the page) and the colormap depict the luminous intensity measurements for the range of points. The red areas of the plots correspond to the most intense areas (up to 8000 cd), and the blue areas correspond to the least intense areas (approximately 0 cd).

The maximum luminous intensity measurements and corresponding measurement locations are given in Table A1.

Table A1. Maximum luminous intensity measurements and locations

Conspicuity Treatment		Max. Luminous Intensity (cd)	Location of Max. Luminous Intensity	
			Horizontal Angle (deg)	Vertical Angle (deg)
Single Low Beam		5043	5	-1
Single High Beam		3601	0	-1
Modulating Low Beam	Maximum	1441	5	-1
	Minimum	360	5	-1
Dual Low Beams		5407	0	-2
Driving Lights		7562	0	-1
Enhanced Parking Lights	With Low Beam	3602	5	-1
	Without Low Beam	421	-5	0
Fork Lights	With Low Beam	4683	5	-1
	Without Low Beam	30	5	0

Summary

The maximum luminous intensity values and luminous intensity mapping plots are fairly accurate representations of the actual beam patterns of each conspicuity treatment. With this data, the light output of the individual treatments are easily compared. In addition, systems with similar luminous intensity characteristics can be implemented for future research or for presentation to the public. Any issues with the current setup are also more apparent. For example, the single high beam headlamp must be adjusted further to meet the luminous intensity requirement of 3000 cd.

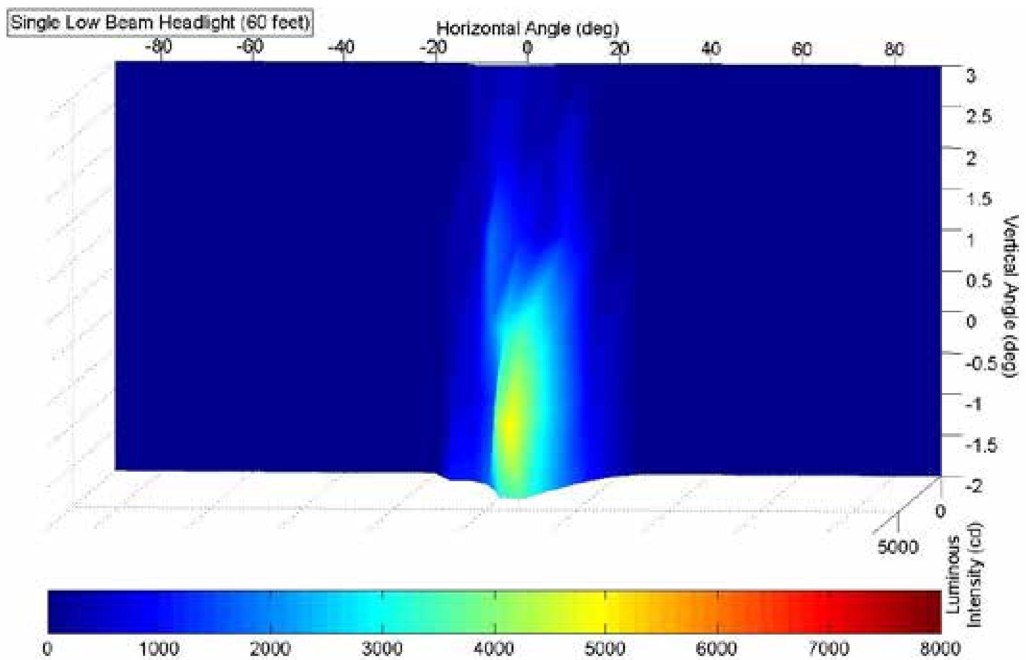
Addendum

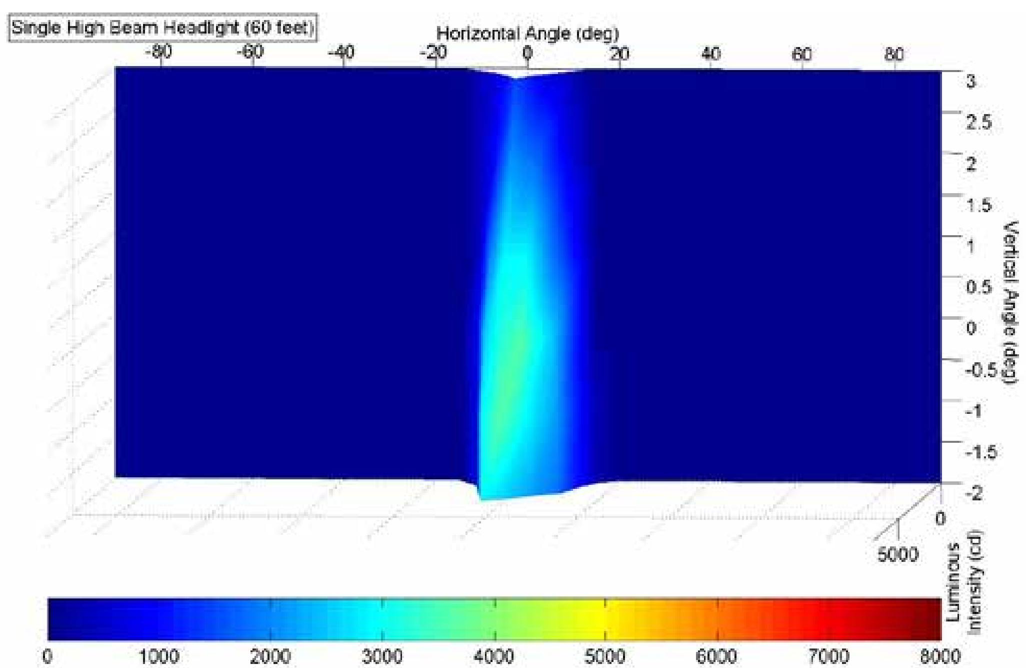
The high beam was adjusted to a maximum luminous intensity of less than 3000 cd, and the test procedure was repeated on this conspicuity treatment. The maximum luminous intensity and corresponding location is given in Table A2, and can be compared with the results of Table A1.

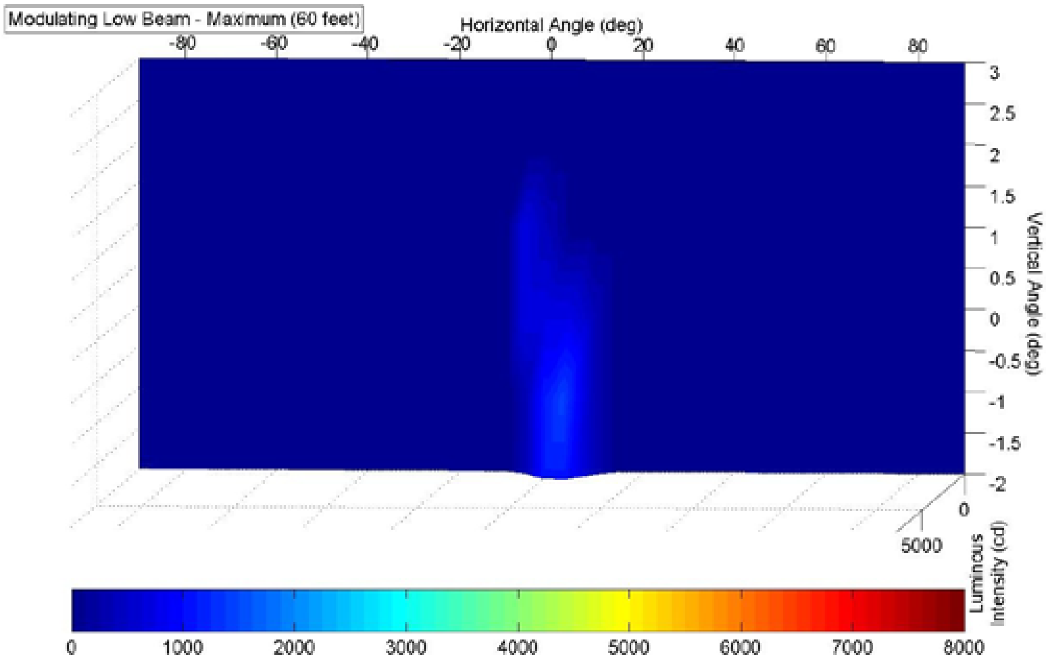
Table A2. Maximum luminous intensity measurement and location for adjusted high beam

Conspicuity Treatment	Max. Luminous Intensity (cd)	Location of Max. Luminous Intensity	
		Horizontal Angle (deg)	Vertical Angle (deg)
Single High Beam - Adjusted	2881	5	0

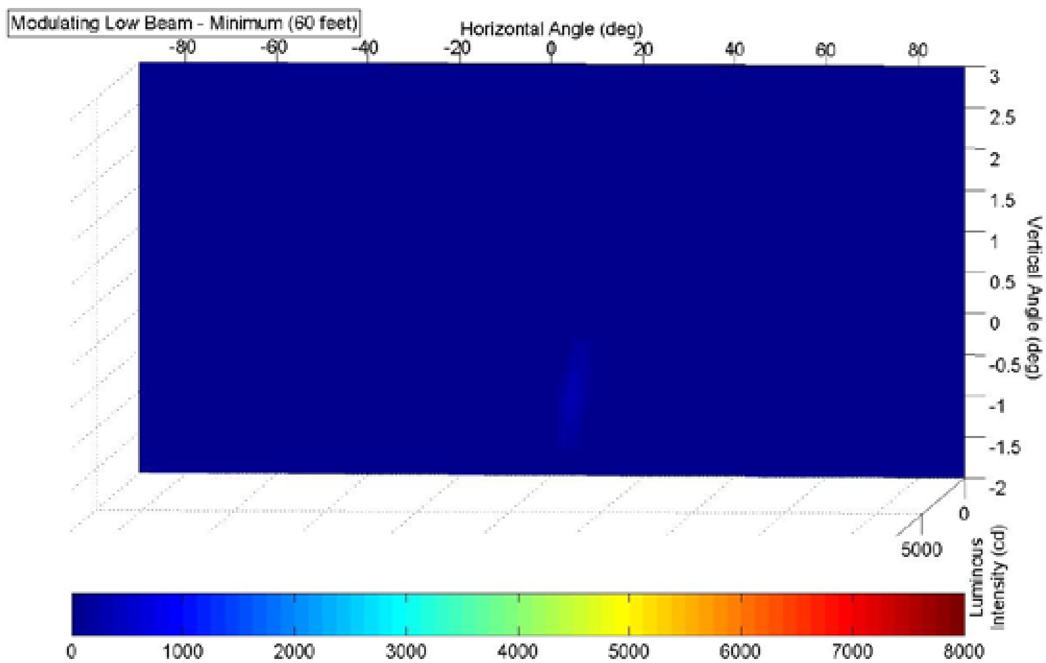
Figure A3. Luminous intensity mapping plots



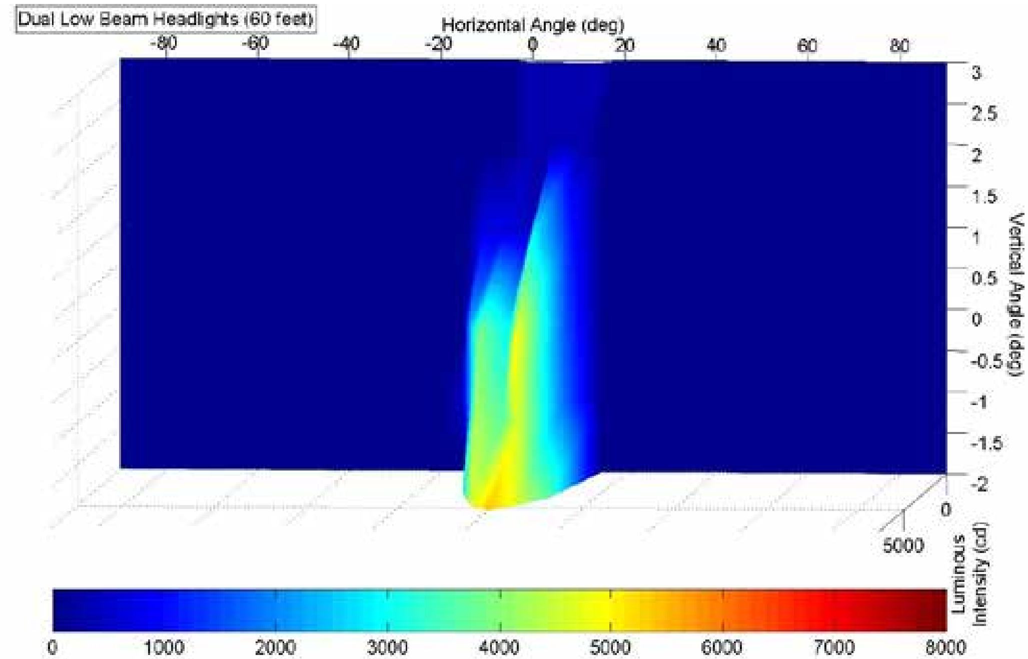


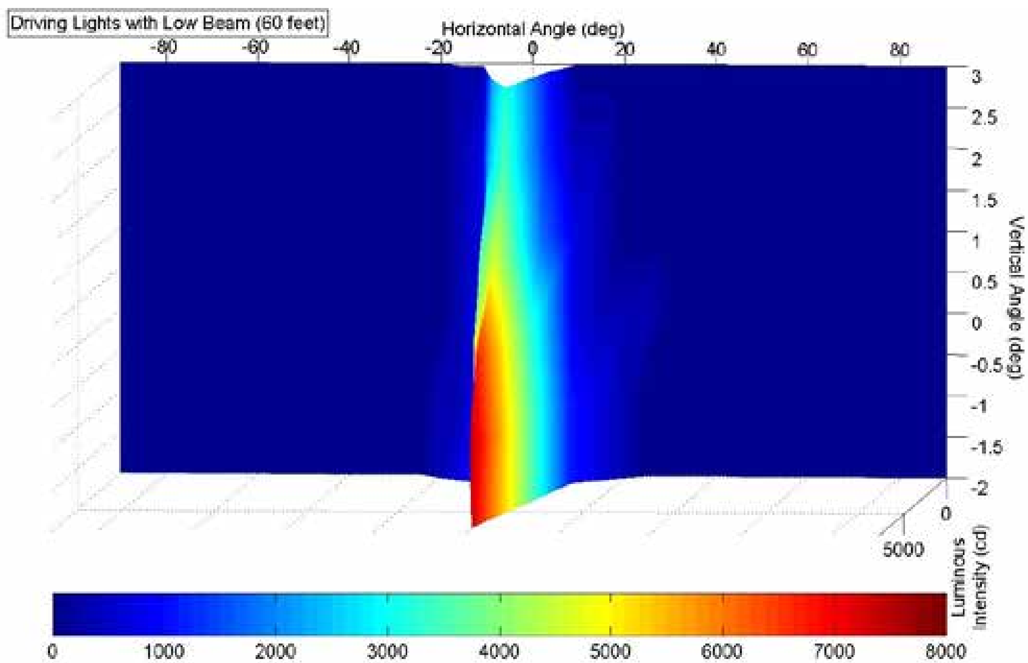


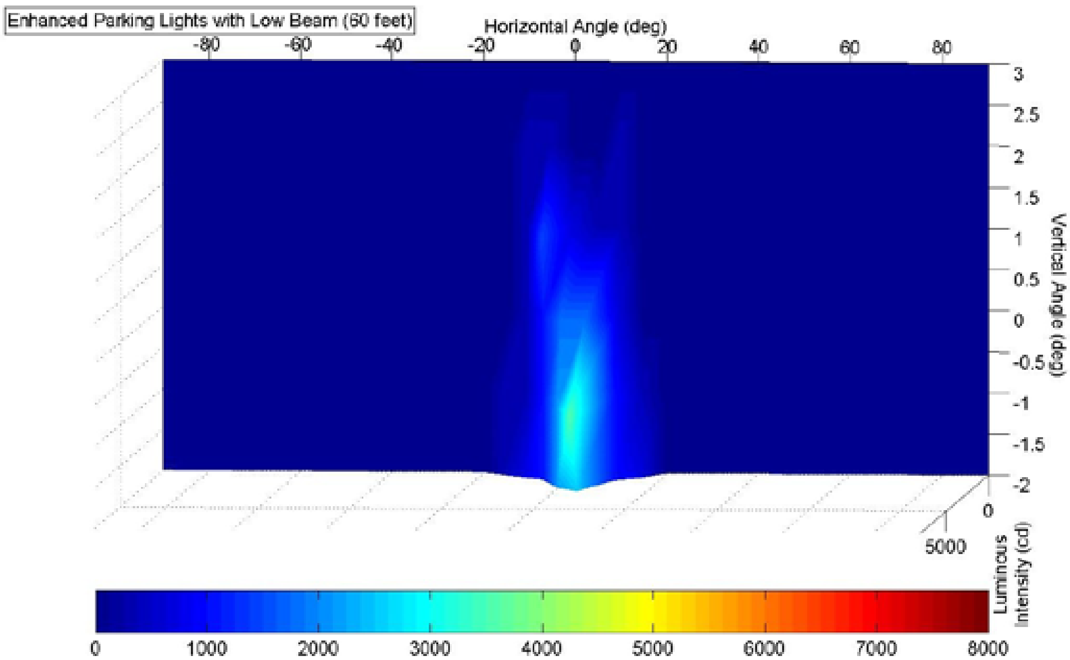
Modulating Low Beam - Maximum (60 feet)
Horizontal Angle (deg)
Vertical Angle (deg)
Luminous Intensity (cd)

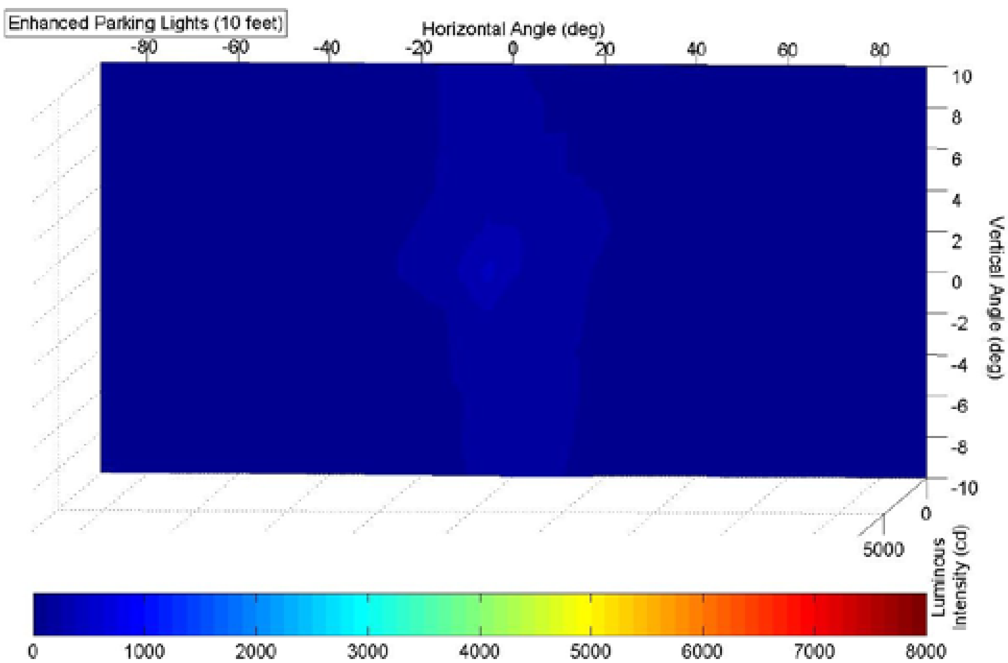


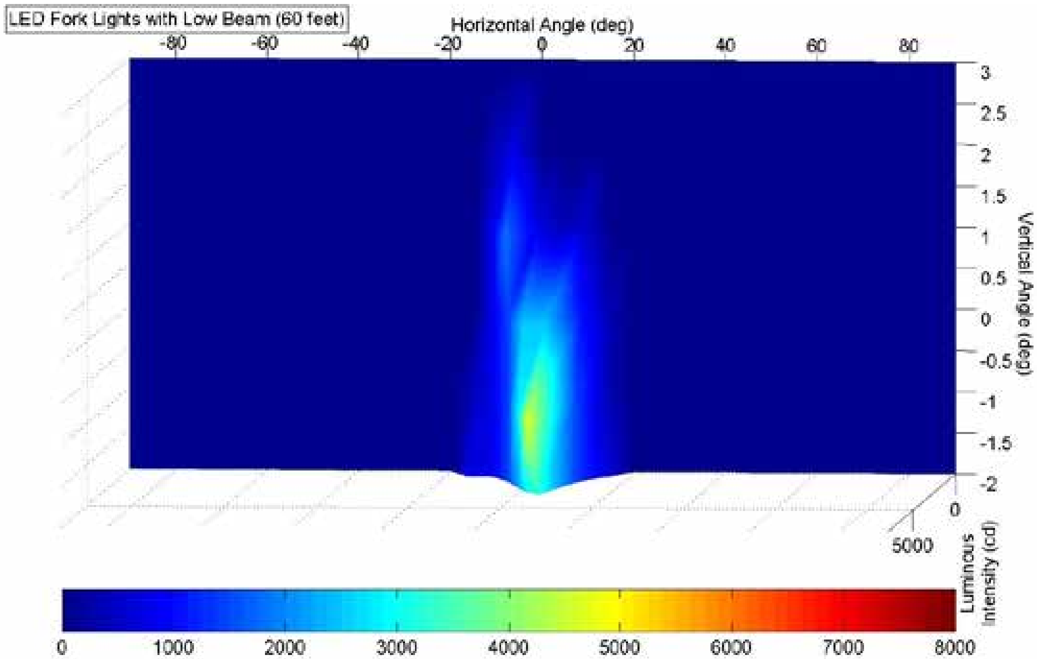
Modulating Low Beam - Minimum (60 feet)
Horizontal Angle (deg)
Vertical Angle (deg)
Luminous Intensity (cd)

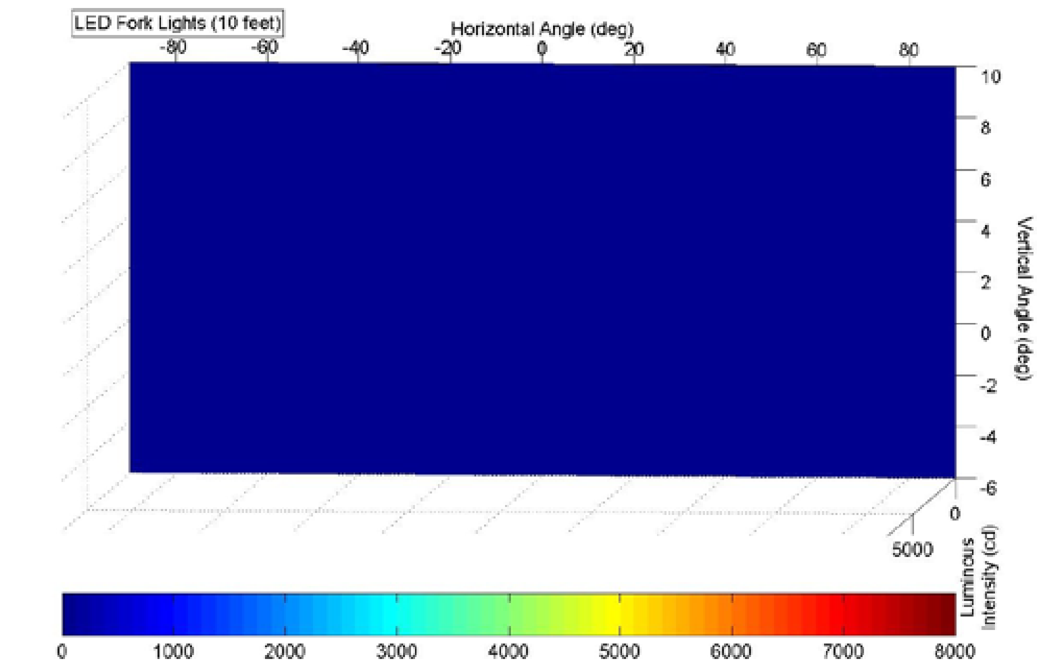

Dual Low Beam Headlights (60 feet)
Horizontal Angle (deg)
-80
-60
-40
-20
0
20
40
60
80
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Vertical Angle (deg)
0
5000
Luminous Intensity (cd)
0
1000
2000
3000
4000
5000
6000
7000
8000

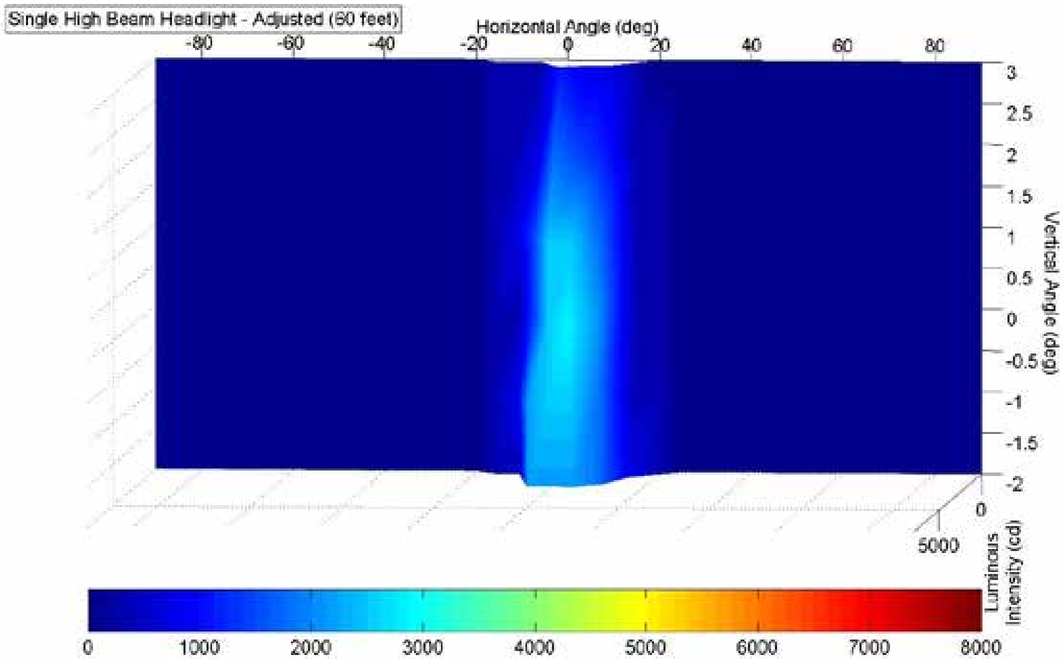

Driving Lights with Low Beam (60 feet)
Horizontal Angle (deg)
-80
-60
-40
-20
0
20
40
60
80
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Vertical Angle (deg)
0
5000
Luminous Intensity (cd)
0
1000
2000
3000
4000
5000
6000
7000
8000


Enhanced Parking Lights with Low Beam (60 feet)
Horizontal Angle (deg)
-80
-60
-40
-20
0
20
40
60
80
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Vertical Angle (deg)
0
5000
Luminous Intensity (cd)
0
1000
2000
3000
4000
5000
6000
7000
8000


Enhanced Parking Lights (10 feet)
Horizontal Angle (deg)
-80
-60
-40
-20
0
20
40
60
80
10
8
6
4
2
0
-2
-4
-6
-8
-10
Vertical Angle (deg)
0
5000
Luminous Intensity (cd)
0
1000
2000
3000
4000
5000
6000
7000
8000


LED Fork Lights with Low Beam (60 feet)
Horizontal Angle (deg)
-80
-60
-40
-20
0
20
40
60
80
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Vertical Angle (deg)
0
5000
Luminous Intensity (cd)
0
1000
2000
3000
4000
5000
6000
7000
8000


LED Fork Lights (10 feet)
Horizontal Angle (deg)
-80
-60
-40
-20
0
20
40
60
80
10
8
6
4
2
0
-2
-4
-6
Vertical Angle (deg)
0
5000
Luminous Intensity (cd)
0
1000
2000
3000
4000
5000
6000
7000
8000


Single High Beam Headlight - Adjusted (60 feet)
Horizontal Angle (deg)
-80
-60
-40
-20
0
20
40
60
80
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Vertical Angle (deg)
0
5000
Luminous Intensity (cd)
0
1000
2000
3000
4000
5000
6000
7000
8000

Appendix B – Test Track Experimenter Protocol

Initial Interview – Daytime Testing
"Allow me to officially welcome you to our study. In a few minutes, I will drive you out to our vehicle at test track to start rating vehicle configurations. Once we arrive at the test track, the engineer will ask you to sit in the driver's seat of the vehicle. Once you seated, please put on your seatbelt. Feel free to adjust the seat as needed." "During the course of the testing, several different vehicles will drive towards you. For each test run of each vehicle, depress the pushbutton mounted on the steering wheel as soon as you see the vehicle start to move, and at the last moment you feel you could make a safe left-hand turn in front of the oncoming vehicle." "When pushing the steering wheel button, press and hold the button firmly for one second, then release. Let us know if you have any difficulty pushing the button." "At no point during the test will you be doing any driving. The vehicle you are going to be sitting in is connected to electronic equipment mounted outside of the car, so it is imperative for the protection of our equipment, our test staff, and you that the car is not put into gear." "The engineer will sit in the rear seat during the session. Feel free to ask the engineer any questions at any time. The engineer will go over these directions with you a second time at the test track." "At the end of the session, the engineer will ask you to rank each configuration on a scale from one to eight, one being the configuration that was the most visible and eight being the configuration that was the least visible. The engineer will then take you back to the interview room to fill out an exit interview." "I will now drive you out to our vehicle, and will also drive you back when you are done."

Interviewer – Initial Interview Procedure
1) Welcome and seat the volunteer. 2) The volunteer may or may not be familiar with the study. To keep from interviewing the same person twice, ask the volunteer if he or she previously participated in a similar study. If the volunteer did not participate in a similar study, open a new instance of the "Interview and Test Form" and proceed with the interview. If the volunteer did participate in a similar study, ask the volunteer to tell you his or her test number. If the volunteer is able to tell you his or her test number, open the corresponding "Interview and Test Form." Ask the volunteer to hand you his or her driver's license. Make sure the volunteer's driver's information matches the driver's license information that appears on the "Interview and Test Form." Also, open the file "Test Subject Number Log." Find the date and time corresponding to the given subject number. Ask the volunteer if his or her previous testing session took place on the date and time listed on the form. If the volunteer does not remember his or her test number or if the volunteered remembered his or her test number incorrectly, open a new instance of the "Interview Form and Test Form" and proceed with the interview. 3) Open the file, "Test Subject Number Log." Assign the next available number to the volunteer. 4) Tell the volunteer his or her subject number. 5) Rename the file "[SUBJECT NUMBER] Interview and Test Form." 6) Fill in the two "Subject Number" fields on the "Interview and Test Form." 7) Tell the volunteer to hold onto the number for now; you will explain its significance later. 8) Start filling in information on the "Interview and Test Form." a) Ask the volunteer to answer "YES" or "NO" to the first set of questions. Read the first four Volunteer Criteria questions and record each answer. b) Ask the volunteer to answer the last two Volunteer Criteria questions to the best of his/her knowledge. Read each question and record each answer. c) Ask the volunteer to hand you his/her driver's license. Record driver's license information in the appropriate section. If the volunteer uses legal corrective lenses, make sure he or she is wearing them. 9) Perform the eye chart test. a) Ask the volunteer to stand a set number of feet away from the eye chart. A piece of

masking tape taped to the floor will mark the exact place where the volunteer will stand.

b) Uncover the eye chart.

c) Ask the volunteer to read line 20.

d) Cover the eye chart.

e) Record the results.

10) Perform the colorblindness test. Record the results.

11) If the volunteer fails one of the eye tests, kindly inform the volunteer that he or she is ineligible for the study.

12) Ask the volunteer to read and sign a copy of the Motorcycle Safety Study Informed Consent Form. Put the form in the file cabinet.

13) Explain the nature of the test to the volunteer. See “Initial Interview – Daytime Testing Only” or “Initial Interview – Nighttime Testing Only” under Suggested Dialogs.

14) Drive the volunteer to the test track and the waiting vehicle.

15) Introduce the volunteer to the test engineer.

16) Exchange jump drives.

17) In between interviews, perform various other needed activities:

a) Copy files from the jump drive to the Motorcycle server.

b) Verify that the data files appear to be correct.

c) Recruit potential volunteers.

18) Make reminder calls to volunteers scheduled for the next workday.

19) After the test is complete, pick up the volunteer from the test track and drive him/her back to the interview room for the Exit Interview.

Motorcycle Safety Study Daytime Exit Interview Form

General Questions
1. Was your vision perfect today? If not, what was wrong?
2. Was your attention perfect today? If not, what was wrong?
3. How would you describe yourself as a driver?

Questions about the Test
1. What was the best thing about the test?
2. What was the worst thing about the test?
3. What could we have done to make the test better?
4. Do you like sharing the road with motorcycles?
5. Have you ever had problems seeing motorcycles when driving?
6. What version of the motorcycle was the *most comfortable* to view? Select one. ☐ Modulating Low Beam ☐ Auxiliary Parking ☐ Fork Lights ☐ Low Beam ☐ High Beam ☐ Driving Lights ☐ Dual Low Beams Why?
7. What version of the motorcycle was the *least comfortable* to view? Select one. ☐ Modulating Low Beam ☐ Auxiliary Parking ☐ Fork Lights ☐ Low Beam ☐ High Beam ☐ Driving Lights ☐ Dual Low Beams Why?
8. What was the *most visible* version of the motorcycle? Select one. ☐ Modulating Low Beam ☐ Auxiliary Parking ☐ Fork Lights ☐ Low Beam ☐ High Beam ☐ Driving Lights ☐ Dual Low Beams Why?
9. What was the *least visible* version of the motorcycle? Select one. ☐ Modulating Low Beam ☐ Auxiliary Parking

☐ Fork Lights ☐ Low Beam ☐ High Beam ☐ Driving Lights ☐ Dual Low Beams Why?
10. Do you think you will look at motorcycles differently now that you have completed our study? Why or why not?
11. What would make the motorcycle and rider more visible?
12. What other kinds of light configurations would make the motorcycle and rider more visible?
13. Do you have any ideas about the motorcycle safety study you would like to draw? If so, please use the sheet of paper provided.

Appendix C – Test Track Subject Information Form

Volunteer Criteria	Answers	
1. Are you a Calspan employee?	☐ Yes	☐ No
2. Do you have a current driver's license?	☐ Yes	☐ No
3. To the best of your knowledge, are you colorblind?	☐ Yes	☐ No
4. Do have either uncorrected or corrected 20/20 vision?	☐ Yes	☐ No
5. Have you ever driven a: a. Heavy Truck or Bus? b. Limousine or Taxi? c. Motorcycle or Moped?	How long ago? a. b. c.	
6. Have you discussed this test series with anyone other than test personnel, including former test subjects?	☐ Yes	☐ No

Subject Information					
Subject Number:		Gender:	☐ Male ☐ Female	Age:	

Driver License Information	
Expiration Date:	
Restrictions:	
Class:	
Other:	

Vision Tests	Results
Eye Chart Test	☐ Pass ☐ Fail
Colorblindness Test	☐ Pass ☐ Fail

Disclaimer	Volunteer Approved
The test subject has read and understands the Driver Perception Informed Consent form.	☐ Yes ☐ No

Test Order					
☐ A	☐ B	☐ C	☐ D	☐ E	☐ F

Current Test Series			
Date		Departure Time to Test Area	

Appendix D – Test Track Informed Consent Form

MOTORCYCLE STUDY:
TEST SUBJECT INFORMED CONSENT

Part 1

A. Purpose

According to the Fatality Analysis and Reporting System (FARS), the number of motorcycle fatalities has increased steadily since 1997. The National Highway Traffic Safety Administration (NHSTA) has contracted Calspan to research this topic and recommend possible solutions.

B. Investigator

Principal Investigator: John Pierowicz

C. Nature of Study

The test series will present you with a series of different configurations of a motorcycle and a single configuration of an automobile. The test series will gauge your reaction to each vehicle configuration.

When you arrive at the Subject Screening room, you will be interviewed to determine your eligibility for the study. If you meet the eligibility requirements, the interviewer will explain your role in the test and give you your instructions. The engineer will then drive you to the test vehicle located at the test track. You will sit in the driver's seat of the test vehicle and the engineer will sit in the back seat. Although the car's engine will be running, no driving will be required. Again, the engineer will give you instructions. It is of paramount importance that you follow the engineer's instructions. Failure to do so may result in cancellation of your test series. At the end of the test series, the engineer will drive you back to the Subject Screening room and you will be asked to fill out a post-test interview form.

Please note that part of the session will be videotaped. However, the video camera will only record your audio comments.

D. Duration

The test series in which you are participating is anticipated to take less than two hours in total to complete.

E. Foreseeable Inconvenience, Discomfort, and Risks

Although you will spend most your test time inside a vehicle with climate control, you should dress appropriately for the current weather conditions. Restroom facilities will be made available to you before you leave the interview area. However, the test track area does not have restroom accommodations.

Due to the nature of the tests, sunglasses and auto-tinting glasses will not be allowed.

F. Benefits to You and Others

The information you provide will help Calspan and NHTSA complete an important piece of safety research. This research may lead to more in depth research programs that will help mitigate motorcycle crashes and fatalities. Your help in this program will add valuable information to a rapidly growing body of knowledge.

G. Confidentiality of Records

All records will remain confidential. Your name will not be associated with any of the data collected. You will be given a test subject number. This number will be given to you verbally. We will not write the number down for you so it is your responsibility to remember it. Should you decide at a later date that the information you gave was incorrect or false, or you would like to find out the results of your test, contact the Principal Investigator with your subject number and we will make the proper corrections or gladly provide you with your result data. It is your responsibility to provide us with correct and accurate information. It is our responsibility to ensure that your participation is anonymous.

H. Compensation

You will be provided with a charge number. Since the test is anticipated to take no longer than two hours, we ask that you charge no more than two hours for your time. Should the test exceed this maximum, the test engineer will give you instructions regarding time extension. If the test is stopped due to unforeseen circumstances, i.e. weather, technical difficulties, etc., and you are still eligible for completing the testing, the test engineer will arrange a mutually agreed time for you to finish your test series.

I. Right to Withdraw from the Study and the Penalties/Hazards Associated with Withdrawal

Participation is voluntary. You have the right to withdraw from the study at any time for any reason, although we hope that you will not volunteer for the study unless you intend to complete it. There are no penalties associated with withdrawal at any time during the study. If you withdraw before completing the test, you may still use the provided charge number, only for the amount of time spent in the study.

J. Answers to Questions

If you have comments, questions or suggestions related to this study, please contact the Principal Investigator, John Pierowicz, at (716) 631-6970.

K. Remedy in the Event of Injury

The test series you are participating in will not put you in any physical or psychological danger. However, unforeseen accidents do occur and can be out of our control. Since you are a General

Dynamics employee and are getting paid for your time with a charge number, any injury you suffer is covered by Calspan Worker's Compensation Insurance.

Should emergency medical attention be needed, the test engineer has access to a cellular telephone to alert the proper authorities.

I certify that the series of test for which ____ is to serve as a subject has been explained to him or her in detail. A copy of this informed consent form will be provided to the subject.

____

Signature of Principal Investigator   Date

Part 2

Your signature below will indicate that you have decided to volunteer as a research subject; that your questions have been answered satisfactorily; and that you have read and understood the information provided above. Note that your name has not been associated in writing with your test subject number.

____

Signature of Research Participant   Date

Appendix E – Test Track Exit Interview Form

General Questions
1. Was your vision perfect tonight? If not, what was wrong?
2. Was your attention perfect tonight? If not, what was wrong?
3. How would you describe yourself as a driver?

Questions about the Test
1. What was the best thing about the test?
2. What was the worst thing about the test?
3. What could we have done to make the test better?
4. Do you like sharing the road with motorcycles? If not, why not?
5. Have you ever had problems seeing motorcycles when driving?
6. What was your *favorite* version of the motorcycle and why?
7. What was your *least favorite* version of the motorcycle and why?
7. What was the *most visible* version of the motorcycle and why?
8. What was the *least visible* version of the motorcycle and why?
9. Do you think you will look at motorcycles differently now that you have completed our study? Why or why not?
9. What do you feel would make the motorcycle and rider more visible?
10. What other kinds of light configurations do you feel would make the motorcycle and rider more visible?
11. Do you have any ideas about the Driver Perception Study you would like to draw? If so, please use the sheet of paper provided.

Appendix F – On-Road Interview Form

US Site Interview Form

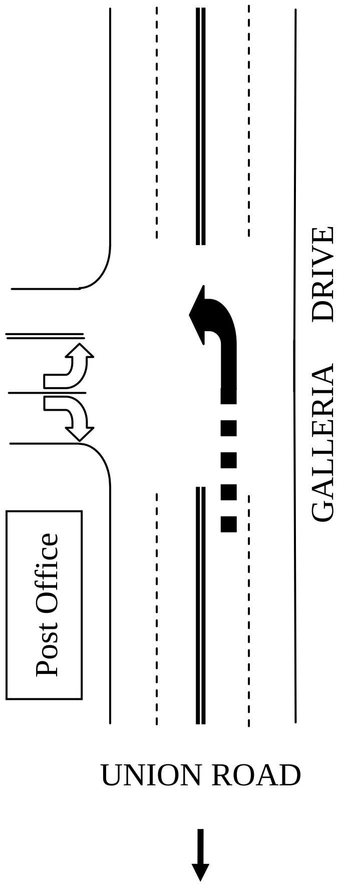
Date:________________________

Time:________________________

Treatment:____________________ Run Number:_________________

Ambient Lighting Conditions:___________________

1. “Did you see any oncoming traffic as you made the left turn off Galleria Drive?”
2. “In which lanes were the oncoming traffic?”
3. “What type of vehicle - for example SUV, truck or motorcycle - was closest to you as you made that turn off Galleria?”



Age Range

- 16-25
- 26-35
- 36-45
- 46-55
- 56-65
- 66-75
- Over 75

Gender

Male

Female

Vehicle

SUV
2-door
4-door
Truck or Van
Mini-Van

State____________

Prov_____________

Canadian Site Interview Form

Date:_________________________

Time:_________________________

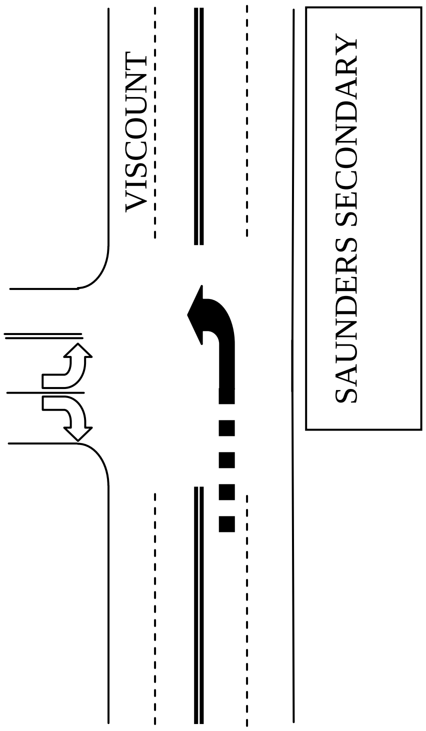
Treatment:____________________ Run

Number:__________________

Ambient Lighting Conditions:____________________

4. “Did you see any oncoming traffic as you made the left turn off Viscount?”
5. “In which lanes were the oncoming traffic?”

6. “What type of vehicle - for example SUV, truck or motorcycle - was closest to you as you made that turn off Viscount?”



Age Range

- 16-25
- 26-35
- 36-45
- 46-55
- 56-65
- 66-75
- Over 75

Gender

Male

Female

Vehicle

SUV
2-door
4-door
Truck or Van
Mini-Van

State____________

Prov_____________

Appendix G – On-Road Interview Results

The main intention of conducting the interviews was to try to assess what drivers were detecting from the traffic scene, i.e., were the test configurations noticeable and memorable? The drivers for the road study were making a left-turn into one of two shopping malls (one in the U.S. and one in the Canada) during daylight hours. Any driver who made a left turn at a designated intersection into these two malls was a potential subject. There were no age or gender criteria. It was assumed that all subjects were licensed drivers.

A series of Chi Square tests were calculated on the road test interview data. The responses to each question were assessed for associations with country and conspicuity treatment. The interview questions were as follows:

- Question 1: Did you see any oncoming traffic as you made the left turn?
- Question 2: In which lanes were the oncoming traffic?
- Question 3: What type of vehicle - for example SUV, truck or motorcycle - was closest to you as you made that turn?
- Question 4: What is you age range - 16 to 25, 26 to 35, 36 to 45, 46 to 55, 56 to 65, 66 to 75, or over 75?

Table G1 below describes each test and the result of the chi-square test. The tests showed an association with country and Questions 2 and 3 ($\chi^2 = 31.04$, $p < 0.0001$ and $\chi^2 = 13.83$, $p = 0.0316$, respectively). The tests also showed an association with conspicuity treatment and Question three ($\chi^2 = 35.89$, $p = 0.0225$).

Table G1. Chi-square tests for interview questions, with country, conspicuity treatment

Variable	Question	DF	Chi square	Probability
Country	1	2	4.0284	0.1334
	2	7	31.0437	<.0001
	3	6	13.8298	0.0316
	4	6	10.0600	0.1221
Conspicuity Treatment	1	6	6.0911	0.4131
	2	21	35.8819	0.0225
	3	18	25.8614	0.1030
	4	18	15.7761	0.6082

Figure G1 below represents the frequency of each response for Question 2 (In which lanes were the oncoming traffic?) by country ($\chi^2 = 31.04$, $p < 0.0001$). Most of the association found in the test was due to the response, “Both lanes,” followed by “Definitely passing lanes” (note: this is the correct response), with Canada respondents more accurately identifying the passing lane.

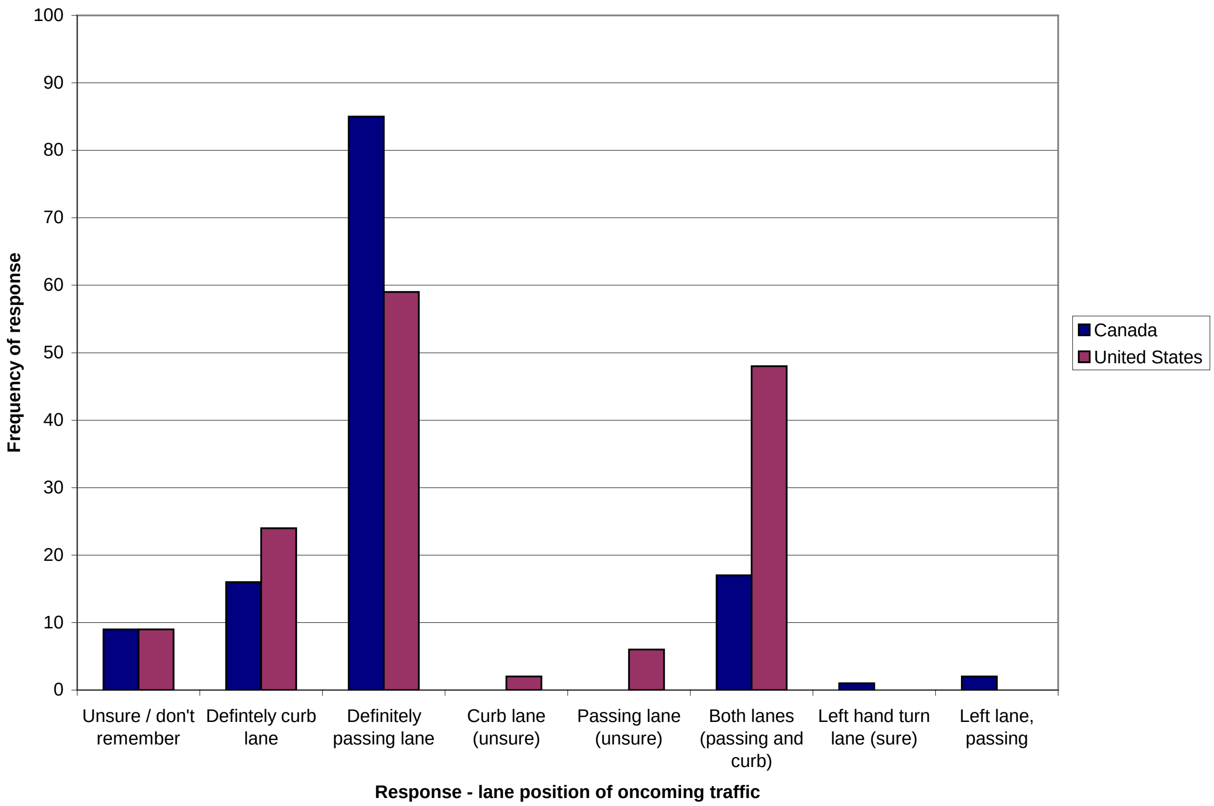


Figure G1. Response frequency for Question 2, country

Figure G2 below represents the frequency of each response for Question 3 (What type of vehicle - for example SUV, truck or motorcycle - was closest to you as you made that turn?) by country ($\chi^2 = 13.83$, $p = 0.0316$). Most of the association found in the test was due to participants responding, “Vehicles even,” with only American respondents selecting that response.

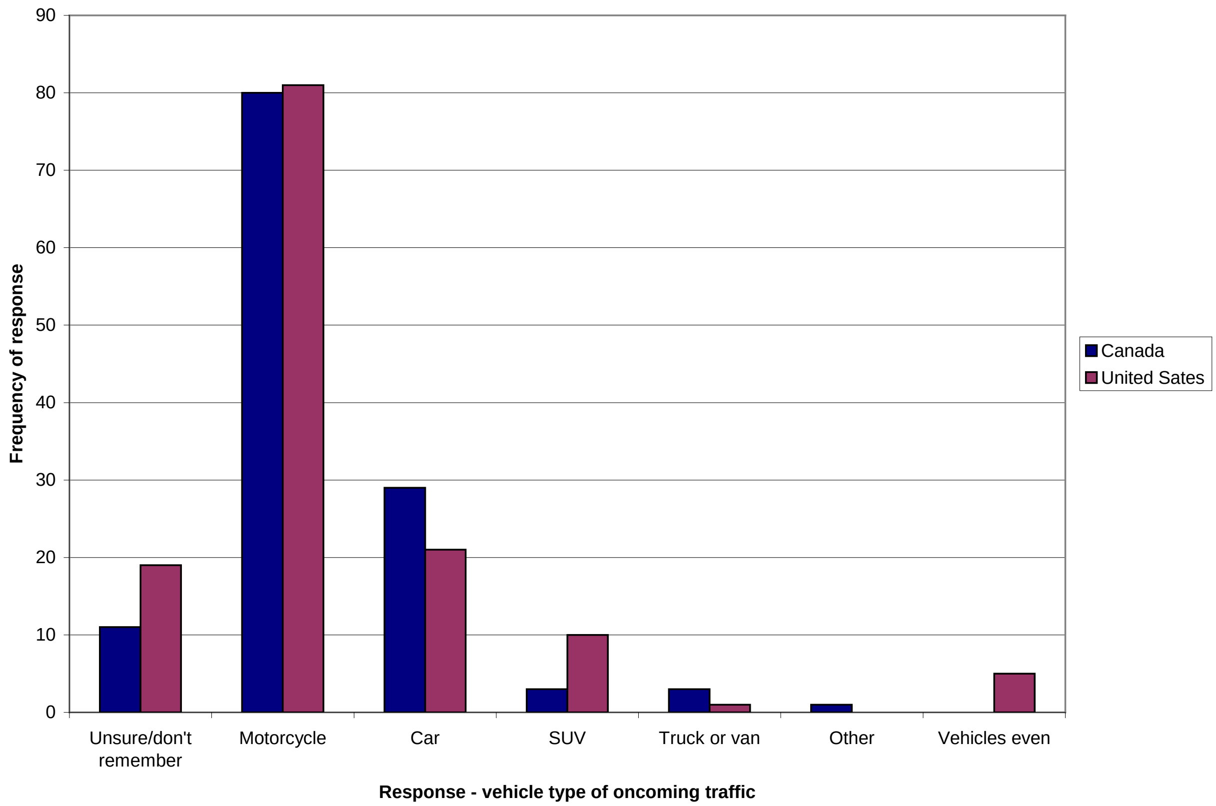


Figure G2. Response frequency for Question 3, country

Figure G3 below represents the frequency of each response for Question 2 (In which lanes were the oncoming traffic?) by conspicuity treatment ($\chi^2 = 35.89$, $p = 0.0225$). Most of the association found in the test was due to participants responding, “Unsure/don’t remember,” with Driving Lights with Lower Beam most often eliciting that response.

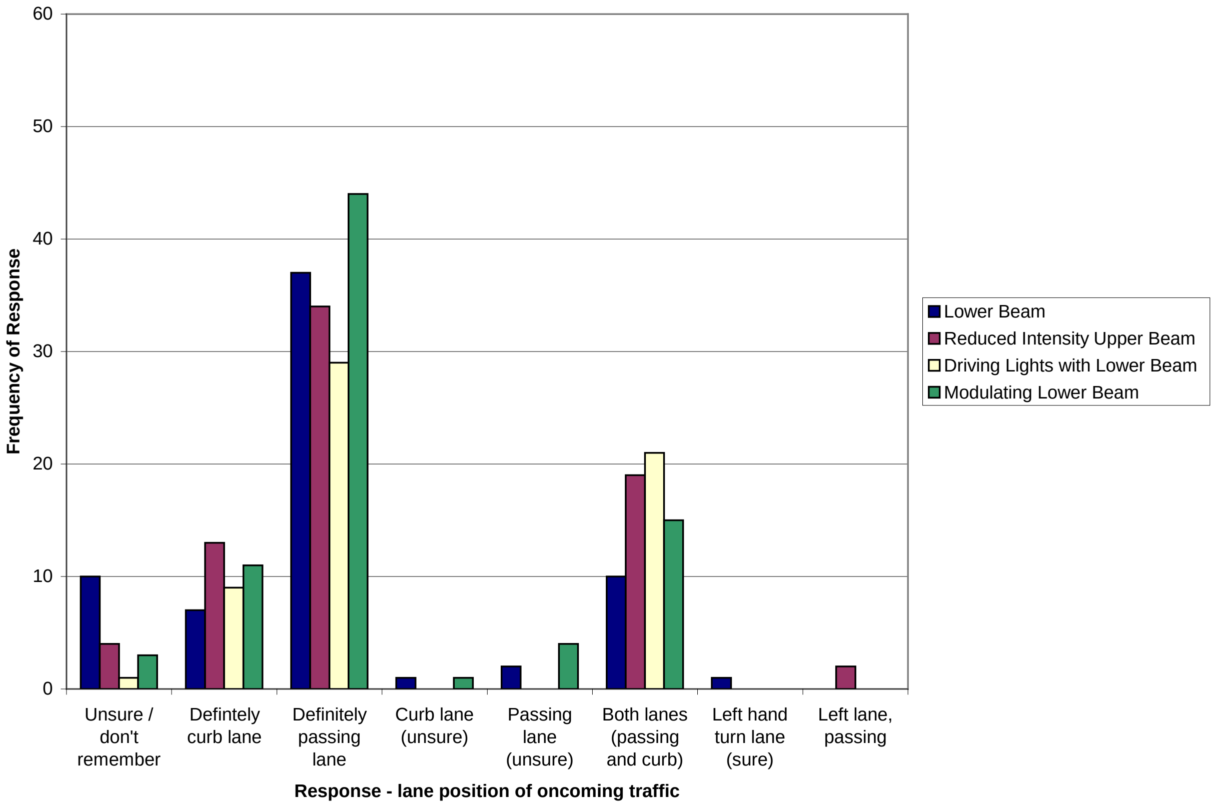


Figure G3. Response frequency for Question 2, conspicuity treatment

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Traffic Safety
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