Motorcycle Conspicuity and the Effects of Motor Vehicle Fleet Daytime Running Lights (DRLs)

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Introduction

It is widely known that motorcyclists experience a higher fatality rate per vehicle mile traveled than other road users – 27 times that of passenger vehicles (National Center for Statistics and Analysis, 2004). In 2003, more than half of all motorcycle fatalities involved a conflict with another vehicle, and 78% of the motorcycles were struck from the front (National Center for Statistics and Analysis, 2004). Researchers have hypothesized that the majority of frontal crashes are attributable to either poor speed-spacing judgment of other motorists or insufficient front motorcycle conspicuity (e.g., Olsen, 1989; Olsen, Halstead-Nussloch, & Sivak, 1979). Speed-spacing judgment refers to the accuracy in 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, and Thom, 1991)." One intention of the current research effort was to look at both speed-spacing judgment and conspicuity.

This research effort was also designed to measure whether daytime running lights (DRLs) on passenger vehicles would affect the driver's response to oncoming motorcycles. Although research has shown that headlamps increase motorcycle conspicuity (e.g., Waller and Griffin, 1977), limited research has been conducted to determine whether increased DRL use among passenger vehicles would degrade this benefit. That is, as drivers become accustomed to searching for two headlamps (i.e., another passenger vehicle), they may inadvertently "overlook" motorcycles with only one headlamp lit. To evaluate the validity of this concern, the on-road data collection was divided between 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, experiences a rate of DRL use of about 90 percent, the United States, which has no such requirement, has a DRL use rate of about 30-50 percent, both rates as measured by the current effort.

Finally, this research effort was designed to evaluate the conspicuity of newer lighting technologies that are available. Such treatments include modulating lower beams and auxiliary driving lights. It should be noted that in the United States, modulating headlamps are permissible as original equipment, however these devices are typically installed as aftermarket equipment. The objective was to determine which, if any, alternative DRL treatments might improve motorcycle conspicuity and increase the length of gaps accepted by unalerted motorists turning left in front of an approaching motorcycle.

Overview of Methodologies

This document is intended to provide a brief overview of the NHTSA Motorcycle Conspicuity evaluation. Detailed findings will be available in the final report, which is expected to be available on the NHTSA website (www.nhtsa.dot.gov) in the first half of 2006.

The current research effort was conducted in two phases, designed to evaluate both speed-spacing and conspicuity. The first phase was a test track evaluation in which participants estimated the shortest safe gap in which to turn left in front of the motorcycle and an on-road evaluation of gap acceptance (left turn across path, or LTAP). The intention of this phase was to determine which, if any, treatments influenced drivers to provide a safer gap.

This methodology was an adaptation of a method used in other research efforts, (e.g., Stroud, Kirkby, and Fulton (1980), and Nagayama, Morita, Miura, Watanabe, and Murakami (1980)). In these studies, the participant sat in a parked vehicle and pressed a button at the last moment they could initiate a turn to safely cross the path of the experimental motorcycle approaching them. Similar to previous research, the current effort evaluated the LTAP. The rationale was two fold: first, analyses of multi-vehicle motorcycle crashes indicated the LTAP was a common right-of-way crash configuration; and second, it provided congruence to the on-road gap acceptance testing, detailed below.

The second phase was comprised of two parts: an on-road assessment of gap acceptance and an interview. The goal of this phase was to determine if any of the treatments provided a safer gap in real traffic and if any of the treatments were more noticeable. The complementary testing in the United States and Canada also allowed an assessment of the impact of passenger fleet DRL use.

The gap assessment was similar to that used by Olsen et al. (1979) – data was collected in real traffic, where the instrumented motorcycle drove through an intersection where unalerted drivers could select when to turn left across it's path. The gap accepted was then recorded. Proponents of this methodology cite the fidelity of attaining a behavioral measure, as no interpretation is needed to determine how drivers will respond to the different stimuli (e.g., Thomson, 1982). However, an observation of gap acceptance does not provide insight as to which variables influenced the driver to accept the gap.

To supplement the gap acceptance data, the second phase included an interview of drivers who were observed turning left in front of the experimental motorcycle. This interview was designed to determine what elements they detected from the traffic scene. This method is similar to that used by Janoff, Cassel, Fertner, and Smierciak (1970). One criticism of this methodology is 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. This criticism was considered when designing the intercept questions.

It should also be noted that one motorcycle and one rider were used throughout the data collection effort. This procedure increased consistency throughout trials and therefore reduced variability within the data. As a result, the data collected represented the highest quality possible for this type of data.

Methodology – Test Track Evaluation

The goal of this evaluation was to narrow down the list of treatments that should be tested on-road by determining which, if any, of the motorcycle treatments increased the subject's judgments of the smallest distance at which they would feel safe to turn in front of an oncoming motorcycle. Of interest were the relative differences by which treatments could be selected for use in the on-road evaluation. The evaluation also included a subjective ranking of treatment noticeability. This test was performed at the Calspan Vehicle Experimental Research Facility (VERF) in Buffalo, New York. This facility has controlled access with sufficient space to permit the test motorcycle to reach and maintain speeds of 45 mph and greater. The facility is shown in Figure 1 below.

Figure 1. Calspan Vehicle Experimental Research Facility (VERF).

For this test, the participant sat at the simulated intersection in the driver's seat of an instrumented automobile in the opposing traffic lane adjacent to the path of the motorcycle. The motorcycle was driven towards the stationary automobile from a distance of 700 ft. (approximately 213 meters). The participant was instructed to press a pushbutton when the motorcycle was at the "last safe distance" at which the subject would initiate a left turn across the path (LTAP) of the motorcycle. The motorcycle traveled at one of two speeds: 25 MPH (~ 40 KPH) or 45 MPH (~ 72 KPH). These speeds were consistent with those used in previous speed estimation studies (e.g., Nagayama et al., 1980). Two radars were used to determine motorcycle speed and distance at which the driver activated the pushbutton. The data from the radars and the subject input was collected on a data acquisition system in the instrumented automobile. The participant was then asked to provide a subjective rating of the conspicuity of each treatment. All tests were completed during daytime conditions with the same motorcycle and rider.

Six conspicuity treatments were evaluated at both speeds:

- Reduced Intensity Upper Beam
- Modulating Lower Beam
- Dual Lower Beam
- Driving Lights with Single Lower Beam
- Enhanced Parking Lamps with Single Lower Beam
- Fork Lights with Single Lower Beam

Two baseline conditions – Single Lower Beam and a Reference Car – were also implemented. The order for testing was counterbalanced using a Latin Square design. It should be noted that parking lamps are not required on motorcycles. It should also be noted that the fork lights were LED light strips approximately 8.5 inches (~ 22 cm) long.

Results – Test Track Evaluation

Twenty-five volunteer participants completed the evaluation for each conspicuity treatment. Participants ranged in age from 25-64 years old and had 20/40 or better (with or without correction) visual acuity. All participants had valid driver's licenses, but did not have motorcycling experience.

For the evaluation, an analysis of variance (ANOVA) revealed significant differences between treatments for LTAP distances ($F = 7.841$, $p > 0.005$). A Scheffe post hoc analysis was performed to determine the specific difference between treatments. The results of the analysis are in Table 1. Means that are significantly different from each other for that dependent variable are indicated by asterisks ($\alpha = 0.05$). Note that only the lowest and highest means showed statistical significance. There were no statistical differences between the motorcycle conspicuity treatments. The participant then ranked each conspicuity treatment. High-level results are summarized in Table 1 – more detailed results will be made available in the final report.

Table 1. Mean LTAP distances (in feet), visibility ranking for each conspicuity treatment.

DRL Treatment	LTAP distance (feet)	Ranking
Reference Car	311.688*	1st
Driving Lights with Single Lower Beam	276.881	2nd
Lower Beam	275.275	7th
Reduced Intensity Upper Beam	274.613	3rd
Fork Lights with Single Lower Beam	267.181	8th
Dual Lower Beams	267.180	4th
Enhanced Parking Lamps with Single Lower Beam	266.449	5th
Modulating Lower Beam	259.518*	6th

Two conclusions can be made from viewing the results in Table 1. First, participants were conservative when estimating the last safe gap. This can be attributed in part to the alertness of participants (i.e., they knew to expect a vehicle approaching), and to the measurement itself (i.e., the measurement indicated when the participant would initiate the turn, not when they would enter the traffic flow). Because the intention was to find relative differences in treatments, this result is not considered to impact the study conclusions.

Second, because the distances were not significantly different from one another, a strong case cannot be made statistically for one treatment over another. However, two treatments – the Driving Lights with Single Lower Beam and Reduced Intensity Upper Beam – showed a trend of higher visibility, as demonstrated by having slightly longer distances, and higher subjective rankings.

Methodology – On-road Evaluation

The on-road data collection took place in two parts. The first part was a gap acceptance measure taken from unalerted drivers. The second part included a driver interview in which participants were asked questions about their perception of the traffic scene when they completed the left turn. This dual-prong approach was used to try to establish a relationship between the behavioral (gap acceptance) and the perceptual (interview questions) of drivers.

Four conspicuity treatments were tested in this evaluation - Lower Beam, Reduced Intensity Upper Beam, Modulating Lower Beam, and Driving Lights with Lower Beam (see Appendix A for pictures of each treatment). These treatments were selected for their prevalence on current motorcycles and/or their opportunity to provide motorcycles with a unique signature; it was hypothesized that a unique signature would increase safety in that it would allow drivers to immediately identify the vehicle as a motorcycle and therefore would allow them to make more accurate assumptions about that vehicle's behavior.

Data was collected at an intersection that provided access to a shopping mall. The test motorcycle traveled at the posted speed limit in the lane closest to the mall parking lot; another experimental vehicle traveled behind the motorcycle to provide a consistent background (DRL on for Canada, DRL off for the United States). When motorists began to turn left into the mall parking lot in front of the path of the experimental motorcycle, the distance from the vehicle to the motorcycle was measured and recorded. See Figure 2 below for the road configurations.

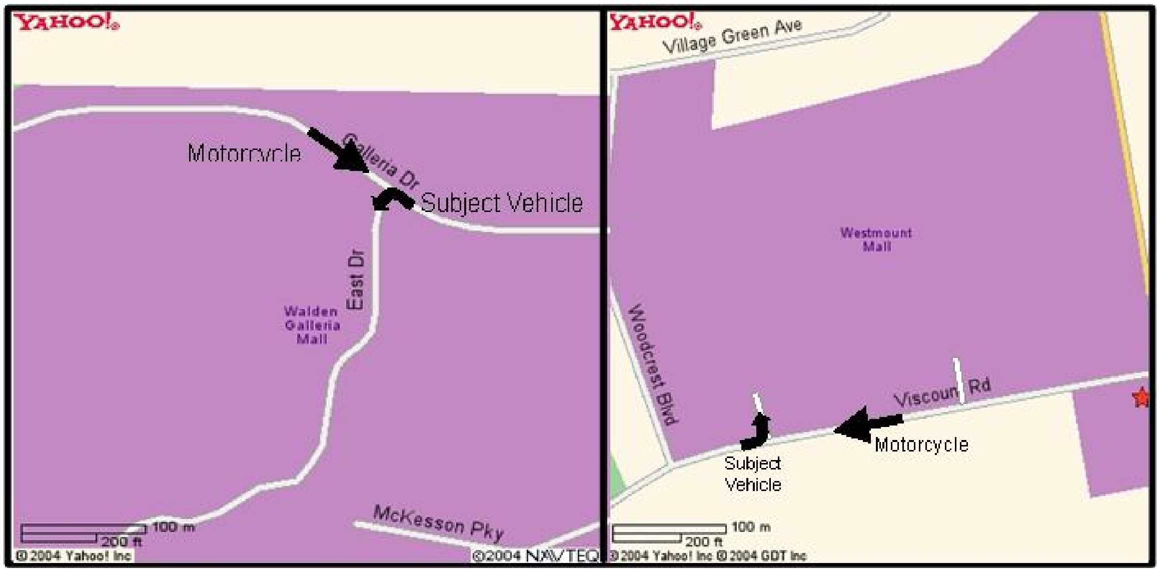

Figure 2. United States and Canadian On-road Data Collection Road Configurations.

After each of the drivers entered the mall and parked their vehicle, they were approached by the mall security officer and asked to answer a few questions for a road study. An experimenter then asked the following series of questions:

- Did you see any oncoming traffic as you made the left turn?
- In which lanes were the oncoming traffic?
- What type of vehicle was closest to you as you made that turn?
- What is your age range (16 – 25, 26 – 35, 36 – 45, 46 – 55, 56 – 65, 66 – 75, and over 75)?

The participants were then given a $5 gift certificate to the mall. Data was collected during the same time every day during the week – evenings and weekends were excluded.

The methodology was completed as described above at shopping facilities in both the United States and Canada. At each of the two locations, more than four hundred participants completed the interview. It should be noted that this method has a high compliance rate: of those drivers approached, only 13 refused to participate.

This effort also included a supplementary data collection – sampling of gaps afforded to the passenger fleet (i.e., vehicles other than motorcycles). These data were collected to provide an assessment of driving patterns for each country.

Discussion

Consistent with the findings of previous research (e.g., Nagayama et al., 1980), the speed-spacing judgment evaluation on the test track found that motorcyclists in general – regardless of the conspicuity treatment – were afforded smaller gaps than passenger vehicles. The only statistically significant difference was found between the Reference Car and the Modulating Lower Beam, which had the longest and shortest gap, respectively. Despite the shorter LTAP distance of the DRL treatments – especially the modulating headlamps – relative to the Reference Car, there was not sufficient statistical evidence to show a strong advantage to any of the treatments. Therefore, the treatments were selected for their prevalence on current motorcycles and/or their opportunity to provide motorcycles with a unique signature.

At the time of this paper, additional analyses were being conducted to supplement the current findings. These additional assessments will allow more in-depth interpretation of the gap data. The final report is expected to be available from the National Highway Traffic Safety Administration early in 2006.

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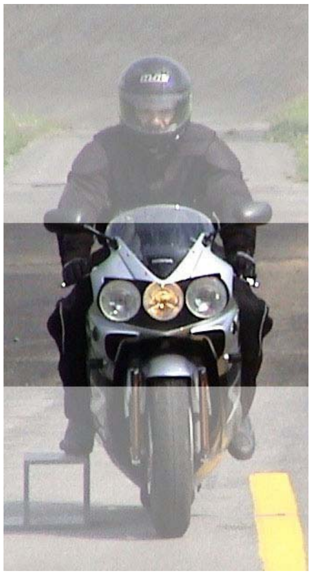
Appendix A: On-road Conspicuity Treatments



Lower Beam

Modulating Lower Beam

Reduced Intensity Upper Beam

Driving Lights with Single Lower Beam