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Differences in geometry of pedestrian crashes in daylight and darkness

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ABSTRACT

Introduction: Previous studies have shown that increased risk in darkness is particularly great for pedestrian crashes, suggesting that attempts to improve headlighting should focus on factors that likely influence those crashes. The current analysis was designed to provide information about how details of pedestrian crashes may differ between daylight and darkness. *Method*: All pedestrian crashes that occurred in daylight or dark conditions in Michigan during 2004 were analyzed in terms of the variables included in the State of Michigan crash database. Additional analysis of the narratives and diagrams in police accident reports was performed for a subset of 400 of those crashes—200 sampled from daylight and 200 sampled from darkness. *Results*: Several differences were found that appear to be related to the characteristic asymmetry of low-beam headlamps, which (in the United States) distributes more light on the passenger's side than the driver's side of the vehicle. These results provide preliminary quantification of the how the photometric differences between the right and left sides of typical headlamps may affect pedestrian crash risk. *Impact on Industry:* The results suggest that efforts to provide supplemental forward vehicle lighting in turns may have safety benefits for pedestrians.

1. Introduction

In prior research, darkness has been shown to increase a pedestrian's risk of fatality in a traffic accident by a factor of about seven (Sullivan & Flannagan, 2007). No other crash type is as strongly linked to light level as pedestrian crashes. With this in mind, there has been renewed interest within the vehicle lighting community to find ways to enhance distribution of low-beam headlighting to address the needs of pedestrians (e.g., Kosmatka, 2006; Rice, 2004). Specific concern is focused on the consequence of the bias of all low-beam headlamps to direct greater illumination toward the right side of the roadway and away from the left side, in order to reduce glare to oncoming drivers. While it is anticipated that such a bias influences pedestrian crashes, there has been little published data describing such effects (see Kosmatka, 2003).

In this study, we examine whether specific characteristics of the light distribution afforded by conventional low beam headlamps are also reflected in the geometric characteristics of the crash incidents. Because conventional crash databases are often limited in the amount of detail about a crash they support, the present analysis collected additional information from copies of the original police reports. We were primarily interested in determining whether additional information could be retrieved from the crash diagrams and narratives that would allow a more complete determination of crash configuration.

The light distribution provided by conventional low-beam headlamps is a compromise between providing sufficient seeing light for the vehicle's driver, while avoiding glare to drivers of oncoming vehicles. This has resulted in a general bias in the distribution of light downward and to the right side of the roadway. One might therefore expect that pedestrians would become less visible on the driver's side of a vehicle compared to the passenger side of the vehicle. When two vehicles are actually meeting, it is reasonable to expect that they will both be using low-beam headlamps. Thus, pedestrians on the driver's side, from the perspective of one of the vehicles, will be less strongly illuminated by that vehicle's headlamps and may also be affected by glare from the lamps of the other vehicle. However, even in nonmeeting situations, it is likely that low-beam headlamps will be used, since most drivers seldom use high-beam headlamps (Mefford, Flannagan, & Bogard, 2006; Sullivan, Adachi, Mefford, & Flannagan, 2004).

The approach taken in this report is to examine the location and direction of travel of a pedestrian relative to an approaching vehicle just prior to a crash. Unlike previously reported dark/light comparisons in which there was a strategy to control variables such as driver fatigue, alcohol involvement, and demographics using daylight saving time analyses (Sullivan & Flannagan, 2002), the analyses described in this report are not subject to the same confounds. Here we are assessing the differences in risk that are associated with direction of pedestrian approach toward an (eventually) striking vehicle in darkness compared to light. If a pedestrian's direction of travel prior to a collision is independent of time of day, fatigue level, demographics, or alcohol use, then light/dark differences in the ratios of a driver-side versus passenger-side approach might be attributed to an effect of light distribution. In the case of low-beam headlamps, in which illumination

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is biased toward the passenger side, we might expect to find a shift in the distribution of pedestrian collisions to the driver side of the vehicle in darkness when compared to the distribution in daylight.

This is not to suggest that a particular direction of approach is more risky than another in darkness or light. Merely that the *distribution* of pedestrian crashes between a driver-side and pedestrian-side approach is likely to be shifted toward the driver side when it is dark. We may find that in *both* daylight and darkness, passenger-side crashes predominate because of the relatively close proximity of a pedestrian entering a roadway to the passenger-side of an approaching vehicle. Such close proximity allows the approaching driver little time to make an evasive maneuver. On the other hand, upon entering the roadway from the left (or driver side), a pedestrian is usually at least one full lane width from the path of the approaching vehicle. This additional safety margin may often be sufficient for the approaching driver to successfully avoid a collision.

Crash datasets are generally useful in ensuring that crashes are described in a standard way so that common characteristics among crashes can be recognized and reported. However, crash datasets might fail to capture key pieces of information about a crash that could be informative either because there is no defined field for this information, or because there is no good way to express a causal chain of events that plays out over time.

Take, for example, a situation in which a pedestrian crosses a 5-lane arterial in two steps—first crossing to the middle turn lane, and then continuing the rest of the way across the street. If the pedestrian is struck in the turn lane, the pedestrian action is likely to be identified as "standing in the street." However, the fact that the pedestrian was attempting to cross the street, and that the pedestrian was likely to be in the driver-side area of the approaching vehicle just prior to a crash is unlikely to be determinable from the data coded in the database alone. If the diagram and narrative content from the original police report are consulted, we may be able to obtain other details that provide a more complete picture of the causal chain of events just before the collision occurred.

2. Method

Pedestrian crashes occurring in darkness and daylight were drawn from the 2004 State of Michigan DOT crash dataset. To simplify the crash circumstances, the sample was restricted to crashes involving only one vehicle and one adult pedestrian (18 years or older), and to include only vehicles in which the prior action had a likely causal connection to the crash (e.g., going straight, turning left, turning right, slowing or stopped in roadway). Crashes unlikely to involve forward lighting were also excluded (e.g., backing crashes, stopped vehicles, driverless vehicle crashes). Crashes were binned as occurring in daylight or dark conditions, with "dark" including lighted and unlighted dark conditions. Cases in which light conditions were coded as dawn, dusk, or unknown were discarded. The resulting dataset contained 1,240 pedestrian crash records.

From this "base" sample of crashes, 200 crashes in darkness and 200 crashes in daylight were randomly selected. The serial number of each crash was then used to retrieve a digitized facsimile of the Michigan UD-10 police report filed for each crash. Each report was reviewed alongside the corresponding crash database record for consistency. Narrative information was reviewed and the diagram was examined to retrieve supplemental information about the location and movement of the pedestrian prior to the crash.

Because the current analysis was designed to relate the light distribution originating from the striking vehicle to pedestrian risk, the geometry of the crash was recast using the striking vehicle as the primary point of reference. Although the Michigan crash dataset provides fields identifying the direction of travel for all units involved in a given crash (i.e., vehicle, pedestrian), the pedestrian direction of travel is frequently omitted from the record. Indeed, in the sample of pedestrian crashes used in this report, 75% of the pedestrian directions are reported as unknown. In examining the UD-10 reports, this information is often omitted entirely from the pedestrian report, although it may be either implied (by the orientation of a pedestrian figure) or explicitly identified (e.g., arrows) in the accompanying diagram and narrative. There are also many cases in which the prior pedestrian or vehicle direction is genuinely unknown—as in fatal hit-and-run collisions.

Even when the direction of travel of both the pedestrian and vehicle is reported, absolute geographical directions must be recast into a vehicle-relative framework. Thus a southbound vehicle colliding with a westbound pedestrian is recoded as a pedestrian approach from the vehicle's driver side, as is a northbound vehicle and an eastbound pedestrian, a westbound vehicle and a northbound pedestrian, and an eastbound vehicle and a southbound pedestrian.

The coding of a vehicle's direction of travel can also be ambiguous and misleading with respect to determining the geometric configuration just prior to the pedestrian crash. For example, an originally northbound vehicle may initiate a left turn and strike a southbound pedestrian. This is sometimes coded as "eastbound going straight" or as "northbound turning left," depending on whether the collision occurred *during* the turn or *after* the turn was completed. For the purposes of this analysis, we would like to know what kind of preview of the roadway a driver had in the seconds prior to the collision. It may matter less whether the driver was *in* the turn or had completed the turn, since we are interested in the situation seconds *before* the collision occurred. Fortunately, crash diagrams in the original police reports often include trajectories or implied trajectories of both the vehicle and pedestrian so that a more complete picture of the sequence of events can be determined. In this particular case, we would describe the scenario as a pedestrian crossing southbound on what was originally the driver's side of the vehicle executing a left turn.

With these considerations in mind, each police report was reevaluated with respect to: whether a vehicle was or had been executing a turn prior to the collision, the direction of the turn, and the direction of pedestrian travel relative to the striking vehicle.

2.1. Crash Report Recoding Procedures

The 400 selected pedestrian crashes from the MDOT-2004 crash dataset (200 occurring in daylight, and 200 in darkness) were recoded into several supplemental data fields using the UD-10. As is common with any experimental coding scheme, many of the new fields proved to be of limited usefulness in resolving crash characteristics related to light distribution. For example, the vertical position of a pedestrian was encoded with the purpose of revealing how much of that person's body may have been illuminated by the approaching vehicle's beam pattern. The vertical position of a pedestrian was identified as upright, sitting or crouching, reclined, or unknown. Among the 400 cases, only 1% (5) of the cases was identified as lying in the roadway (all in darkness), 3% (12) were identified as sitting or crouching (evenly split between darkness and daylight), and 90% (361) were identified as upright (evenly split). With such small numbers, it would take a much larger sample to resolve real differences between the darkness and daylight distributions of this attribute. Furthermore, even if it was found that pedestrian crashes in darkness involve more reclined pedestrians, several non-light-related explanations are plausible (e.g., incidence of alcohol involvement is higher at night, a person reclining in the roadway in daylight is likely to attract public attention and be removed quickly). This report will therefore restrict discussion to the supplemental data fields that proved to be useful in suggesting that low-beam light distribution might influence pedestrian crashes. These fields include:

- **Lateral position of the pedestrian:** This field identified the lateral position of the pedestrian relative to the striking vehicle just prior to the crash. Field values could be one of the following: left, right, straight ahead, or unknown.