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Public Perceptions in the United States about Automotive Headlamps: 2004-2009

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Abstract

The goal of this report is to describe the public's perceptions in the U.S. of automotive headlamps, especially in regards to headlamp visibility and headlamp glare. By examining a sample of U.S. newspaper articles published from 2004 to 2009, it is possible to get a sense of public misperceptions as well as correct perceptions about automotive headlamps. This report outlines the main areas of concern in terms of headlamp safety and describes potential areas for future study.

Keywords: ..... headlamp, visibility, glare, safety, color, weather

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ABSTRACT

The goal of this report is to describe the public's perceptions in the U.S. of automotive headlamps, especially in regards to headlamp visibility and headlamp glare. By examining a sample of U.S. newspaper articles published from 2004 to 2009, it is possible to get a sense of public misperceptions as well as correct perceptions about automotive headlamps. This report outlines the main areas of concern in terms of headlamp safety and describes potential areas for future study.

BACKGROUND

In December 2009, researchers at Rensselaer Polytechnic Institute's Lighting Research Center (LRC) used LexisNexis to search U.S. public newspaper articles on topics related to automobile headlamp visibility and glare. The search included five years (2004 to 2009) of newspaper articles.

HID Headlamps

High-intensity discharge (HID) headlamps have been incorporated as a common automotive technology for multiple reasons. For some drivers, HID headlamps might be preferred as an aesthetic alternative to traditional halogen headlamps. Because HID headlamps first began to be available on luxury vehicles, they are often perceived as an expensive feature on automobiles. However, HID headlamps are functional; they actually provide more light than halogen headlamps, especially in the visual periphery, which leads to greater visual performance (Jost 1995; Van Derlofske et al. 2003). Furthermore, light with greater spectral content in the blue or short-wavelength portion of the visible spectrum, which is common in HID headlamps, can produce shorter reaction times in detecting targets in the periphery (Van Derlofske et al. 2004). HID headlamps also tend to provide longer visibility distances than halogen headlamps (NHTSA 2008). Other draws to the lights are their energy efficiency (while a halogen headlamp works at 55W, an HID headlamp only uses 35W), and their longer operating life (an HID headlamp lasts 3,000 hours compared to 1,000 hours for a conventional halogen headlamp).

Despite these advantages, drivers approaching HID headlamps on the roadways have complained that the technology causes discomfort and reduced visibility. Due to the outcry about this issue, the National Highway Traffic Safety Administration (NHTSA) began a multi-year investigation in 2001 to examine the safety of these lights. One outcome of this study showed that HID headlamp glare was "noticeable but acceptable" to a majority of drivers (Singh and Perel 2003). Further investigations have shown that other factors may be causing the discomfort glare. For instance, one study indicated that higher mounting heights may be contributing to the glare problem, and that by lowering the mounting height of the headlight unit, disability glare may be reduced. (NHTSA 2008). Another study indicated that misalignment of the headlights may cause glare (Bullough et al. 2008). Throughout all these studies and investigations, it became evident that there is no direct evidence to support that HID headlamps cause an increased amount of accidents (NHTSA 2007). Nonetheless, drivers continue to cite HID headlamps as a major source of discomfort while driving.

Because of the height difference between sport utility vehicles, pickup trucks, and vans, commonly referred to as land transport vehicles (LTVs), and standard-sized sedans, LTV headlamps can be mounted so that they shine brightly into the rearview mirrors of smaller vehicles. A 1999 study by the SAE Lighting Committee (NHTSA, 49 CFR Part 571) showed that historically, between 3 and 6 lx of light typically illuminated side mirrors with sealed beam headlamps and early replaceable-bulb types using transverse bulb filaments. However, side mirrors are now illuminated to more than 50 lx with the advent of axially-oriented bulbs in newer replaceable-bulb headlamps, when the headlamps are 12 inches higher than the mirror (NHTSA, 49 CFR Part 571). This is a common height difference between car mirrors and LTV headlamps. Consequently, the amount of glare has increased exponentially since LTVs have

been introduced to the market. It should be noted that this issue is not specific to HID headlamps since most LTVs in the U.S. use halogen headlamps.

Complaints about the HID headlamps providing more light are somewhat founded. Typically, HID lamps produce two to three times more luminous flux than comparable halogen lamps (Jost 1995; Van Derlofske et al. 2001). HID headlamps offer about 3000 lumens and 90 mcd/m2 versus halogen lamps which offer 1400 lumens and 30 mcd/m2. Federal Motor Vehicle Safety Standard (FMVSS) No. 108 regulates the amount of illumination required on each vehicle, but many illegal HID conversion kits exceed these limits. According to one investigation, the NHTSA found a kit exceeding the maximum allowable candlepower by over 800% (Officer.com). Such intensities might very well be creating visual discomfort, especially in the eyes of older drivers who have increased glare sensitivity and photostress recovery time (Mainster and Timberlake 2002). However, the majority of HID headlamps are original equipment that meets FMVSS 108 requirements.

A number of measures have been put into place by manufacturers to prevent headlamp intensity from bothering other drivers. Headlamps are not designed to direct intense light upwards, such as towards the rearview mirrors of the vehicle in front of them. Rather, the headlamps should have a beam pattern that allows the brightest light to illuminate the roadway and offer less light shining upwards. Despite their design, headlamps may be knocked out of alignment if the automobile is in an accident or hits a significant bump in the road. Misalignment of headlamps is frequently cited by car experts in the newspaper articles reviewed as a key cause of headlamp glare, and correctly so. A 2008 study indicated that while most new vehicles had both headlamps properly aimed, most in-use vehicles had at least one headlamp out of alignment (Bullough et al. 2008). In Europe, manufacturers have equipped a self-leveling feature in HID headlamps, although this method is not commonly used by all manufacturers for HID headlamps in the U.S.

"Wipers on, Lights on" Legislation

While the public seems dissatisfied with the glare created by HID lamps, the public does agree on the effectiveness of the "wipers on, lights on" legislation passed among many states. Several states require headlamps to be on either when windshield wipers are on or during inclement weather (e.g. rain, snow, fog). Table 1 indicates which states have adopted this law and which have not.

Table 1: A state-by-state listing of those that have adopted a "wipers on, lights on" law, as of April 2010.

State	Require Headlamps during inclement weather or when wipers are on?		Note
	Yes	No	
Alabama	Yes		§ 55-9-401.
Alaska		No	When visibility is less than 1000 feet. Headlamp use required on all highways.
Arizona		No	28-922. When visibility is 500 feet or less.
Arkansas	Yes		Section 27-36-204.
California	Yes		Statute 24400.
Colorado		No	When visibility is less than 1,000 feet.

State	Require Headlamps during inclement weather or when wipers are on?		Note
	Yes	No	
Connecticut	Yes		Section 14-96a.
Delaware	Yes		§4331.
Florida	Yes		316.217
Georgia	Yes		O.C.G.A. § 40-8-20. When raining.
Hawaii		No	§291-25.
Idaho		No	49-903. When visibility is less than 500 feet.
Illinois	Yes		According to DMV guide.
Indiana		No	IC 9-21-7-2 When visibility is 500 feet or less.
Iowa	Yes		Bill HF02101.
Kansas	Yes		8-1703.
Kentucky		No	189.030.
Louisiana	Yes		
Maine	Yes		§2067.
Maryland	Yes		§22-201.2.
Massachusetts		No	1-14-90-7.When visibility is less than 200 feet.
Michigan		No	257.684 When visibility is less than 500 feet.
Minnesota	Yes		Statute 169.48.
Mississippi		No	Sec. 63-7-11 When Visibility is less than 500 feet.
Missouri	Yes		Section 307.020 RSMo. Supp. 2004.
Montana		No	61-9-201 When visibility is less than 500 feet.
Nebraska		No	60-6-221 When visibility is less than 200 feet.
Nevada		No	NRS 484D.100 When visibility is less than 1000 feet.
New Hampshire		No	Section 266.31.When visibility is less than 200 feet.
New Jersey	Yes		NJSA 39:3-46.
New Mexico	Yes		Wipers on, headlamps on, or when visibility is 500 feet or less.
New York	Yes		§ 375.
North Carolina	Yes		§ 20-129.
North Dakota	Yes		39-21-01.
Ohio	Yes		4513.03.
Oklahoma		No	As of 2/2/2010 bill just passed the Senate. SB1831.
Oregon		No	816.040 When visibility is 1000 feet or less.
Pennsylvania	Yes		Section 4302.
Rhode Island	Yes		Section 31-24-1.
South Carolina	Yes		Section 56-450.
South Dakota		No	32-17-4. When visibility is 200 feet or less.
Tennessee	Yes		55-9-406.
Texas		No	Section 547.302. When visibility is 1000 feet or less.
Utah		No	41-6a-1603. When visibility is 1000 feet or less.
Vermont		No	§1243. When visibility is 500 feet or less.
Virginia	Yes		§ 46.2-1030.
Washington		No	RCW 46.37.020. When visibility is 1000 feet or less.
West Virginia	Yes		§17C-15-2.
Wisconsin		No	347.06.
Wyoming		No	31-5-910. When visibility is 1000 feet or less.

There is a great deal of ambiguity in these laws, which can easily cause confusion with the driving public. For instance, stating that headlamps are needed “when visibility is 1000 feet or less” is not only impossible to enforce, but difficult for any driver to quantify.

Most articles examined in this study showed support for this law, and many articles were reminding the public to adhere to this law during poor weather. Drivers can not only see the roadway better with headlamps on during rain and snow, but perhaps more importantly, illuminated headlamps allow for other motorists to see one another better as well.

Whether HID headlamps produce higher levels of reflected light from wet roadways is not well understood. Because the HID headlamps do provide more light than traditional halogen lights, the new light sources may create more of this reflected glare. However, most of the articles reviewed during this study do not specifically cite weather-related glare as an issue. The general public seems to overwhelmingly support legislation requiring headlamps on during poor weather.

METHOD

Researchers ran two keyword searches using Lexis-Nexis: (1) headlight/headlamp and glare, and (2) headlight/headlamp and visibility.

The search brought back more than 100 articles related to each type of search. Researchers reviewed these articles to evaluate which key topics were emphasized, in order to provide a snapshot of the issues of primary interest to the driving public in the U.S.

RESULTS

HEADLAMP GLARE

Figure 1 shows the top-rated topics relating to headlamp glare.

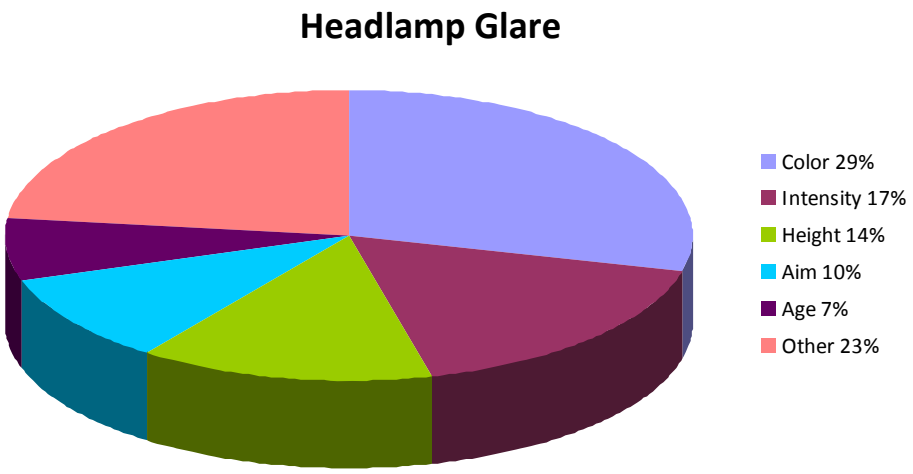

Figure 1: Headlamp Glare-Related Topics

Color

The color of headlamps was the primary concern noted in the glare-related newspaper articles. Figure 2 shows the top-rated glare concerns related to color. Authors cited that the blue-white color of HID headlamps reduced visibility (35%), caused annoyance (29%), created discomfort (24%), and were distracting (12%).

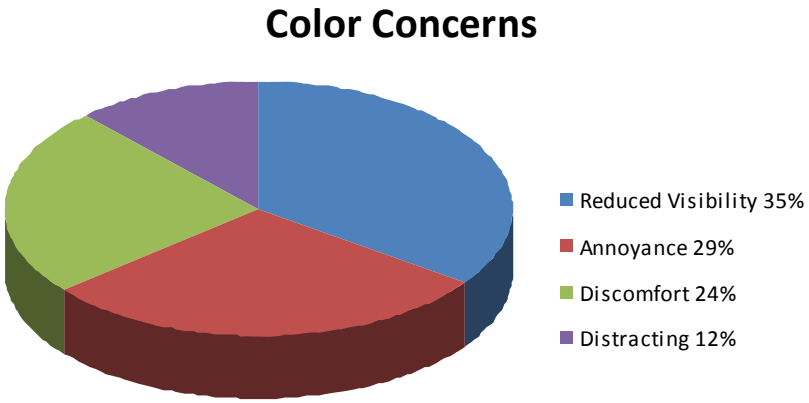

Figure 2: Headlamp Glare Concerns Regarding Color

Predominantly, the articles vocalized concerns about the blue-colored HID headlamps. One article clearly articulated the author's concerns that, "research has suggested the blue tint causes about 46 percent more glare than clear bulbs without increasing the light emitted. 'There is no advantage to blue lights, period,' he said" (Gridlock 2005).

Another article vocalized a similar concern, this time ripe with descriptive language to illustrate the author's point: "For decades, automakers used headlights that shine in the yellow, easy-on-the-eyes end of the color spectrum. However, xenon-gas-ignited HID lights pour out light on the harsher blue end of the spectrum. Even factory-installed HID lights can surprise and hurt the eyes of oncoming drivers, a University of Michigan study found" (Rose 2008). The author is making a very direct point by using "easy-on-the-eyes" to describe halogen headlamps and "harsher" and "surprise and hurt" to describe HID headlamps.

A less biased article simply mentioned that "The U.S. Department of Transportation asked the public in 2001 for comments on headlight glare...on the specific matter of HID headlights, the researchers hypothesized that their blue color was more sensitive to the eyes, and their novelty attracted attention" (Fellone 2007).

One article cited that "by law, headlights are supposed to be white, but it is difficult to cite someone using blue headlights because the color is so close to white. The law says 'any hue of white.'" There are, in fact, limits on the color of headlamps in terms of their chromaticity. FMVSS 108 requirements for headlamps cite the color standard of the Society of Automotive Engineers (SAE). Nonetheless, it is difficult to judge whether a light near the acceptable boundary between white and "non-white" meets the requirements without specialized measurement equipment.

Some complaints from the public regarding HID headlamps may reflect the increased discomfort that these lamps produce compared to halogen headlamps, but it should be noted that HID headlamp illumination does not reduce visibility any more or less than halogen illumination of the same intensity (Bullough et al. 2003).

Intensity

The intensity of headlamps was another major concern described in the articles. Figure 3 shows the top-rated glare concerns related to intensity. Authors noted that the intensity of the lights caused reduced visibility (80%), increased crashes (10%), and annoyance (10%).

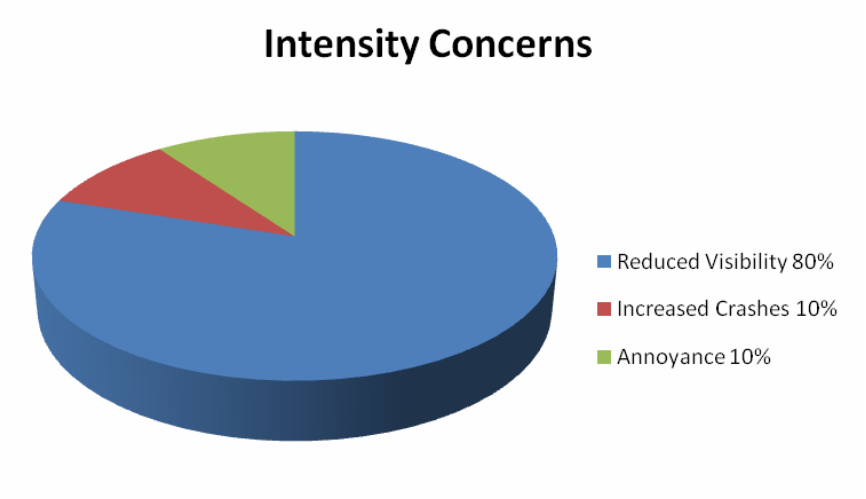

Figure 3: Headlamp Glare Concerns Regarding Intensity

Despite studies that have shown that changes in headlamp design have improved night vision while driving, including improvements in intensity (Mace 2001; Skinner and Bullough 2009), the public is largely biased against HID headlamps. Similar to the color concerns, the commentary about intensity was fairly direct: "HID lights are, in short, unnecessary," said one journalist (Fetzer 2007).

Another pointed article stated that "'freakishly bright headlights...are very dangerous...' 'They actually blind you is what they do'" (Schmidt 2007). Furthermore, in the effort to pinpoint what, exactly, is wrong with HID headlamps, one journalist said "According to the ongoing [NHTSA] investigation, the data, so far, indicates the 'blue bulbs' and HID conversions presently on the market may not be in compliance because of the higher wattage" (Hoeker 2008).

Although many opinion articles expressed dislike of the HID headlamps, most automotive experts pointed out that "...according to our sources at the NHTSA, they haven't found any hard evidence yet that these headlights are actually causing accidents" (Magliozzi et al. 2006). Hence, the claims by the public that HID headlamps cause accidents is largely unfounded.

Mounting Height

One documented reason that the headlamps cause glare is because of the varying heights of the headlamps. LTV headlamps can more readily shine into the eyes of shorter vehicles. Figure 4 shows the top-rated glare concerns related to height of the headlamps. Journalists sited reduced visibility (75%), discomfort (12%) and distraction (12%) caused by headlamps shining into their rearview mirrors from behind.

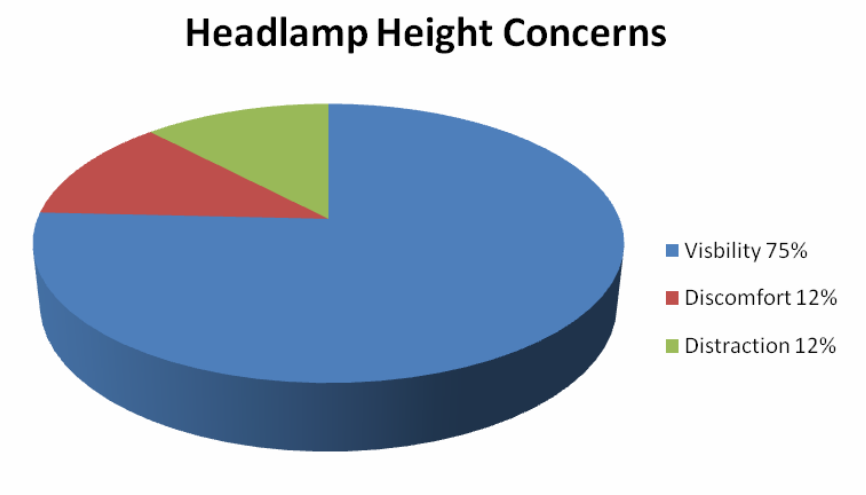

Figure 4: Headlamp Glare Concerns Regarding Headlamp Height

Most journalists were aware that the mounting height of headlamps was just one of many factors causing headlamp glare. "Blinded by the light: there is a glaring problem with the blinding headlights that automobile drivers are faced with, particularly from oncoming SUVs. While these drivers may have great vision, they're blinding the rest of us. One would think that designers would keep these safety issues in mind when they're at the drawing board. There should be a standard height for headlights on all vehicles" (Beaven 2007).

While some letters to the editor were merely complaints, most articles actually attempted to proactively offer solutions. "There are several theories as to what can be done to reduce the glare from HID headlights. Some have suggested that lights of that intensity need to be mounted lower so they don't shine into the eyes of oncoming drivers" (Magliozzi and Magliozzi 2006). Another article by the same authors reiterated the idea: "In terms of the mounting height, there are people who believe that carmakers are allowed to mount headlights too high, and that lowering the height requirement for headlamps might really help cut down on glare from oncoming traffic" (Magliozzi and Magliozzi 2005).

Headlamp Aim

Although headlight height is cited as a cause of glare, many car experts informed the public that improperly aimed headlamps can also cause lights to flash in driver's eyes. Figure 5 shows the top-rated glare concerns related to aim of the headlamps. Articles cited reduced visibility (85%) and distraction (17%) caused by improperly aimed headlamps.

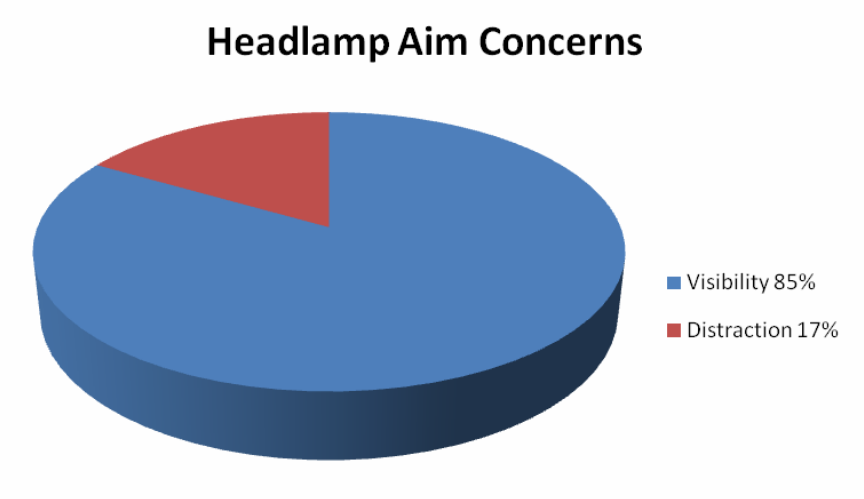

Figure 5: Headlamp Glare Concerns Regarding Headlamp Aim

Headlamp aim is recognized, correctly (Bullough et al. 2008; Skinner et al. 2010), as one of the leading problems causing glare from headlamps. Most of the reviewed articles acknowledge that this is a problem. For instance, one article states that "...poor headlight aim also appears to be a widespread problem. A minor accident or other incident can easily knock a headlamp out of proper alignment" (Schmidt 2007). Many articles offering tips on minimizing glare recommended visiting a local automotive technician to ensure that one's car headlamps are aimed properly.

"'There are two reasons a headlamp will glare another driver...Either the lamp is out of proper aim, or the other driver did not dim his lamps as required by state law...How do you force everyone to keep headlamps and fog lamps aimed correctly and ensure that they dim their lights at the correct times while driving? ...The state police said the blinding has more to do with the headlights' angle than brightness. 'I'm not aware of there being any problems with drivers who have 'double lights' as long as they are adjusted properly when on low beam" (Gridlock 2009).

Some articles mentioned alternative methods that municipalities and government were taking to help alleviate headlamp aim concerns. For instance, one article discussed a concrete median barrier installed to cut down on headlamp glare (Shartin 2004) and other articles cited landscaping and other appurtenances to help block headlamp glare from oncoming traffic.

VISIBILITY ISSUES

Figure 6 shows the top-rated topics relating to headlamps and visibility:

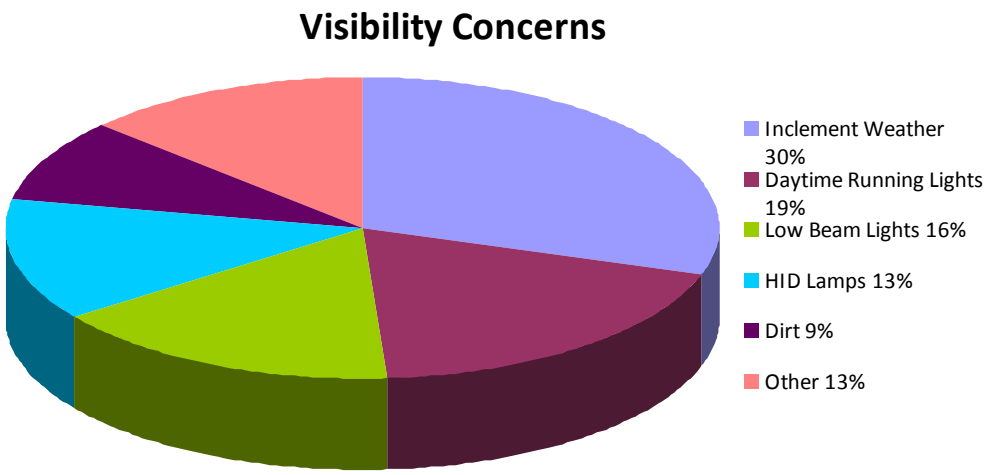

Figure 6: Concerns Related to Visibility from Headlamps

Inclement Weather

Inclement weather was the most frequently cited concern about visibility while driving. Many of the articles discussed newly-adopted legislation requiring headlamps to be on during times of inclement weather – the so-called "wipers on, lights on" laws. Many of those articles that were not reminding the public about this law commented that this common-sense driving strategy should be a law. Overwhelmingly, the public commented that this law made sense and approved its adoption.

Most articles were simply reminding the public about the "wipers on, lights on" laws, such as this article by the Maryland Gazette: "'It is never advantageous to be in a hurry (or) speeding while it is raining,' he said. 'Reduce your speed and use your headlights – after all it's the law'" (Rawlyk 2007) and the Patriot Ledger: "heavy rains, dark skies, fog and flooded roads all contributed to some precarious driving situations...Despite these adverse conditions, some drivers neglected to turn on their headlights. Would it be possible for the newspapers and media to once again encourage people to turn their lights on for safety?" (Libby 2006).

Other articles tried to illustrate why rain can be so dangerous to driving. A Hartford Courant article described an accident where a pedestrian was hit by a school bus. It was dark and raining; the bus had the headlamps on, but the pedestrian was wearing dark clothing. The darkness and weather were blamed in part for the accident: "visibility is diminished by the darkness, by the rain, the wet roads" (Munoz 2009).

Other articles voiced similar concerns about the dangers of rain. For example, they describe "...problems with headlight glare particularly on rainy nights when the rain on the windshield seems to disperse the glare across wider portions of the field of view. The wipers don't seem to help at all. It can be dangerous on Route 22, for instance, while cruising along at 60 or so and bounded by multiple tractor-trailers, trying to discern which lane you're in. You're forced to back way off the accelerator. Which isn't necessarily a bad thing, of course. But providing the clearest possible vision should be the goal of any good traffic engineer" (Hartzell 2007).

"Glare is dangerous and prevents people from seeing danger ahead. If you have contacts or eye correction and age, glare makes it even harder to see. Glare kills night vision by making pupils smaller and darkening the area around glaring light. Rainy weather, look out kid, you're going to be run over!" (Chattanooga Times Free Press 2008).

Daytime Running Lights

Despite the overwhelming support for the "wipers on, lights on" laws, there was in the newspaper articles a great deal of confusion over whether daytime running lights (DRLs) would meet the requirements for the "wipers on, lights on" law. For instance, the Philadelphia Inquirer states that "The law's language is a little foggy however. It does not explicitly require full headlamps, so daytime running lamps – not to be confused with parking lights – are acceptable" (Kabada 2007). On the other hand, the Telegraph Herald (Dubuque, IA) states that "daytime running lamps or fog lamps are not enough. Drivers must have their low-beam headlamps, tail lamps, and side marker lamps on in any low-visibility situation" (Collins 2008.). In fact, the mixed information about DRLs also illustrate that drivers are confused about what constitutes DRLs—some writers indicated that they thought parking lights were the same thing as DRLs.

Analysis of the articles showed that 89% of the articles regarding DRLs were concerned with the conspicuity of DRLs, and approximately 11% of the DRL articles praised the technology for reducing crashes (11%). One article stated that "most studies estimate that 'daytime running lights' reduce the number of accidents 5 percent to 9 percent" (Lange 2007). A notable amount of praise-worthy articles concerning DRLs related to motorcycles and their legal requirement to have DRLs on at all times.

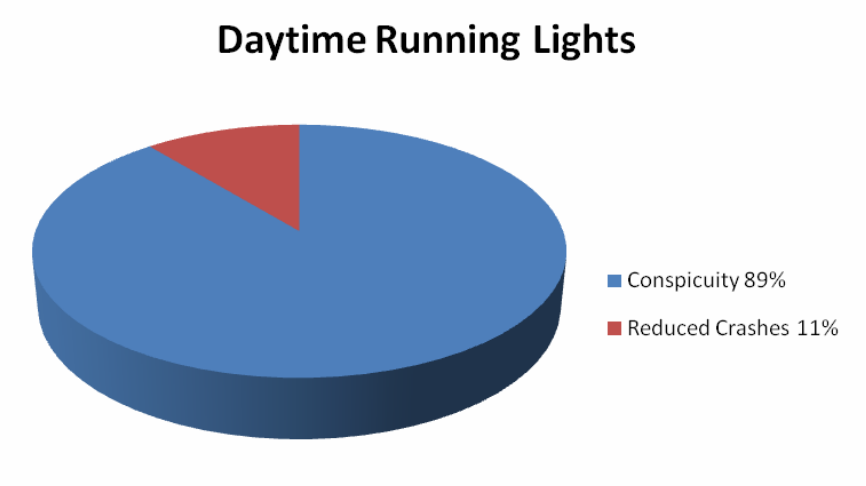

Figure 7: Headlamp Visibility Concerns Regarding Daytime Running Lights

Most journalists and editorials were in support of DRLs. One Seattle article sums this sentiment up well: "Daytime running lights are separate from regular headlights and are aimed higher to help ensure better visibility so that drivers see them; standard headlights... are aimed at the road. Initially there were complaints about glare from 'daytime' lights 'but they've worked those out'" (Lange 2007).

Other articles claimed that while DRLs are nice, they are not enough; a few articles advocated for the use of low-beam headlamps during the daytime. "Legislators of our state should generate a bill to establish a requirement to automotive manufacturers that future vehicles modify the lighting system to turn lights on when the ignition is turned on! Many vehicles are manufactured now with daytime running lights, which are good in clear weather, but are much smaller than headlights and not adequate for inclement weather lighting. Also the DRLs provide nothing to the rear of the vehicle" (Vallejo Times Herald 2008).

Many articles extolled the benefit of DRLs on motorcycles, including one Kalamazoo article that said, "riding with headlamps on, even during the day, and wearing bright colors such as yellow or red increases riders' visibility" (Kalamazoo Gazette 2009). Many of these positive articles mentioned that modulating DRLs are even more effective in enhancing motorcyclists' safety. "The modulating headlights, which alternate between high and low beam six times a second, are designed to increase the motorcycle officers' visibility to other motorists and prevent accidents" (Anderson 2008). Yet another article campaigned for modulating DRLs on motorcycles to be a requirement: "A flashing headlight will draw the eye of the driver of an approaching vehicle. We, as bikers, should demand from the motorcycle manufacturer that this modulating be standard equipment" (Gunderson 2009).

Despite the fact that the articles are, by and large, positive towards the use of DRLs, the way in which the articles describe the DRLs may be confusing to some readers. Some articles describe DRLs as dim daytime headlamps, others simply describe them as DRLs, while other articles go on to talk about how they compare to low beam and high beam headlamps. For instance, the following article could prove to be confusing to some readers who are unfamiliar with the difference between DRLs and low-beam headlamps, especially when discussing the "wipers on, lights on" law: Many articles say that "driving with headlights on low beam provides better road illumination in snow and fog than using high beams" (Omaha World-Herald 2008), but this might be misconstrued into reading DRLs versus regular headlamps. Providing clearer differentiation of the different lighting options available on automobiles may help curb some confusion on this topic.

Low Beam Headlamps

Low beam headlamps were frequently cited in articles related to visibility. 75% of the articles explained that low beam lights improved visibility in fog and snow whereas 19% of the articles cited the potential for "overdriving" them and 6% of the articles mentioned that low-beam lights reduced crashes in foggy weather. Overdriving refers to driving at such a speed that one's stopping distance is greater than the illumination distance of his or her headlamps.

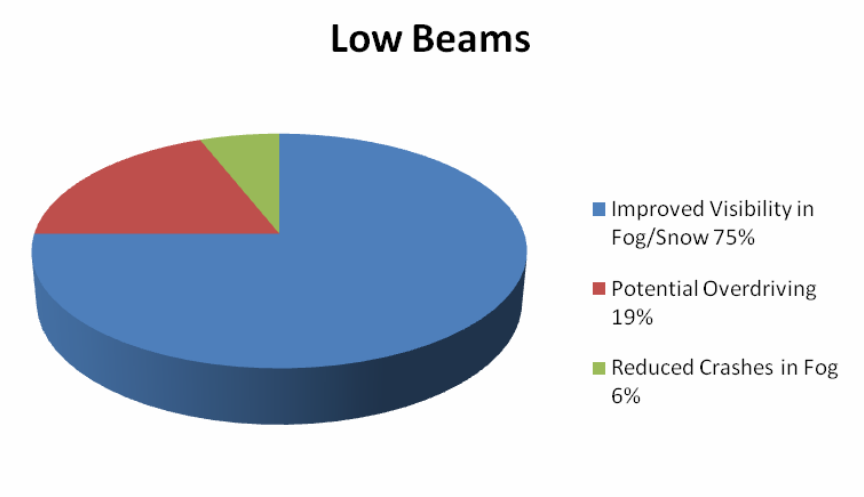

Figure 8: Concerns Related to Visibility: Low Beams

Overall, the articles seemed to understand that low-beam headlamps are effective in some scenarios, but in other scenarios they do not provide enough illumination.

In rain and inclement weather, low-beam headlamps are recommended. In fact, it was often stated that low-beams provide optimal visibility. In fog: "use low beams and fog lights," said one article (Asbury 2009). In smoke: "drive with lights on low beam. High beams will only be reflected back off the smoke and actually impair visibility even more" (Pacheco 2009). Low-beams are also preferred in snow: "Driving with headlights on low beam provides better road illumination in snow and fog than using high beams" (Omaha World-Herald 2008). One curious and probably misguided article recommends wearing sunglasses along with low-beam headlamps during low-visibility times: "Improve visibility. Leave headlamps on low beam at night when driving in snow or fog to minimize reflection and glare. And wear quality sunglasses, preferably with polarized lenses, to help highlight changes in the terrain and road surface even in low visibility conditions" (Massey 2008). Most of these articles extolled the benefits of low-beam headlamps and commended them for their ability to deter collisions in poor visibility conditions.

In nighttime driving applications, low-beam headlamps were recommended only when other automobiles are present. Otherwise, high-beam headlamps were recommended. "When following another vehicle, keep headlights on low beams so other drivers are not blinded" (Walker 2007).

As stated in the section previously about DRLs, for motorcycles, most writers agree that requiring low-beam headlamps while the motorcycle is in operation is a good thing. However, some articles would agree that DRLs adequately provide this requirement.

Despite the fact that the majority of the articles demonstrated a positive attitude towards low-beam headlamps, a few articles were not as favorable. A Cleveland article commented that low-beam headlamps were ineffective. "A big part of the nighttime problem is low-beam headlights... an internationally known safety research from Sweden wrote in a 2003 Society of Engineers technical paper, 'The low-beam system is a compromise between good illumination and limited

glare. The result is that neither visibility nor glare is as good as drivers would like'" (Jensen 2006).

One article pointed out that driving with your headlamps on "may decrease your fuel economy by one percent." The article further went on to say to "stop using those energy-hogging headlights at night" (Magliozzi and Magliozzi 2009).

Overdriving one's headlamps was also a topic of concern. "Don't drive beyond your headlights," said one article from Maine (Miller 2007). However, there was very little discussion regarding what speeds would be appropriate for different headlamp levels. Conversations about exact speeds were nonexistent. "Headlamps are not strong enough for the speeds that we drive at," said one journalist (Barrett 2007). What speeds the author were referring to were left up to the reader to interpret. Only one article gave a very vague guideline: "Low beams typically are aimed down to illuminate the area just ahead of the car. Drivers at night can quickly surpass the sweep of their headlights at speeds as low as 35 mph" (Grand Rapid Press 2005).

High-Intensity Discharge Lamps

Twelve percent of the visibility-related articles focused on high-intensity discharge lamps as a point of concern. Of these articles, most claimed that HID headlamps improved visibility (77%), were preferred over traditional headlamps (15%), and were praised for their longer life (8%).

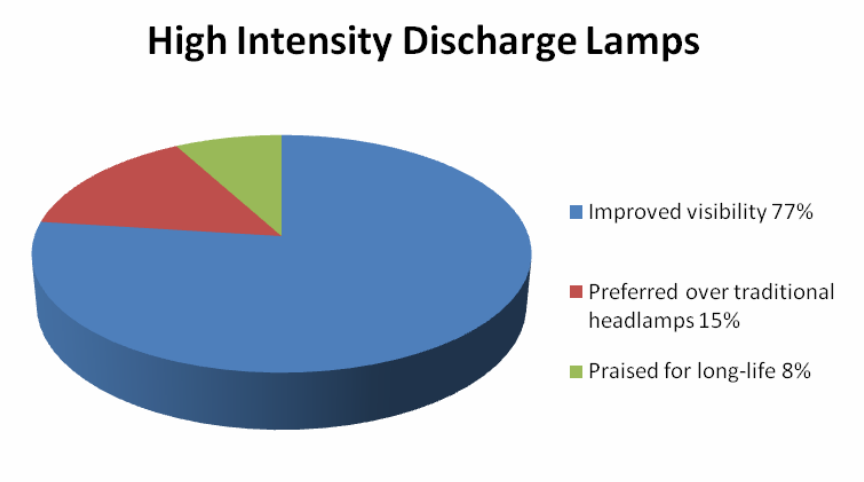

Figure 9: Concerns Related to Visibility: High-Intensity Discharge Lamps

The amount of articles discussing visibility-related concerns with HID lamps were few. For instance, one writer commented that he liked the HID lamps because it allowed him to see further; some stated that they "...recommend premium lights, though some suggest the brighter headlights can be disturbing to other drivers. 'I can see that argument'...[but HID headlights] project 'a clearer light, so it travels farther'" (Holliday 2005).

Other articles were not as positive. One author commented, "'They look good on black cars, but they're annoying when I'm driving towards somebody who has them...' 'It looks like they're driving with their high beams on'" (Yochum 2006).

Another writer vocalized the same sentiment a little more pointedly: "I'm writing about overly bright headlights....they are technically xenon or high-intensity discharge headlights. Well, I'm writing to let you know that when a car is coming at me with those lights, it feels like lasers are piercing my retinas! I detest those things. And yes, I do put my brights on when a car approaches me with those on. I doubt they get the message, but it makes me feel better" (Magliozzi and Magliozzi 2005).

DISCUSSION

The articles reviewed in this report demonstrate the public's concerns over headlamp glare and visibility concerns associated with vehicle headlamps. The two most pressing concerns appear to be the color of the headlamps creating glare and inclement weather negatively effecting visibility.

The information provided in this report demonstrates that there are several important areas where gaps in the public's knowledge exist and where future study would likely be fruitful:

- Color, intensity, height, and aim are top-ranked factors associated with glare. Color is blamed for visibility, discomfort, and distraction. More studies need to be done to determine whether the color of an automobile's headlamps can be correlated to positive or negative driving performance or safety. Scientific evidence suggests that discomfort is "real" (Bullough et al. 2002, Bullough and Van Derlofske 2003) but there is little evidence to back up that headlamps reduce visibility. Whether the color of headlamps are "distracting" is even less clear.

- A number of U.S. states have recently proposed or passed legislation requiring use of headlamps in rain or inclement weather, and many articles were published as reminders that these laws are in effect. Because the states are pretty evenly split on whether it is required as a law or not, more could be done to alert drivers of these laws, especially when traveling across state lines. In addition, it might be possible to investigate the safety effects of these laws. Many of these laws could be clarified, such as the visibility/distance requirements. Furthermore, it may be helpful to evaluate the safety of wiring automobiles so that when the wipers come on, low-beam headlamps or DRLs automatically turn on. This was recommended as a standard feature in vehicles in some articles.

- Driving in inclement weather (fog, snow, and rain) received much attention. HIDs were recognized as providing improved visibility during poor weather, but there were many complaints about the glare that HIDs cause, especially with regard to the color of HID headlamps. More research can be done to determine whether HIDs are safer than incandescent lights or if they cause more glare in times of inclement weather.

- Headlamp aim was frequently cited as a major cause of glare on the roadways, and correctly so, given the present status of headlamp aim in the U.S. (Bullough et al. 2008; Skinner et al. 2010). Because there are so many headlamps out of alignment, more could be done to promote proper headlamp aim, either in the automotive industry to enable headlamps to auto-adjust or correct themselves as a safety measure, or through requirements for checking and correcting mis-aim, or creating increased awareness of headlamp aim as an important factor.

- There was a great deal of confusion over the many types of headlamps available on cars (headlamps, high beams, fog lamps, auxiliary lights, etc.). The articles reviewed contained conflicting instructions to drivers about which headlamps to use at which time, and which lights comply with state laws (such as the "wipers on/lights on" laws) and which do not.

More could be done to clarify and distinguish between the headlamp types and when it is appropriate to use each type of headlamp.

- Further study could be completed to more clearly define the driving speeds at which one would not "overdrive" his or her headlamps. There was widespread speculation that "overdriving" one's headlamps are possible, but there was a great deal of ambiguity over what those speeds and headlamp levels may be.

- These articles do not discuss LED headlamps at all. Because this is an emerging technology, more could be done to alert the public of the pros (and cons) of using LED headlamps in one's automobile.

- The driving public is vocal about the glare and even sensations of pain associated with viewing high beams from oncoming traffic. Studies could be done to determine the feasibility of turning off high beams when other headlamps are detected, or even reducing high beam intensity in a localized portion of the beam pattern (Skinner and Bullough, 2009) as a standard safety feature.

- The mounting height of headlamps on larger vehicles was frequently cited as a cause of glare and lack of visibility for oncoming traffic. Research is needed to investigate the feasibility of making lower headlamp mounting heights a standard feature on all vehicles, especially LTVs and vehicles with larger heights.

- DRLs on motorcycles were cited in the literature as a positive safety feature, and many articles lauded the safety effects of modulating DRLs. Research is needed to investigate the feasibility and safety of making modulating DRLs a standard feature on all motorcycles.

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REFERENCES

Anderson, P. 2008. Police cycle headlights confusing some drivers. Topeka Capital-Journal, August 20, 2008.

Asbury, J. 2009. Socked in: Weather-related crashes close I-15 for hours. The Press Enterprise, June 11, 2009. Pg. A01.

Barrett, R. 2007. Vision quest: Technology to help drivers see better. Milwaukee Journal Sentinel, June 7, 2007.

Beaven, S. 2007. The unbearable heaviness of lights. The Oregonian, February 19, 2007.

Bullough, J. D., N. P. Skinner, R. P. Pysar, L. C. Radetsky, A. M. Smith and M. S. Rea. 2008. Nighttime Glare and Driving Performance: Research Findings, DOT HS 811 043 [report to the National Highway Traffic Safety Administration]. Washington, DC: National Highway Traffic Safety Administration.

Bullough, J. D., Z. Fu and J. Van Derlofske. 2002. Discomfort and disability glare from halogen and HID headlamp systems (SAE paper 2002-01-0010). Society of Automotive Engineers 2002 World Congress, Detroit, MI, March 4-7. In Advanced Lighting Technology for Vehicles, SP-1668 (pp. 1-5). Warrendale, PA: Society of Automotive Engineers.*

Bullough, J.D. and Van Derlofske, J. 2003. Shedding Light on Glare. Optical Engineering Magazine, 3(6): 17-18.

Bullough, J. D., J. Van Derlofske, P. Dee, J. Chen and Y. Akashi. 2003. An Investigation of Headlamp Glare: Intensity, Spectrum and Size, DOT HS 809 672 [report to the National Highway Traffic Safety Administration]. Washington, DC: National Highway Traffic Safety Administration.

Chattanooga Times Free Press. 2008. Letters to the editor. Bobby Thompson. City lights cause dangerous glare. Pg. G3.

Collins, W. 2008. Use lights while driving in fog. Telegraph Herald, January 14, 2008.

Fellone, F. 2007. Drivetime Mahatma: Headlights rain or fog; It's the law. Arkansas Democrat-Gazette, December 22, 2007.

Fetzer, M. 2007. High-tech high beams blinding us with science. University Wire, March 7, 2007.

Grand Rapid Press. 2005. Letter to the editor. Gentex beaming over new headlight; Breakthrough automatically controls low and high beams. January 11, 2005. Pp. C1.

Gridlock, D. 2005. Blue-tinted headlights not all created equal. Inland Valley Daily Bulletin, May 16, 2005.

Gridlock, D. 2009. Gridlock Guru: Six troopers Ubiquitous? Impossible. Arkansas Democrat-Gazette, April 24, 2009.

Gunderson, J. 2009. Installation of headlight modulator could help prevent motorcycle accidents. Kalamazoo Gazette, July 2, 2009.

Hartzell, D. 2007. Screen out rubbernecking on Rt. 22? Why do you look? Morning Call, August 13, 2007.

Hoeker, M. 2008. Headlights cause glare but are legal to use. Muskegon Chronicle, February 26, 2008.

Holliday, B. 2005. Too bright or just right. The Pantagraph, February 4, 2005.

Jensen, C. 2006. Staying safe in the dark; Auto industry uses technology to help drivers see better at night. Plain Dealer, February 16, 2006.

Jost, K., "Anatomy of high-intensity discharge headlamps," Automotive Eng., (Nov.): 38, 1995.

Kadaba, L. 2007. Pa's bright idea: Lights in the rain; If your windshield wipers are on, your headlights must be, too, under a law taking effect tomorrow. The Philadelphia Inquirer, January 28, 2007.

Kalamazoo Gazette. 2009. Editorial. What a driver doesn't see can kill somebody. June 14, 2009.

Lange, L. 2007. Daytime headlights indeed can save lives. The Seattle Post-Intelligencer, July 30, 2007.

Libby, V. 2006. Turn on car lights. The Patriot Ledger, July 13, 2006.

Lighting Research Center. 2008. Summary Report of NHTSA's Forward Lighting Research Program. DOT HS 811 007. [report to the National Highway Traffic Safety Administration]. Washington, DC: National Highway Traffic Safety Administration.

Mace, D; Garvey P, Porter R, Schwab R, Adrian W. 2001. "Countermeasures for Reducing the Effects of Headlight Glare." Prepared for AAA Foundation for Traffic Safety. Found online at: http://www.aaafts.org/pdf/HeadlightGlare.pdf [accessed 11 June 2010].

Magliozzi, T. and R. Magliozzi. 2005. I got the blues in the night (over high-intensity headlights). Pittsburgh Post-Gazette, July 31, 2005. Pp. K-8.

Magliozzi, T. and R. Magliozzi. 2006. Tell feds about those irritating, bright blue headlights. The Seattle Post-Intelligencer, June 23, 2006.

Magliozzi, T. and R. Magliozzi. 2009. Click & Clack: Savings vs. Safety. Washington Post, May 31, 2009.

Mainster, MA and GT Timberlake. 2002. Why HID headlights bother older drivers. Br J Ophthalmol. 87(10): 113-117. Online at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1771460/ [accessed 11 June 2010].

Massey, S. 2008. Get car, mind ready for old man winter. Pittsburgh Post-Gazette, January 2, 2008.

Miller, K. 2007. Summer brings moose to roads; Drivers can lessen odds of collision. Bangor Daily News, July 2, 2007.

Munoz, H. 2009. Civil trial begins in bus fatality. Hartford Courant, July 15, 2009.

National Highway Traffic Safety Administration. U.S. Department of Transportation. February 2007. Report to Congress. Nighttime glare and driving performance. Available online at: http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2007/Glare_Congressional_Report.pdf [accessed 01 July 2010].

National Highway Traffic Safety Administration. U.S. Department of Transportation. July 2008. Summary Report of NHTSA's Forward Lighting Research Program. DOT HS 811 007. Available online at: http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2008/811007.pdf [accessed 01 July 2010].

National Highway Traffic Safety Administration. U.S. Department of Transportation. 49 CFR Part 571. Docket No. 01-8885; Notice 01. RIN 2127-AH81. Glare from Headlamps and other Front Mounted Lamps. Federal Motor Vehicle Safety Standard No. 108; Lamps, Reflective Devices, and Associated Equipment. Online at: http://www.nhtsa.dot.gov/cars/rules/rulings/glare.html [accessed 11 June 2010].

Officer.com: The source for law enforcement. http://forums.officer.com/forums/showthread.php?t=94511 [accessed 11 June 2010].

Omaha World-Herald, 2008. Letters to the editor. Preparedness is the watchword for safe road travel in wintry weather: Driving tips. December 9, 2008, pp. 01B.

Pacheco, W. 2009. Superfog, a serious danger to motorists, is subject of intense study. Orlando Sentinel, March 16, 2009.

Rawlyk, H. 2007. Rain multiplies road dangers. The Maryland Gazette, October 27, 2007.

Rose, J. 2008. HID blindness: The bright light blight. The Oregonian, December 8, 2008.

Schmidt, S. 2007. Whose bright idea was this? Drivers see hazards in high-intensity headlights. The San Diego Union-Tribune, March 26, 2007.

Shartin, E. 2004. Purpose of pike barriers is twofold. The Boston Globe, December 12, 2004.

Singh, S. and Perel, M.. 2003. Drivers' perceptions of headlight glare from oncoming and following vehicles, DOT HS 809 669 [report to the National Highway Traffic Safety Administration]. Washington, DC: National Highway Traffic Safety Administration.

Skinner, N. P. and J. D. Bullough. 2009. Visual recovery and discomfort following exposure to oncoming headlamps (reprint of SAE paper 2009-01-0546). Society of Automotive Engineers International Journal of Passenger Cars - Mechanical Systems 2(1): 745-749.

Skinner, N. P., J. D. Bullough and A. M. Smith. 2010. Survey of the present state of headlamp aim. Transportation Research Board 89th Annual Meeting, Washington, DC, January 10-14. Washington, DC: Transportation Research Board.

Vallejo Times Herald. 2008. Letters to the editor. Chuck Begrin. Turn those lights on!

Van Derlofske, J., D. Dyer and J. D. Bullough. 2004. Visual benefits of blue-coated lamps for automotive forward lighting (reprint of SAE paper 2003-01-0930). Society of Automotive Engineers 2003 Transactions Journal of Passenger Cars - Mechanical Systems 112(6): 933-940.

Van Derlofske, J., J. D. Bullough and C. M. Hunter. 2001. Evaluation of high-intensity discharge automotive forward lighting (SAE paper 2001-01-0298). Society of Automotive Engineers 2001 World Congress, Detroit, MI, March 5-8. In Lighting Technology Developments for Automobiles, SP-1595 (pp. 1-7). Warrendale, PA: Society of Automotive Engineers.

Van Derlofske, J., J. D. Bullough and C. M. Hunter. 2003. Visual benefits of high-intensity discharge automotive forward lighting (reprint of SAE paper 2002-01-0259). In Advances in Lighting Technology, PT-98 (pp. 249-254). D. J. Holt, editor. Warrendale, PA: Society of Automotive Engineers.

Walker, J. 2007. As night falls earlier, be more alert on roads. Richmond Times Dispatch, November 5, 2007.