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Summary Report of NHTSA's Forward Lighting Research Program

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This document summarizes the current research activities and subsequent reports being completed by the Lighting Research Center at Rensselaer Polytechnic Institute for the National Highway Traffic Safety Administration. The research program addresses both disability, meaning reduced visibility, and discomfort, the sensation of annoyance or even pain that drivers may experience from glare.

Assessment of Headlamp Glare and Potential Countermeasures: The Effects of Headlamp Mounting Height

Overview: This project examined the effects of headlamp mounting height on the sensation of discomfort caused by glare. This project also evaluated how glare from different headlamp types (high intensity discharge [HID], and halogen) and different mounting heights affect object detection and visibility distance.

Approach: This was performed through a field test and a computer simulation study. In the field test, subjects evaluated the discomfort glare from oncoming and following headlamps with different mounting heights and different intensity of headlamps. Two analyses were performed using computational models of visual performance to evaluate the effect of mounting height and beam pattern on object detection distance.

Findings: As the headlamp mounting height of an oncoming vehicle increases, the increased glare resulted in greater discomfort and reduction of visual performance, mainly increased reaction times to detect objects and decreased detection distances. Another finding was that, in general, the HID headlamps used in the analysis provided longer seeing distances in the presence of glare than the halogen headlamps. However, this evaluation proved that there are exceptions, e.g., one halogen headlamp with a low mounting height provided the longest detection distance in the presence of glare. This was due in part to its beam pattern that produced high illumination in the forward direction.

What we learned: The findings show that while lower mounting heights may reduce glare, they may also reduce detection distance. The study also showed that because beam patterns interact with mounting height to affect visibility and glare, glare can be reduced through changes in the headlamp light distribution.

Status: This report was published on the NHTSA Web site in June 2008.

Sensitivity Analysis of Headlamp Parameters Affecting Visibility and Glare

Overview: The goal of this research effort was to evaluate the extent to which disability glare (i.e., a reduction in seeing distance) and discomfort glare (i.e., a reduction in comfort) are affected by various factors including headlamp type (halogen or HID), mounting height, and mis-aim.

Approach: A computer model of visual performance was used to assess the extent to which disability and discomfort glare are affected by headlamp light source type, mounting height, optical system type, alignment type, and mis-aim.

Findings: Key findings included:

- For visibility (in the absence of oncoming glare), HID headlamps provided longer visibility distances than halogen headlamps in general, which is consistent with their generally higher light levels.
- Lamp type had a significant effect on discomfort glare, with HID headlamps receiving worse ratings than halogen headlamps.
- Lower mounting heights reduced the amount of disability glare for the two-lane, straight-road driving scenarios that were evaluated.

What we learned: Many factors contribute to glare, including aim, lamp type, and mounting height. In particular, interactions with aim often magnified the effects of lamp type and mounting height. Based on these findings, we can summarize that no one approach is a "silver bullet" for reducing glare. In addition, many of the glare reducing countermeasures would decrease seeing distance by lowering the headlamp intensity in certain directions. Therefore, to accommodate the widest array of driving situations, advanced forward-lighting systems could have the potential to change the beam intensity depending on the situation.

Status:
A draft report has been received by NHTSA and is expected to be published by the end of summer 2008.

Visual Recovery and Discomfort Following Exposure to Oncoming Headlamps

Overview:

The presence of oncoming headlamps in the field of view temporarily increases the visual adaptation level, resulting in reduced visual capability for a short time following headlamp exposure when the visual system re-adapts to a lower light level. This project was designed to measure the effects of dosage (defined as the combination of illuminance at the eye, and the amount of time the driver was exposed to the glare) of light received at the eye on visual recovery and subjective discomfort.

Approach:

During a field experiment, participants were exposed to glare, and then the time to detect objects was recorded. Additionally, participants provided subjective ratings of glare.

Findings:

The dosage had a statistically significant effect on recovery times, with the conditions with the higher dosage resulting in longer recovery times. Older participants had a longer recovery time than did younger. Dosage did not affect discomfort glare, but did correlate with the peak light intensity.

What we learned:

Because recovery time depends on the total illuminance received during the time a person is exposed to glare during an encounter with an approaching vehicle, glare control needs to focus on the entire beam pattern, not just peak intensity limits.

Status:

A draft report has been received by NHTSA and is expected to be published by the end of summer 2008.

Advanced Forward-Lighting System (AFS) Prototype Development and Evaluation

Overview:

Currently, vehicle headlamps have two beam patterns - a high beam and a low beam. The high beam pattern is designed with forward visibility in mind and has little glare control; therefore it should be used the absence of nearby traffic. The low beam was designed to balance forward visibility against glare to other drivers, making it ideal in the presence of other traffic. The objective of this study is to examine the reaction of drivers to a concept for an advanced forward-lighting systems (AFS), which can provide beam patterns that place a lot of light to the front of the vehicle (to increase visibility) but reduce the amount of light to other drivers.

Approach:

A prototype AFS was developed to emphasize glare reduction. Field tests were then used to compare the AFS against a low beam and high beam in terms of object detection (i.e., reaction time) and discomfort glare.

Expected Findings:

Preliminary analyses indicate that the AFS can be designed to maintain visibility while reducing glare, relative to a high beam.

What we expect to learn:

The results of this study should provide an indication of the potential benefits of a glare reducing AFS.

Status:

The report has not been submitted to NHTSA, but is expected to be published in fall 2008.

Headlamp Aim Study

Overview:

While many studies, including several mentioned in this report, emphasize the importance of headlamp aim on glare and visibility, little is known of the current rate of alignment in the passenger vehicle fleet. A pilot aim study sponsored by NHTSA showed that two-thirds of vehicle headlights were not aimed properly. This current study expands on this initial effort.

Approach:

Vertical aim measurements for low-beam headlamps were made for more than 100 vehicles currently owned or leased and operated by individuals, and for 20 new vehicles (measured at a new-car dealership).

Expected Findings:

Similar to the pilot study, the results from this study are expected to provide an indication of the mis-aim on a sample of vehicles which can be used to assess the expected contribution of mis-aim to glare.

What we expect to learn:

This study is designed to determine whether better control of aim should be considered as a potential countermeasure for glare in the passenger fleet. The study will also be able to help determine whether there are systematic differences in headlamp aim among different headlamp types or vehicle types.

Status:

The report is expected to be published by the end of summer 2008.

Driving Behavior Study

Overview:

A previous research effort found that when exposed to glare, drivers consistently altered their driving behavior (i.e., speed, position in the lane). This effort was designed to expand on those findings to better assess driver behavior in the presence of glare and as a function of historic crash risk in different locations.

Approach:

Subjects drove through two similar intersections during nighttime study sessions using a vehicle instrumented to measure speed, throttle, braking, head movements, light level on drivers' eyes, and light exposure on the forward-facing side of the interior rear-view mirror. The two intersections were rated by the New York State Department of Transportation as having different levels of crash risk, based on crash data available for the past few years. Regression analyses will be conducted to determine which performance measures (speed, throttle, brake, head movement and subjective ratings) are related to crash risk in intersections.

A second study further evaluated the relationship between exposure to glare and driving behavior.

Expected findings:

Preliminary analyses indicate that some behaviors may be related to crash risk, including changes in throttle and head movement, and that a subset of these behaviors appear to be related to headlamp glare.

What we expect to learn:

As one approach to identify metrics that can be used to evaluate the effects of glare, the study will provide a preliminary assessment of the sensitivity of various measures of driving behavior in response to glare levels and further to relate these measures to crash risk.

Status:

The report is expected to be published by the end of fall 2008.

Real-World Measurement of Oncoming Headlamp Illumination

Overview:

This study measured and compared the real-world intensities of different headlamp types and vehicle mounting height factors.

Approach:

In order to measure the characteristics of oncoming illumination from representative vehicles in real-world conditions, a novel approach was developed to sample a large number of passenger vehicles using an array of sensors and detectors to simultaneously measure illuminance and chromaticity values at a typical oncoming-driver viewing position. The beam cut-off height and headlamp height were also estimated.

Expected findings:

Early results indicate a weak relationship between mounting height and illuminance at the oncoming drivers' eye positions. The relationship between aim and oncoming-driver eye illumination level appears to be somewhat stronger. The large differences arising from headlamp condition (e.g., new/clean versus old/damaged), and variations in vehicle position appear to account for more variance in the data than either mounting height or aim.

What we expect to learn:

Because headlamp height, cut-off height and oncoming-driver eye illuminance were measured simultaneously on a sample of vehicles, this data will help determine the extent to which mounting height and aim affect glare for oncoming drivers in real-world settings.

Status:

The report is expected to be published by the end of summer 2008.

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