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Summary of Headlamp Research at NHTSA

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Background: As a result of many complaints from the public about headlamp glare, NHTSA initiated a multipronged research program to examine the reasons for the complaints as well as possible solutions. In addition the legislation known as SAFETEA-LU (Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users) included a requirement to develop recommendations for reducing glare based on a study of "the risks associated with glare to oncoming drivers, including increased risks to drivers on two-lane highways, increased risks to drivers over the age of 50, and the overall effects of glare on driver performance."

Objectives: There are many possible reasons why drivers might be complaining about glare. The most obvious reason appears to be the increasing prevalence of high-intensity discharge (HID) lighting systems. However, there are several additional, more fundamental factors that can be hypothesized as contributing to glare. These include the light color, the novelty of a differently appearing light, the beam pattern distribution, higher mounting height, smaller headlamps, mis-aim, and lamp intensity. Thus, the objective of our research program is to understand how these factors affect driver nighttime visibility and response to glare.

Approach: Multiple studies were conducted using field measurements, laboratory studies, computer analyses, and instrumented vehicle tests to examine the effects of different headlamp factors on driver performance.

Summary of findings to date:
With respect to headlamp factors that affect glare and possible solutions, our available studies have shown the following:

- Discomfort ratings increased due to bluish color of HID, but disability glare effects (i.e., reductions in seeing distance) were only influenced by lamp intensity.
- Higher lamp intensity attracts drivers' visual attention, not the bluish color of HID lamps.
- Increasing mounting height increased discomfort ratings to oncoming drivers and in rearview mirrors, but only had a minor effect on reducing seeing distance.
- Upward mis-aim can significantly increase both discomfort and disability glare. Our measurements of real-world aim from a small sample of vehicles suggest that although some lamps are aimed high, many lamps are actually aimed low. Drivers having vehicles with headlamps aimed too low will have shorter seeing distance.
- The effect of different beam patterns and intensity levels on visual recovery time was studied. Older people had longer recovery times, but there were no differences between the age groups in terms of rated discomfort. Their discomfort ratings were determined by the peak intensity but their detection of roadway objects was affected by the duration of exposure to light. This implies that restrictions on maximum luminous intensity at isolated points in the beam pattern is not sufficient to minimize glare recovery. The total exposure of drivers to the passing beam pattern affects recovery.
- Analyses of a sample of different beam patterns found that in general HID lamps are more intense than halogen headlamps, but some data indicates that there are individual

variations in optical designs that can result in some halogen headlamps having more intensity directed at oncoming drivers or in rearview mirrors than HID lamps. Because HIDs are more intense, they can be more glaring when mis-aimed or when driving on curved or hilly roads.

- One potential solution to reducing glare without lowering the vision of drivers using the "glaring headlamp" is an adaptive lighting system that adjusts intensity automatically in response to the presence of nearby vehicles. Our research explored this concept in two ways: lowering intensity when high ambient lighting from street lights is sensed; and reducing the intensity of the beam pattern in the direction of an oncoming or nearby lead vehicle. Both approaches showed promise but more research is needed to determine the effectiveness of this concept and its practicality.

The implications of our findings to date are that:

- Light levels are a compromise. A glare source to one driver is a source of seeing light to another driver.
- Discomfort ratings of glare are a somewhat different phenomenon than the effects of glare on driver visual performance.
- The relation of light levels and glare to crash risk can not be quantified directly. Thus, other metrics of safety need to be used.
- Based on these proxy measures, minor improvements in glare reduction and visual performance may be possible with new aim control requirements, control of excessive mounting height, and updating the NHTSA lighting standard to tighten control of glare.
- There is potential for additional improvements using advanced forward lighting technology which can automatically adjust the beam intensity to reduce glare in the direction of nearby vehicles. However, this is a long-term, costly solution.

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