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16. Abstract

This study was designed to compare the illuminated surface areas of HID and tungsten-halogen low-beam headlamps in the U.S. A sample of 20 tungsten-halogen lamps and 17 HID lamps for model year 2000 vehicles in the U.S. was examined. The illuminated surface area was determined using a modified version of an ECE method for evaluating the illuminated surface of signaling devices. The main finding is that the HID low beams generally have smaller illuminated surface areas than do the tungsten-halogen low beams. Because smaller light sources result in more discomfort glare (presumably via greater luminance), the present finding suggests that the smaller illuminated area is one reason for drivers reporting more discomfort from HID lamps. An implication is that the increased discomfort from HID lamps could be reduced by increasing their illuminated surface area.

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INTRODUCTION

High-intensity discharge (HID) headlamps produce more light than tungsten-halogen headlamps and therefore hold great promise for improving nighttime traffic safety (e.g., Sivak et al., 2002a, 2002b). However, ever since their introduction over a decade ago, there has been concern that because of their spectral power distribution they may produce more glare than halogen headlamps. Indeed, laboratory studies (e.g., Flannagan et al., 1989, 1991) and field studies (e.g., Flannagan et al., 1992) have shown that the same amount of illuminance from HID lamps produces more discomfort (i.e., subjective) glare. Importantly, however, HID lamps do not increase disability (objective) glare (Flannagan et al., 1999).

Current HID headlamps tend to direct *less* light towards oncoming drivers than do current halogen lamps. This has been shown for the low beams in the U.S. (Sivak et al., 2002b) as well as in Europe (Grimm and Hamm, 2001), partially counteracting the increased sensitivity to discomfort from HID illumination. Nevertheless, drivers (especially in the U.S.) continue to complain about glare from HID headlamps. The purpose of this study was to evaluate the hypothesis that the increased discomfort glare from HID headlamps on the road is partly a consequence of their smaller illuminated surface area. This hypothesis is based on a previous finding that the same amount of illuminance is more discomforting when it comes from a smaller apparent source (e.g., Sivak et al., 1988; Alferdinck and Varkevisser, 1991, Manz, 2001; but see Flannagan, 1999). In other words, the previous research tends to show that discomfort glare is influenced by the luminance of the light source. Consequently, if HIDs are indeed smaller, the increased discomfort could partly be explained by their higher luminance, and discomfort-glare complaints could be reduced by increasing their illuminated area.

METHOD

Approach

To quantify the illuminated surface area of each headlamp, we used a modified version of a procedure described in ECE Regulation 48, Paragraph 2.9.2 (ECE, 2001). The ECE procedure was designed to determine the illuminating surface of signaling devices, but conceptually matches the aim of this study. Specifically, the ECE procedure defines the illuminating surface of a signaling device as:

> "…the orthogonal projection of the lamp in a plane perpendicular to its axis of reference and in contact with the exterior light-emitting surface of the lamp, this projection being bounded by the edges of screens situated in this plane, each allowing only 98 percent of the total luminous intensity of the light to persist in the direction of the axis of reference."

We modified the ECE procedure in two aspects. First, the criterion used was 90 percent of the total light output to more reliably estimate the area. Second, we evaluated the light output at a representative glare point (see below).

Photometry

All photometric measurements were performed in a darkened laboratory using a Minolta T-1 illuminance meter. The photometer was positioned 15 m from the lamp, and at 3.4° left and 0.6° up with respect to the lamp axis—corresponding to the main glare test point (B50L) in the ECE regulations (ECE, 1992). The measurements were recorded at 12.8 V, with only the low beam energized. The aiming of all lamps was done visually.

Lamp samples

The tungsten-halogen sample consisted of 20 low beams produced by 8 lighting companies. All lamps were for model year 2000 vehicles, and they were designed for the best-selling 20 vehicles produced by 5 vehicle manufacturers for sale in the U.S. The lamps used in this study are the same as the lamps in the U.S. subsample of Schoettle et al. (2001).

The HID sample consisted of 17 low beams produced by 5 lighting companies. All lamps were for model year 2000 vehicles, and they were designed for various models produced by 7 vehicle manufacturers for sale in the U.S. The lamps in this sample are 17 of the 19 lamps that we used in a recent study on light output of HID lamps (Sivak et al., 2002b).

None of the tungsten-halogen lamps were projector lamps. On the other hand, 8 of the 17 HID lamps (47%) were projector lamps. A breakdown of the lamps by type of optics is shown in Table 1. The light sources used in the tested lamps are summarized in Table 2.

Table 1
Optics of the tested lamps.

Lamps	Optics	Number
Tungsten-halogen	Complex reflector	12
	Lens optics	8
	Subtotal	20
HID	Complex reflector	4
	Lens optics	5
	Projector	8
	Subtotal	17

Table 2
Light sources used in the tested lamps.

Lamps	Light source	Number
Tungsten-halogen	HB1 (9004)	1
	HB2 (9003)	3
	HB4 (9006)	7
	HB5 (9007)	9
	Subtotal	20
HID	D2R	9
	D2S	8
	Subtotal	17

Procedure

After establishing a stable 100% illuminance value (unscreened) for a given lamp, the 90% illuminance value was calculated. Then, vertical and horizontal screens (made of rigid, non-reflective black material) were individually moved into place from left, right, top, and bottom to locate the edges of the illuminated surface that would each produce this 90% illuminance value. For example, a horizontal screen was moved from the left across the surface of the lamp until the measured illuminance was reduced to 90% of the initial, unscreened illuminance. The final lateral location of this screen was recorded and the screen was then removed. This was repeated for the three remaining screens. These four measurements were then used to determine the left, right, upper, and lower limits of the illuminated surface of each lamp. In turn, these limits defined a rectangular surface area for each lamp. Figure 1 shows a schematic diagram of the procedure.

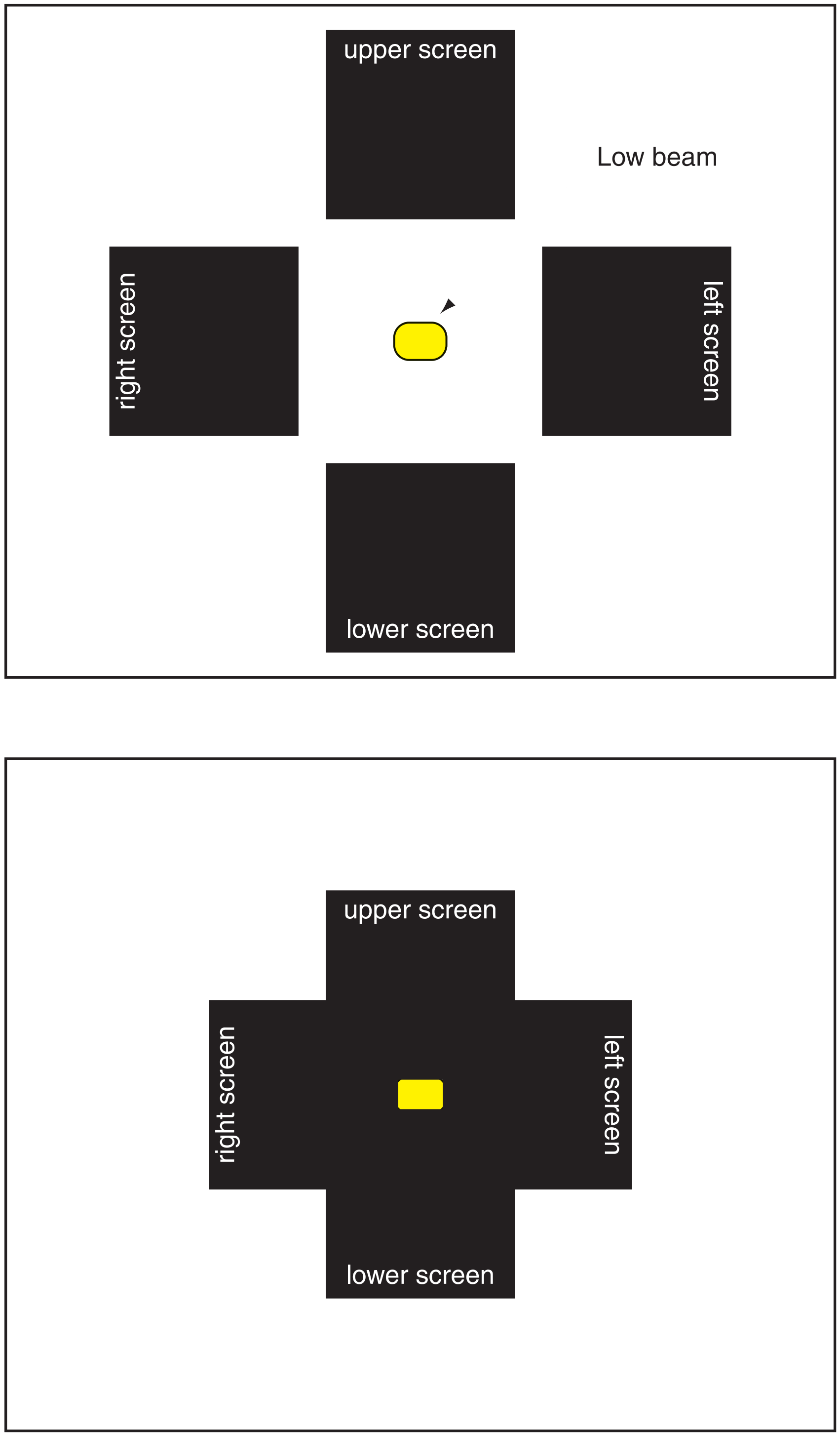

Figure 1. A schematic of the procedure. The top panel shows the setup used to determine the 100% (unscreened) illuminance value. The bottom panel conceptually shows the final positions of the four adjustable screens, with each position yielding 90% of the nominal illuminance. (Only one screen was used at any given time. See text for additional details.)

RESULTS

Table 3 presents summary information on the illuminated surface areas of the two lamp samples. The information in Table 3 includes the minimum, 25th percentile, median (50th percentile), 75th percentile, and maximum for the two lamp types. Also included are the ratios of these measures between the lamp types.

The data in Table 3 indicate that the HID lamps generally have smaller illuminated surface areas than do the tungsten-halogen lamps. For example, the minima differ by a factor of 3.1 and the medians differ by a factor of 1.8. The interquartile ranges (25th to 75th percentiles) do not overlap. In other words, the 75th percentile HID lamp is *smaller* than the 25th percentile tungsten-halogen lamp. This relation is illustrated in Figure 2.

Table 3
Illuminated surface areas (in mm^2) by lamp type.

Measure	HID lamps	Tungsten-halogen lamps	Ratio of HID lamps to tungsten-halogen lamps
Minimum	594	1,813	3.1
25th percentile	3,328	6,446	1.9
Median (50th percentile)	4,028	7,216	1.8
75th percentile	5,950	8,327	1.4
Maximum	8,050	11,656	1.4

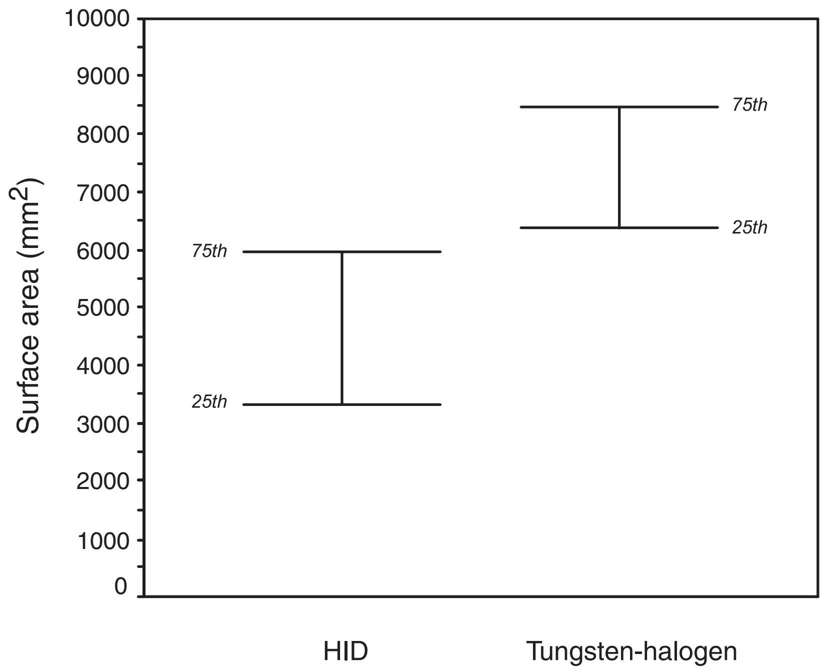

Figure 2. The interquartile ranges (25th to 75th percentiles) of the illuminated surface areas for the two lamp types. Note that the two ranges do not overlap. (The 75th percentile HID lamp is smaller than the 25th percentile tungsten-halogen lamp.)

Table 4 compares the median surface areas by lamp construction and lamp type. As is evident from the information in this table, the projector lamps had the smallest area. This, along with the fact that there were no projector tungsten-halogen lamps in our sample, contributed substantially to the overall difference in area between the HID and tungsten-halogen lamps.

Table 4.
Median surface areas by lamp optics and lamp type (in mm^2). (There were no projector tungsten-halogen lamps in our sample because there were no projector lamps on any of the top 20 best-selling vehicles in the U.S. in 2000.)

Lamp optics	HID lamps (n)	Tungsten-halogen lamps (n)
Complex reflector	5,820 (4)	6,708 (12)
Lens optics	4,028 (5)	7,834 (8)
Projector	3,239 (8)	-- (0)

CONCLUSIONS

The present study evaluated the illuminated surface area of 17 HID and 20 tungsten-halogen low beams manufactured for use on model year 2000 vehicles sold in the U.S. The hypothesis was that the increase in complaints of discomfort glare with HIDs is, in part, a consequence of their smaller area, and the resulting greater luminance. The results indicate that the HID low beams tend to have substantially smaller areas than do the tungsten-halogen low beams of the same vintage. Projector lamps, constituting 47% of the HID sample but 0% of the tungsten-halogen sample, contributed substantially to the overall differences in area between the two lamp types. The main practical implication of these results is that a reduction in discomfort-glare complaints from HID lamps could be achieved by increasing their illuminated surface area. This could be done either by increasing the functional area, or by providing a nonfunctional luminous annulus (e.g., Neumann, 1994).

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