

The Persistence of Headlight Glare as a Problem for the Driving Public

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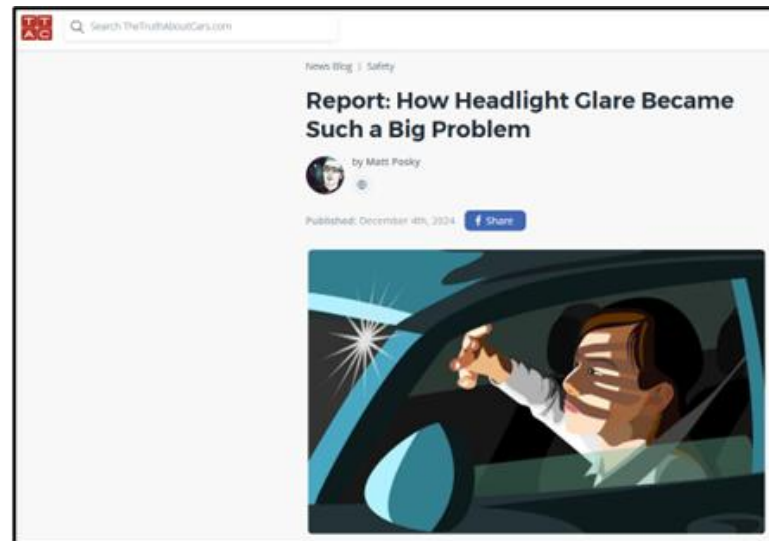
Light and Health Research Center, Icahn School of Medicine at Mount Sinai

SAE Lighting Systems Group Conference
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Background

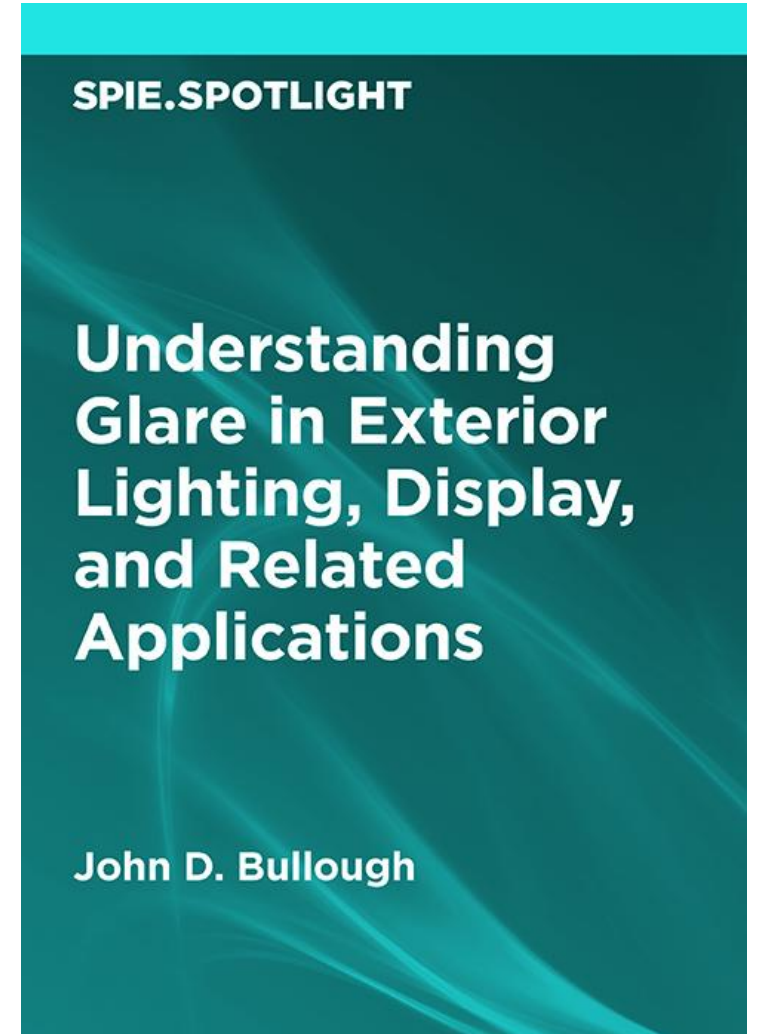
- Glare remains a major concern of the U.S. driving public



What is Glare?

- Disability Glare

- The eye is not perfectly clear so light scatters within it, reducing contrast of objects in the field of view
- Proportional to the illuminance at the eyes
- Inversely proportional to the square of the angular distance between the glare source and the line of sight
- Largely unaffected by spectrum (color) or maximum source luminance
- Visibility impacts are straightforward to predict (Fry, 1954)



What is Glare? (cont'd.)

- Discomfort Glare

- This is the form of glare most drivers seem to be aware of
- Sensation of annoyance or even pain
- Mainly measured by subjective rating scales
- Safety-relevant consequences of discomfort glare are difficult to assess
- Discomfort and disability glare can be (but are not always) simultaneous

1: no or just noticeable glare
2
3: satisfactory
4
5: just permissible
6
7: disturbing
8
9: unbearable

Headlights: Then and Now

- Then:

- Sealed-beam, halogen-bulb headlights
- Largely mechanically aimed
- Mostly passenger cars; fewer pickup trucks
- Standards for headlighting photometric performance were developed largely at this time



- Now:

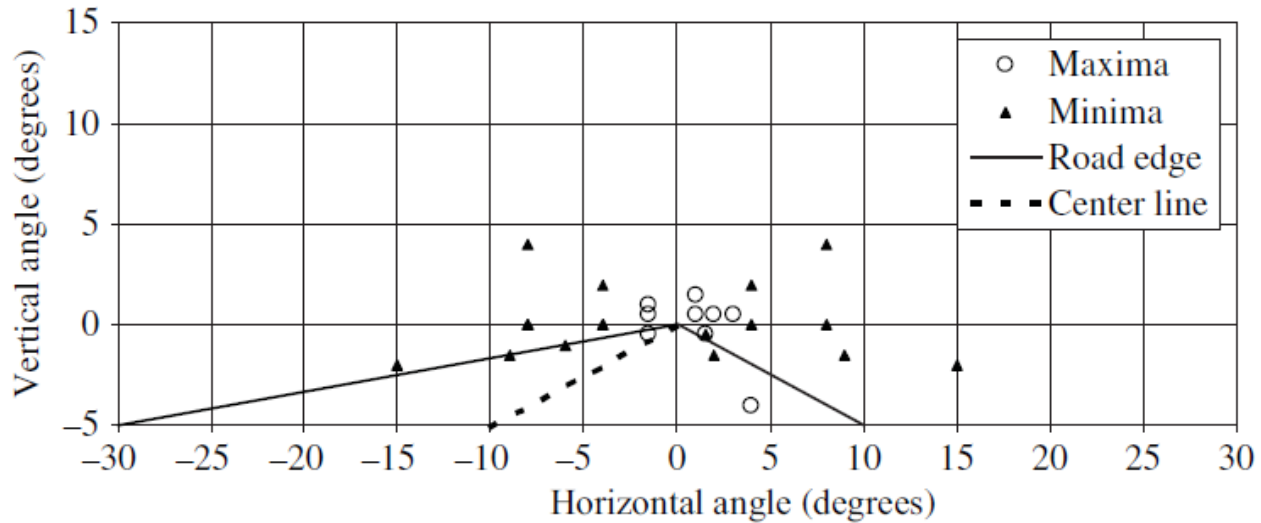
- Light-emitting diode (LED) headlights
- Largely optically aimed
- Much larger proportion of pickup trucks
- Standards for headlighting photometric performance were tweaked during this time



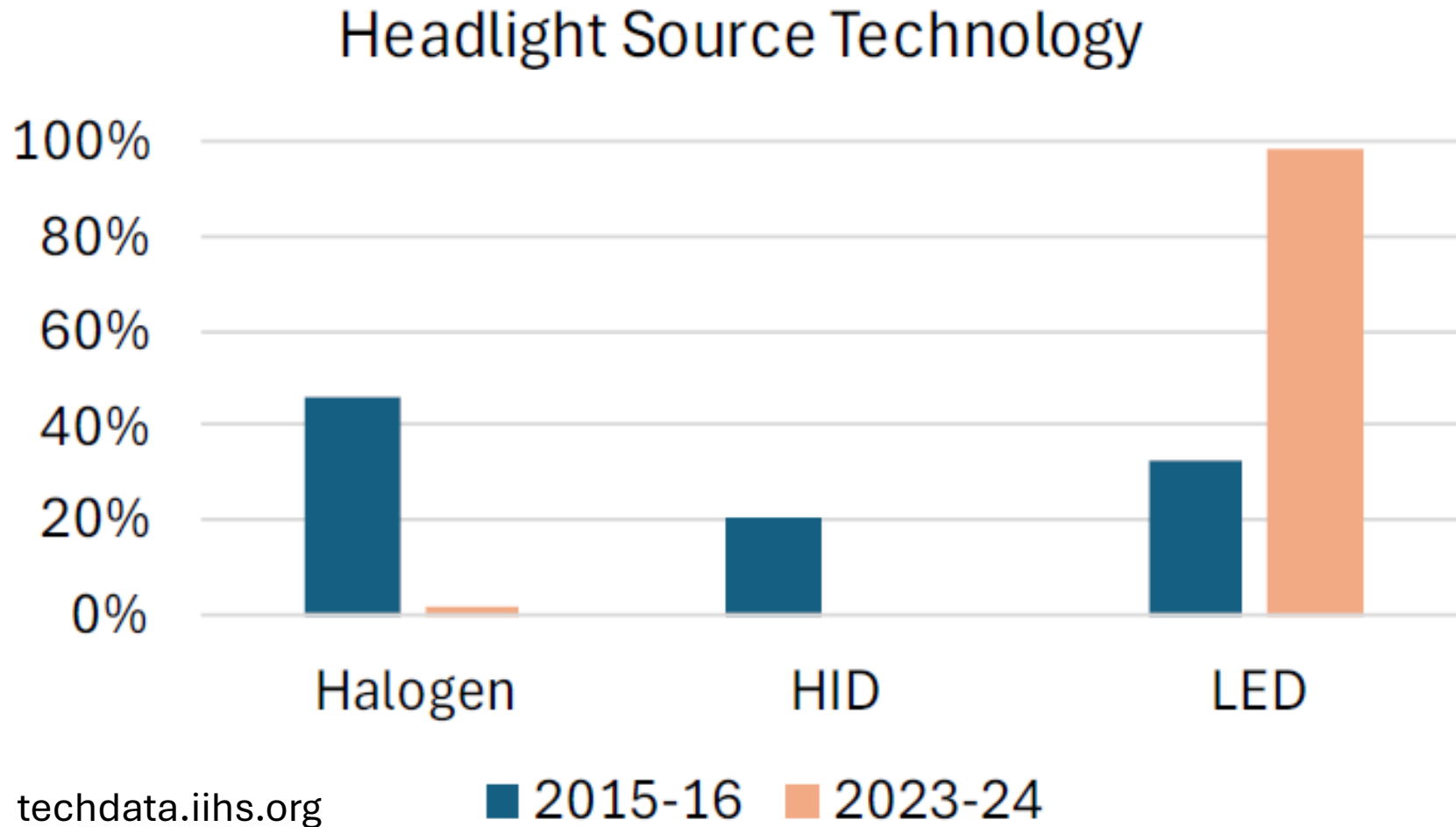
Selected Low-Beam Photometric Requirements

Angular location (degrees)	Maximum luminous intensity (cd)	Minimum luminous intensity (cd)
8° left, 0° up and 8° right, 0° up	—	64
8° left, 4° up and 8° right, 4° up	—	64
4° left, 0° up and 4° right, 0° up	—	125
4° left, 2° up and 4° right, 2° up	—	125
1.5° right, 0.5° down	20,000	8,000
6° left, 1° down	—	750
2° right, 1.5° down	—	15,000
9° left, 1.5° down and 9° right, 1.5° down	—	750
15° left, 2° down and 15° right, 2° down	—	700
1.5° left, 1° up	700	—
1.5° left, 0.5° up	1,000	—
1.5° left, 0.5° down	3,000	—
1° right, 1.5° up	1,400	—
1° right, 0.5° up, 2° right, 0.5° up, and 3° right, 0.5° up	2,700	—
4° right, 4° down	8,000	—

Selected Low-Beam Photometric Requirements (cont'd.)



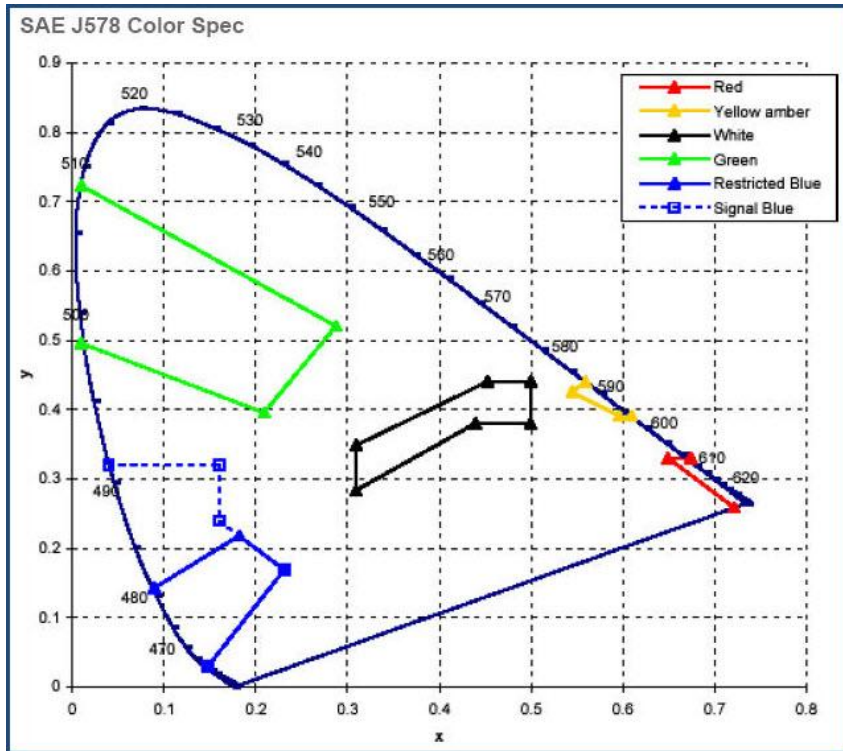
Recent Technological Evolution



A Common Question: Are Headlights Brighter than They Used to Be?

- Yes, and no... but yes
 - Yes: Photometry \neq perception
 - No: The primary photometric standards defining headlight performance have not changed substantially in several decades
 - Photometric standards have lots of “wobble room”

Spectral/Color Differences Between Halogen and LED Headlights

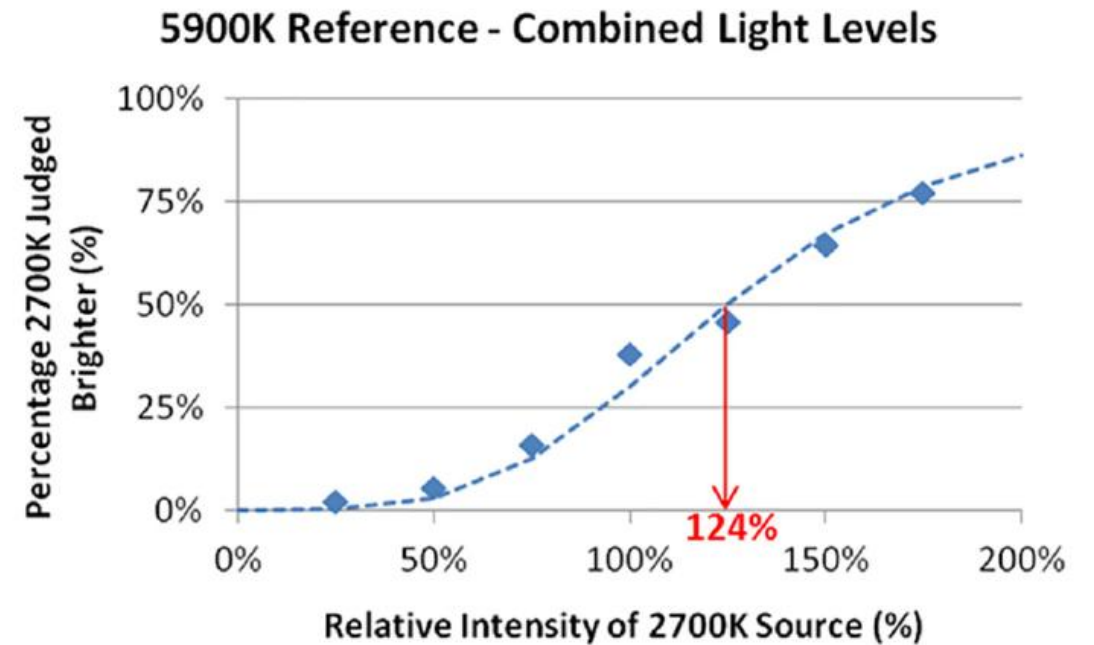
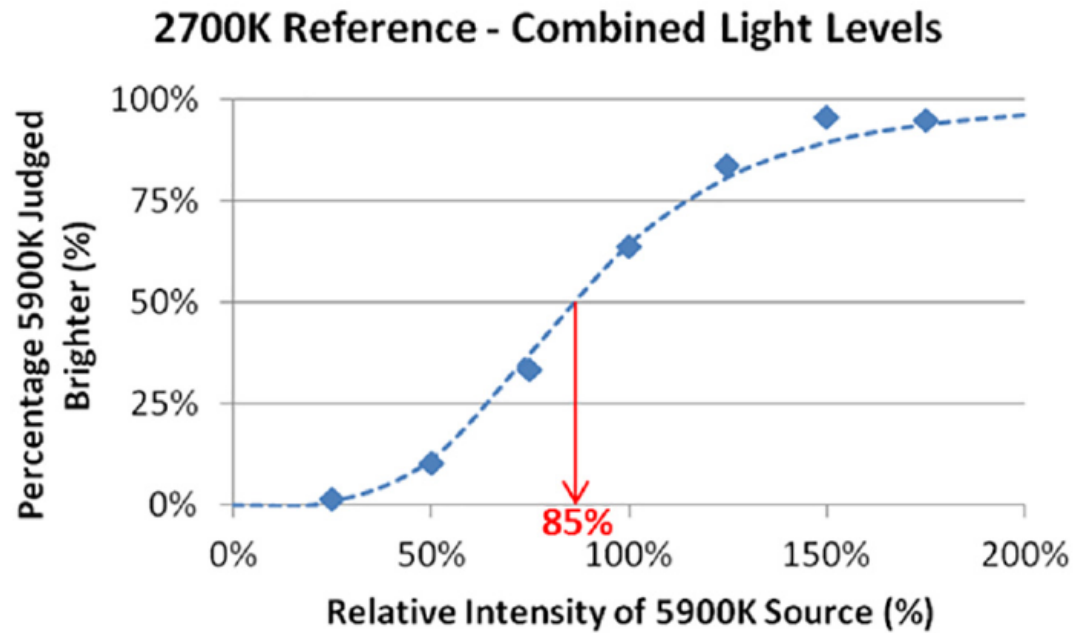


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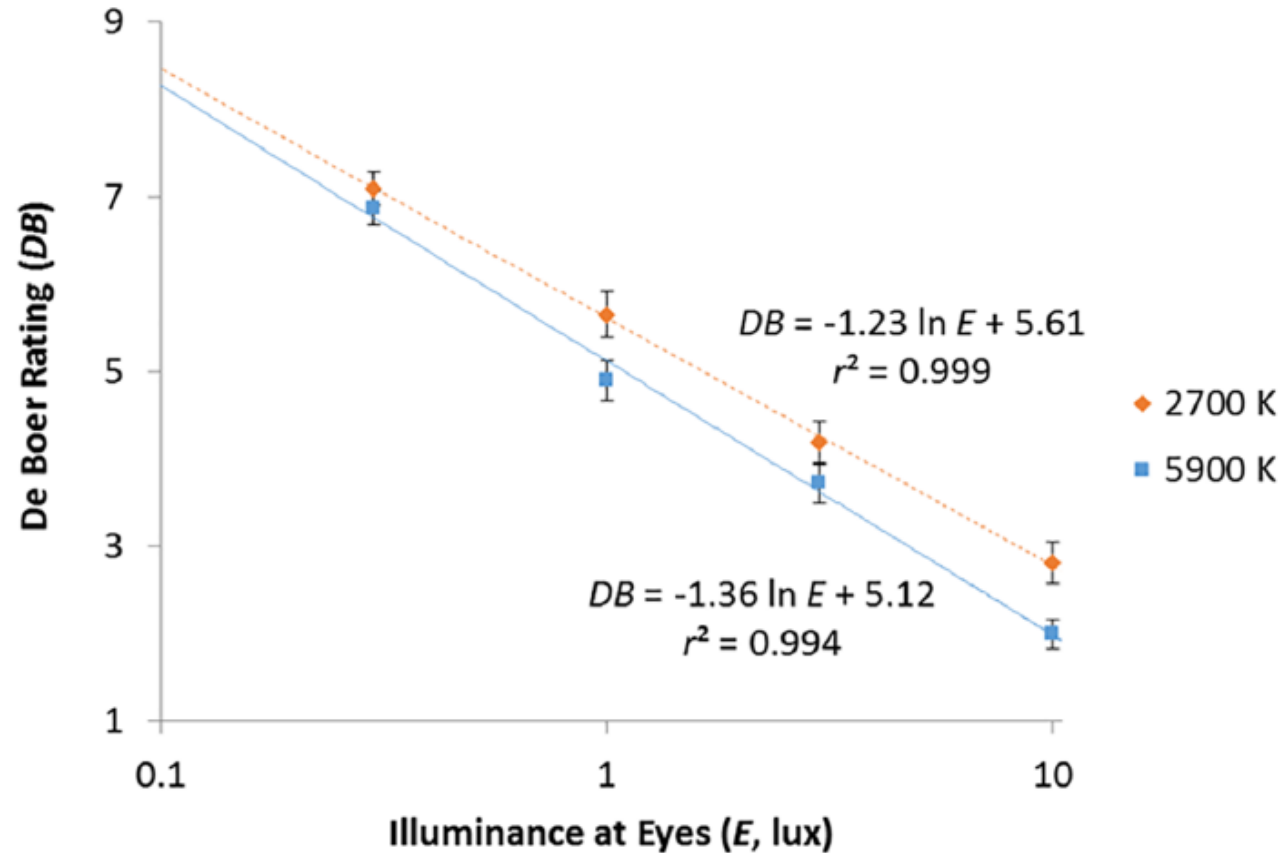
- A correlated color temperature (CCT) of 6000 K is common for LED headlights
 - LEDs don't have to have high CCTs!

Example: LED CCT and Perceived Brightness



(Bullough and Liu 2019)

Example: LED CCT and Discomfort Glare



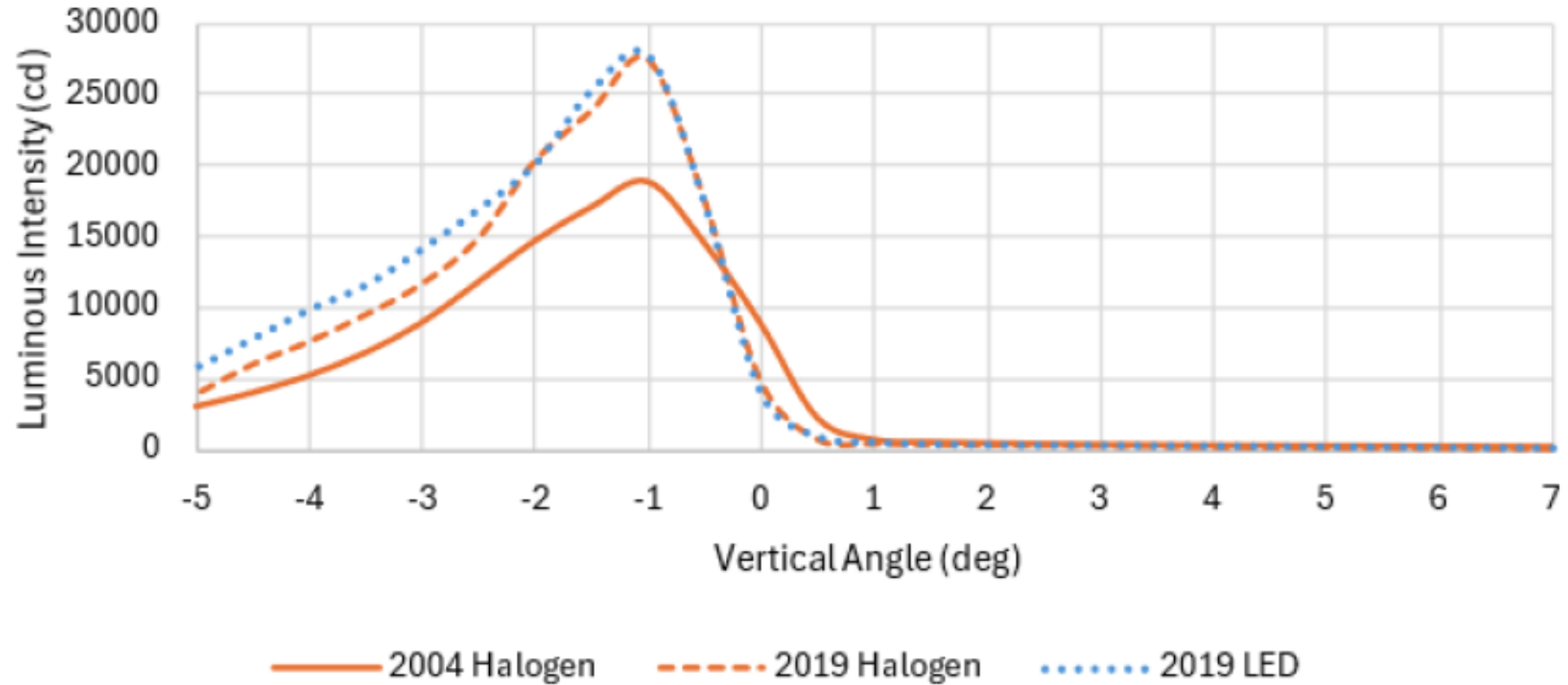
(Bullough and Liu 2019)

What About Disability Glare Impacts?

- Increased brightness perception and even increased discomfort glare from headlights with higher CCT (“whiter” or “bluer”) **might** not necessarily impact driving safety at night
- If the photometric standards for low-beam headlights have not changed, how could luminous intensity, which affects the illuminance at the eyes, change?

Trends in Photometric Performance

Low Beam Intensity Profiles Forward Direction



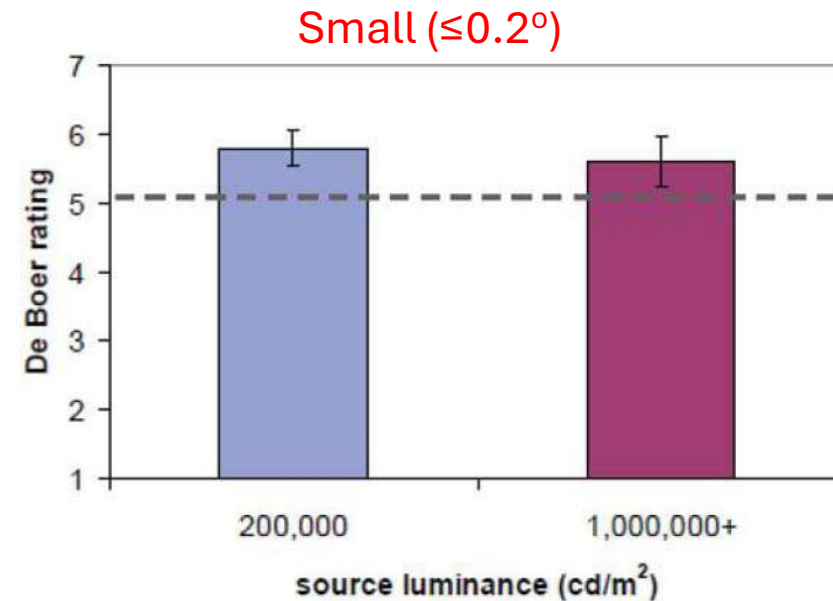
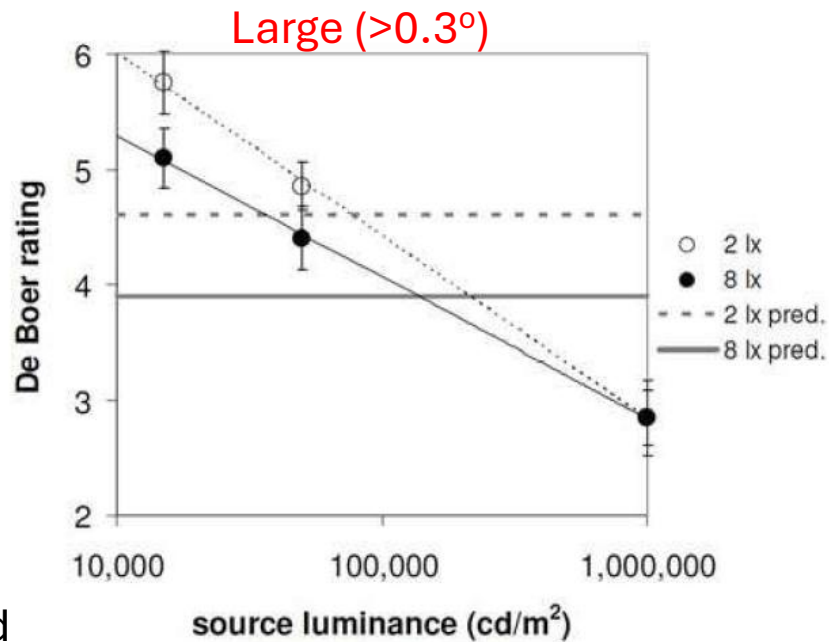
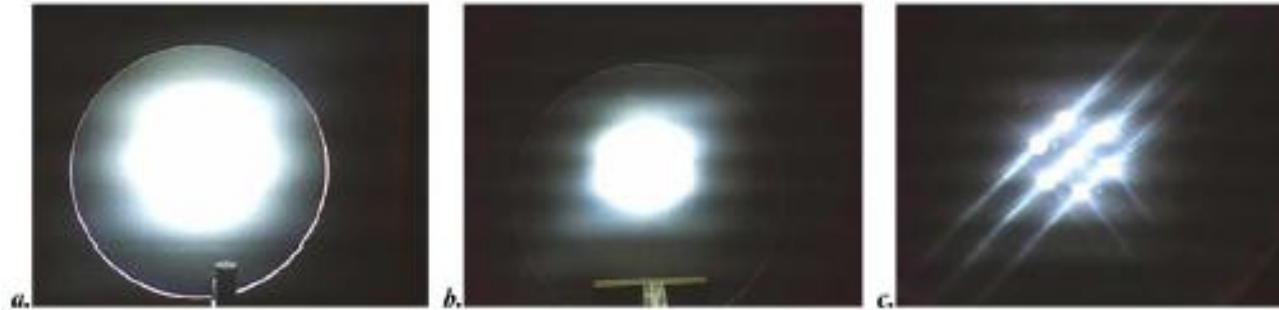
(Schoettle et al. 2004; Flannagan 2019)

Impacts of Maximum Luminance

- Advances in light source technology (smaller sources) and optical design have permitted new options for styling and smaller headlight profiles with higher maximum luminances



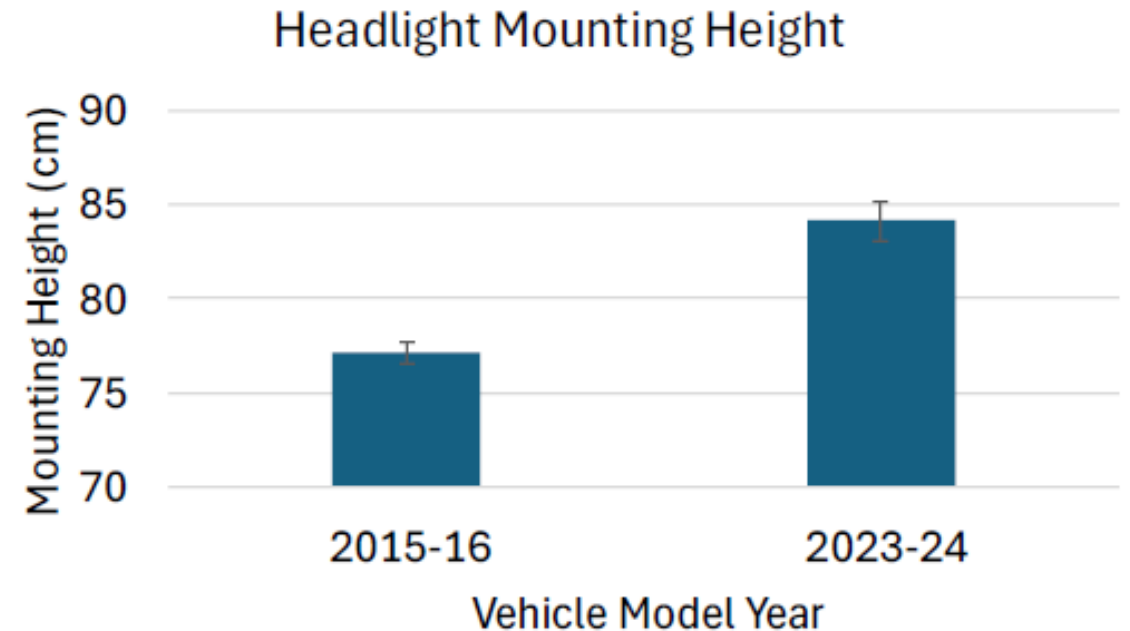
Maximum Luminance and Discomfort Glare



(Bullough and
Sweater Hickcox 2012)

Implementation Factors

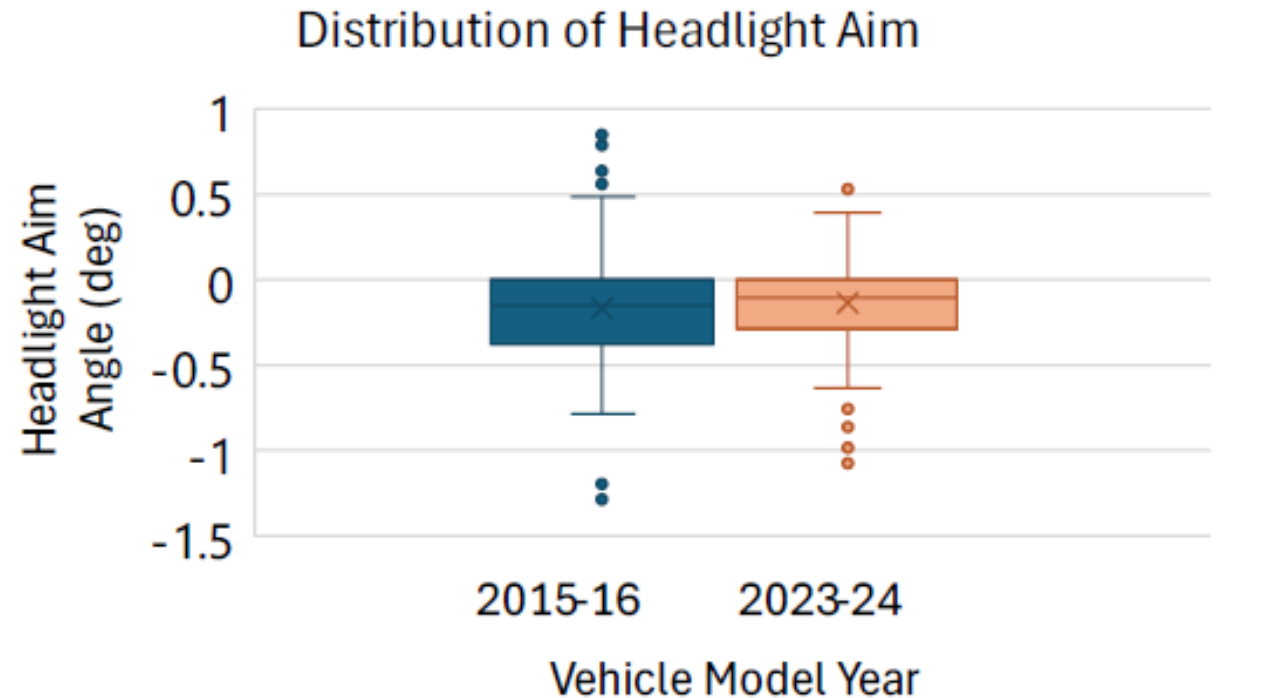
- Headlight mounting height
 - Average (market-weighted) headlight mounting heights increased between 1996 and 2002 (Sivak et al. 2002; Schoettle et al. 2006)
 - This trend has continued in recent years



techdata.iihs.org

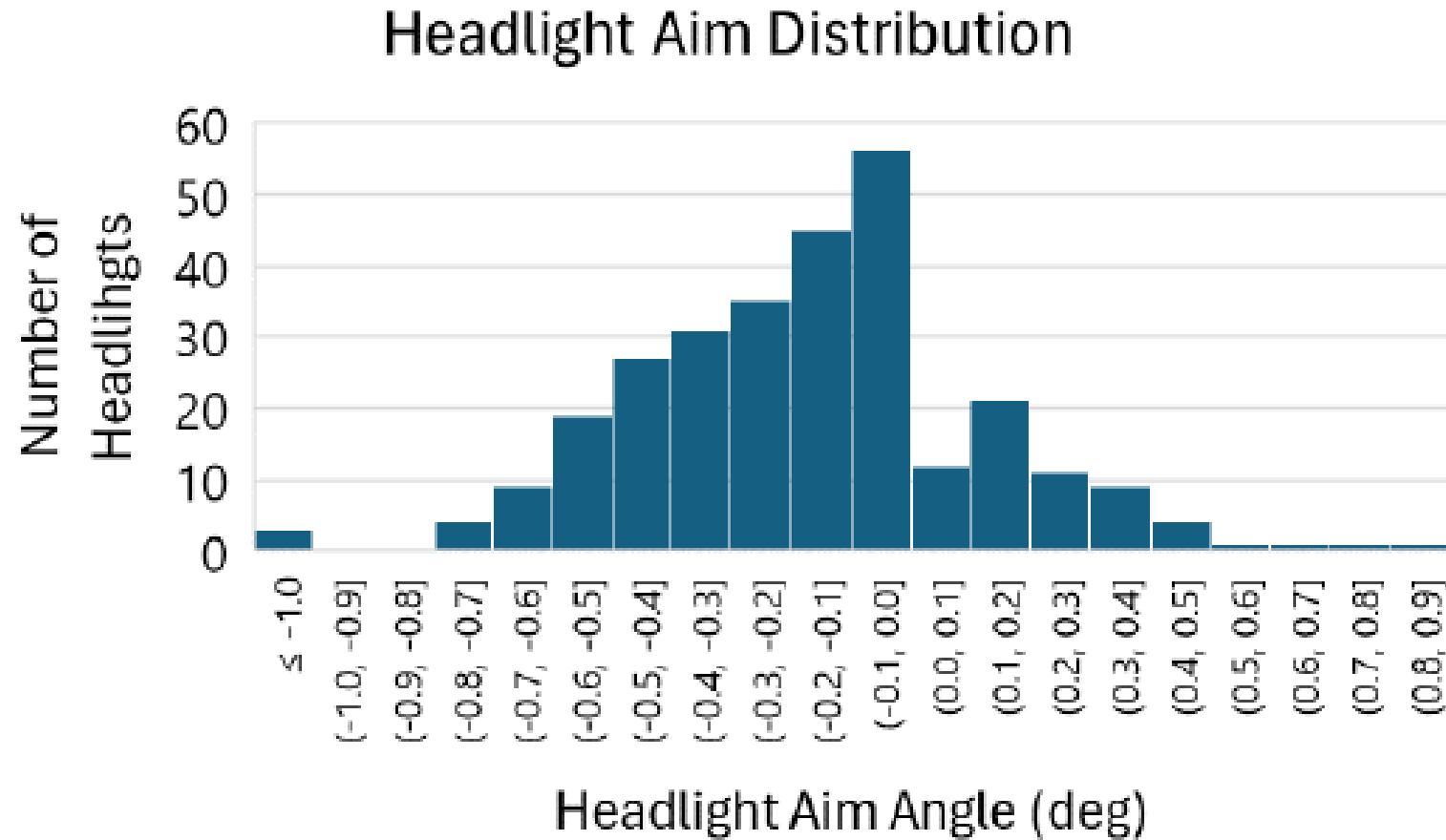
Implementation Factors (cont'd.)

- Headlight aim
 - Vertical aim of headlights in the U.S. has never been stellar (Flannagan 2011)
 - Recently the proportion of properly aimed headlights measured by the Insurance Institute for Highway Safety has increased



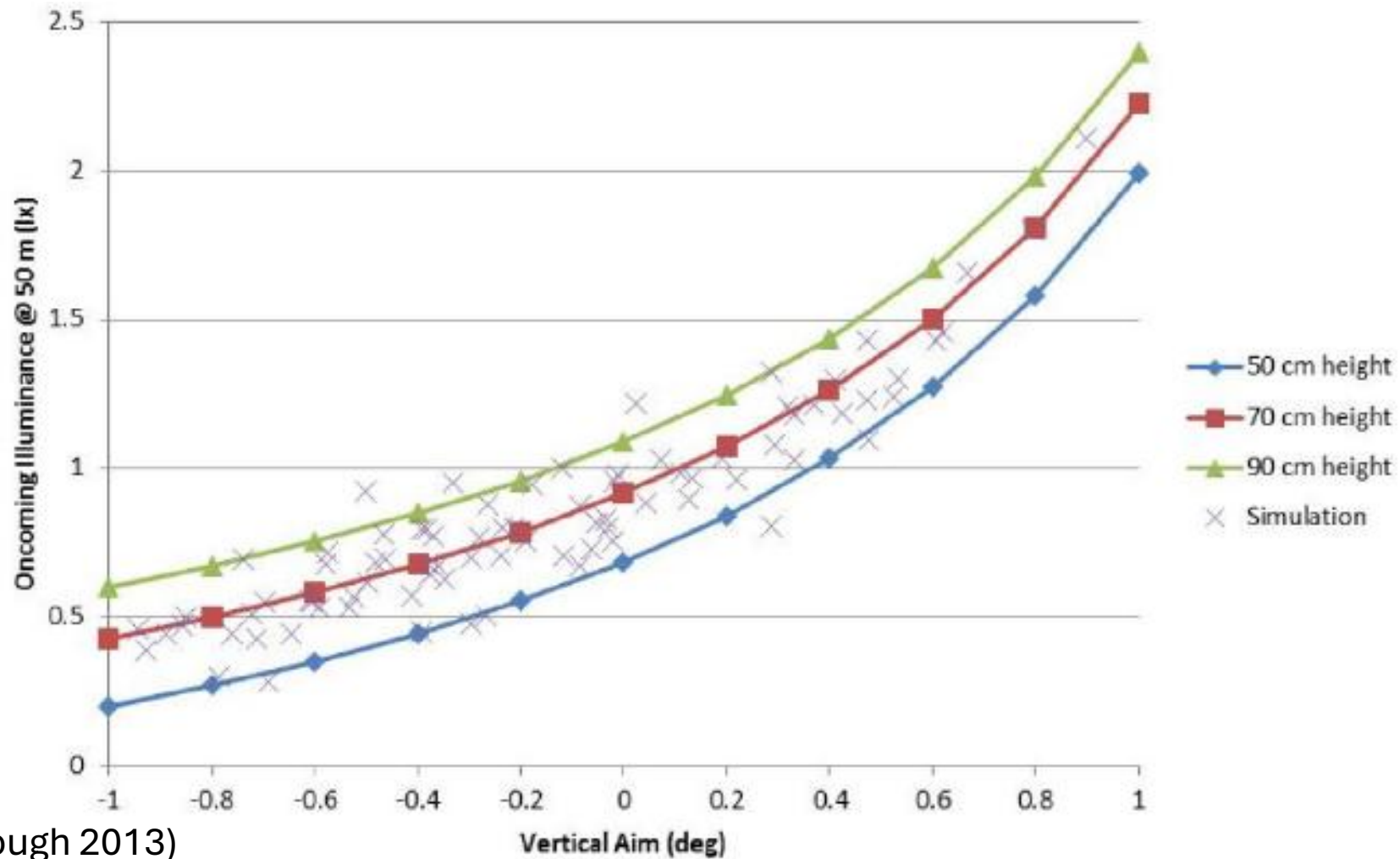
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Prevalence of Upward vs. Downward Misaim: 2015-2024



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Interactions Between Aim and Mounting Height



(Bullough 2013)

What Could Be Done?

- Limit color / CCT?
 - “Warm white” LEDs have similar luminous efficacies as “cool white”
 - Addresses discomfort glare/brightness perception but not disability glare
- Limit mounting height?
 - Photometric requirements and angular locations are defined w/r/t the headlight, not the roadway
- Limit vertical misaim?
 - Automatic headlight leveling?
- Maximum luminous intensity(intensities)?
 - Consideration of “zonal” luminous intensity limits for angular regions below but close to the horizontal to account for potential vertical misaim
 - Objective: Reduce likelihood of oncoming/preceding drivers experiencing luminous intensities approaching those similar to high-beam headlights
- Adaptive driving beam (ADB)?

Thank You

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