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# Has Headlight Glare Worsened in the New Millennium?

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Driving Vision News Glare Workshop

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# Outline

- Public interest in the topic
- Types of glare – disability, discomfort, recovery <sup>2</sup>
- How (and why) have headlights changed in recent decades
  - Geometry
  - Light source spectrum / color
  - Luminance / size
  - Distribution
  - Aim
- Are there practical solutions / countermeasures?

# What I'm Not Discussing Today (But Our Community Has To)



High beam



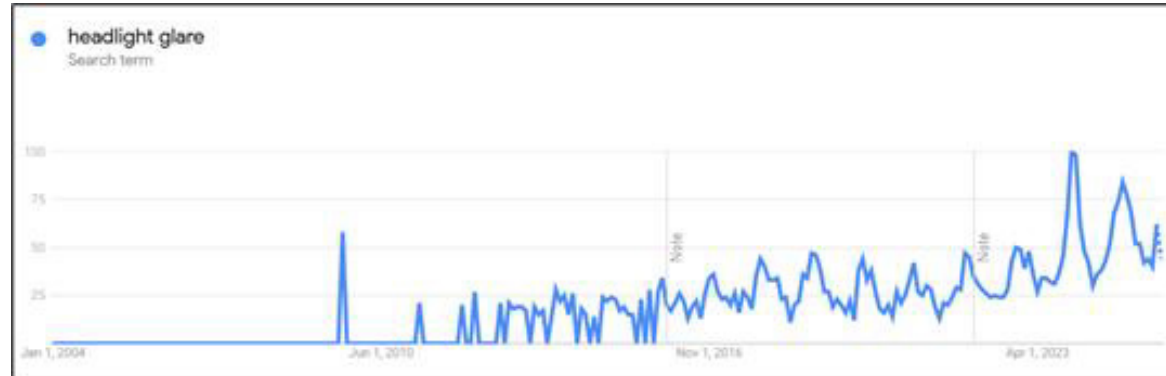
Low beam



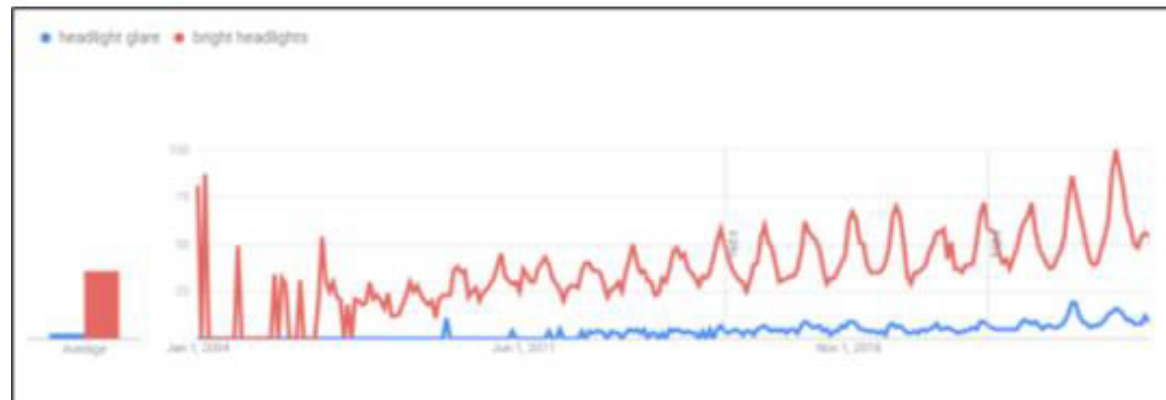
Adaptive driving beam

Adaptive Driving Beam (ADB) Headlighting Systems

# Public Interest in Glare – Google Trends

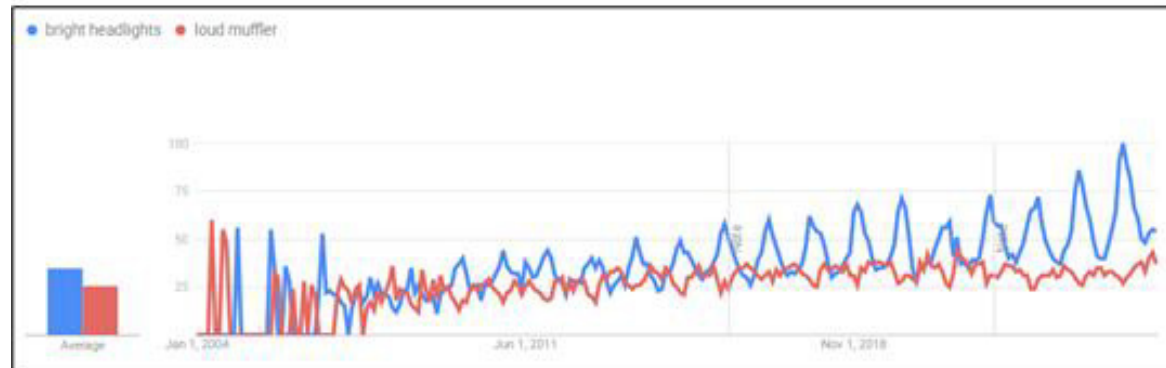


Headlight glare



Bright headlights

Headlight glare



Bright headlights

Loud muffler

# Headlight Glare on Social Media

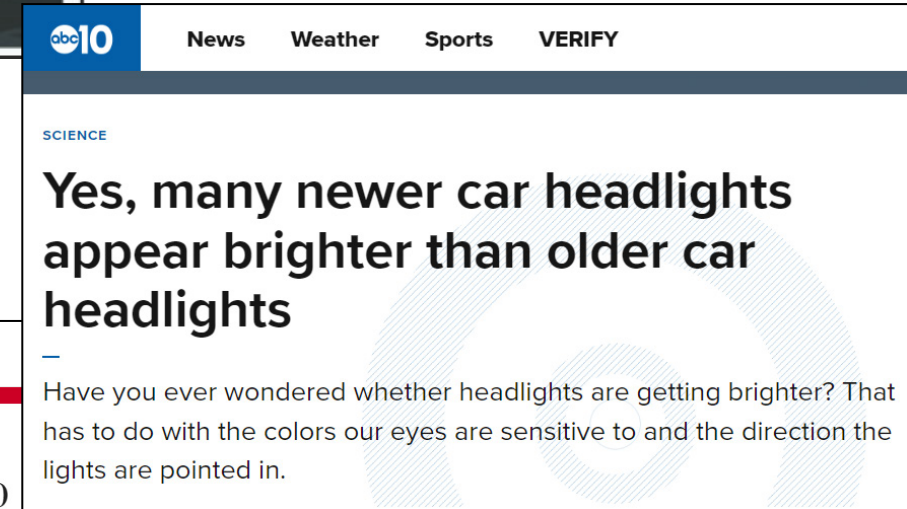
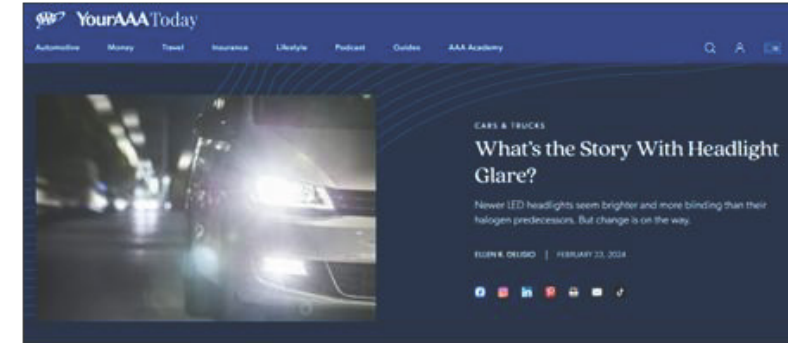
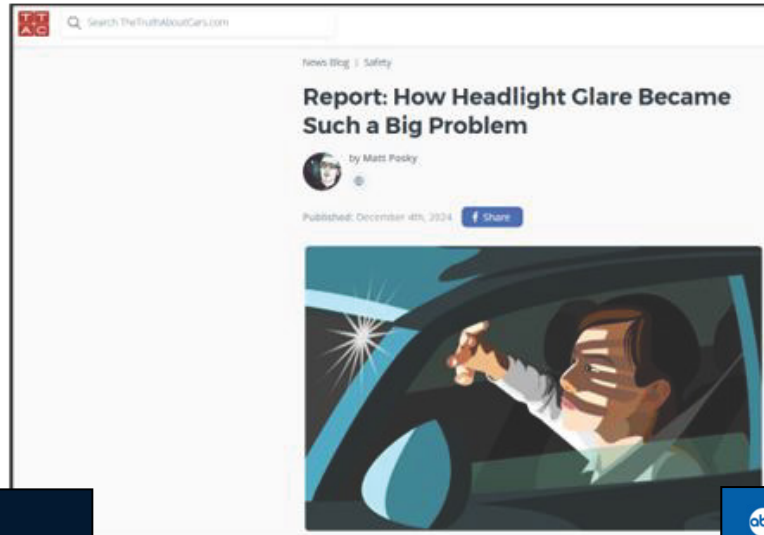
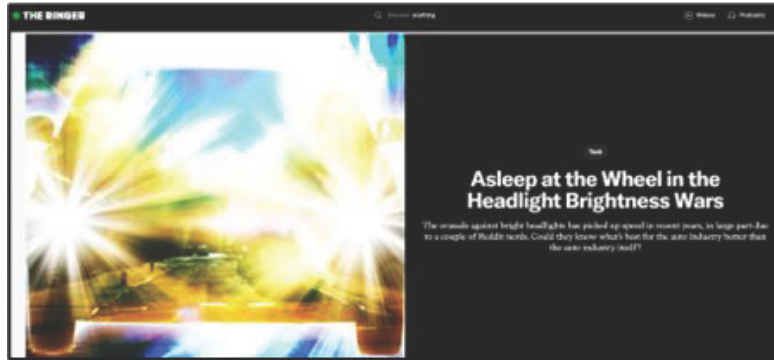


When the car behind you turns on their high beams to blind you, But you turn your rear mirror up to reflect their light back to them



r/mildlyinfuriating

# Headlight Glare in “Regular” Media



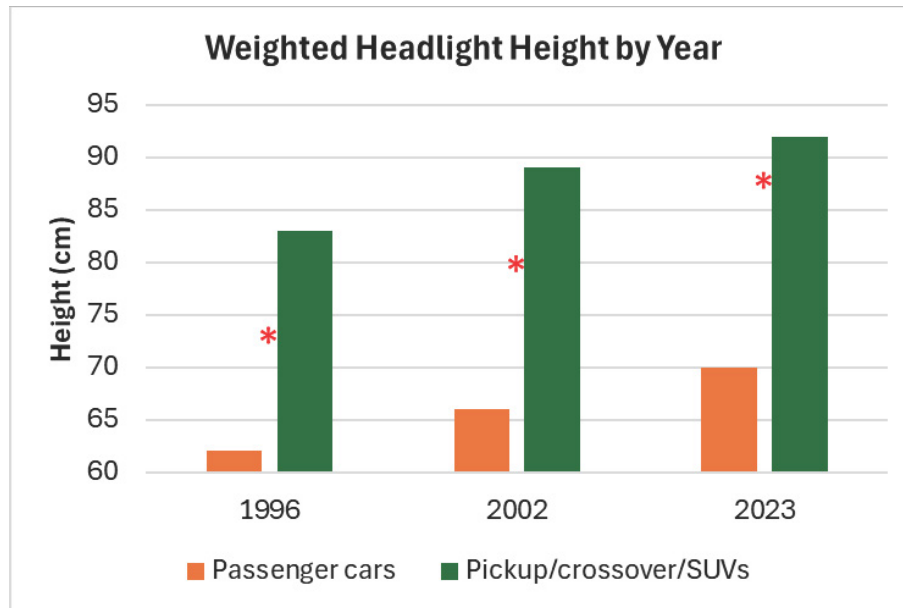
# What is Glare?

- Disability Glare: reduction in contrast caused by scattered light in the eyes
- Discomfort Glare: sensation of annoyance or pain from a bright light in the field of view
- Glare Recovery: duration following exposure to bright light when contrast sensitivity is reduced

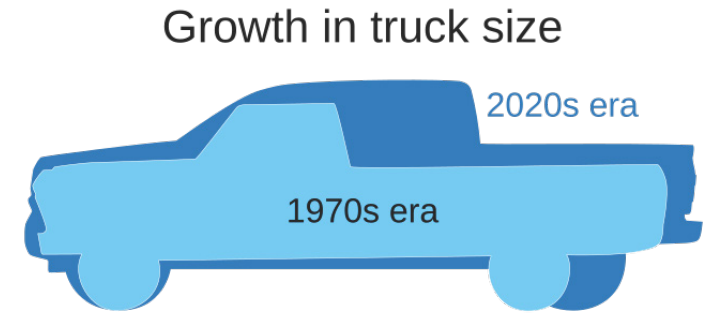


# Headlight Geometry

- Vehicles overall have increased in size and of most relevance, height
  - 9% increase in driver eye height between 1996 and 2023
  - 21% increase in headlight mounting height over the same period of time

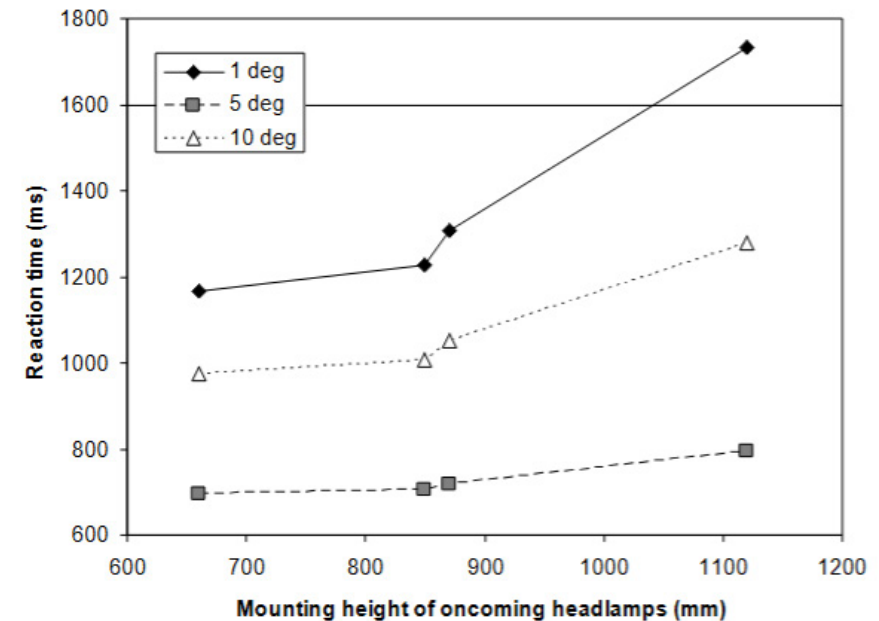


(Bullough 2025)



(shown: Ford F-150 silhouettes)

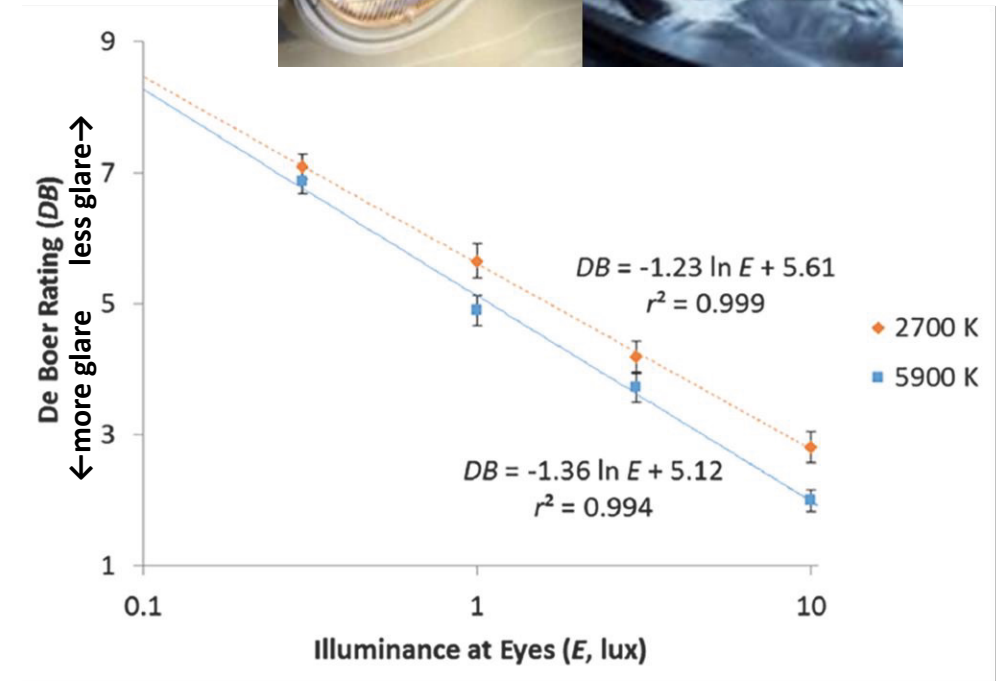
(RCraig09 - CC BY-SA 4.0)



(Akashi et al., 2008)

# Correlated Color Temperature (CCT)

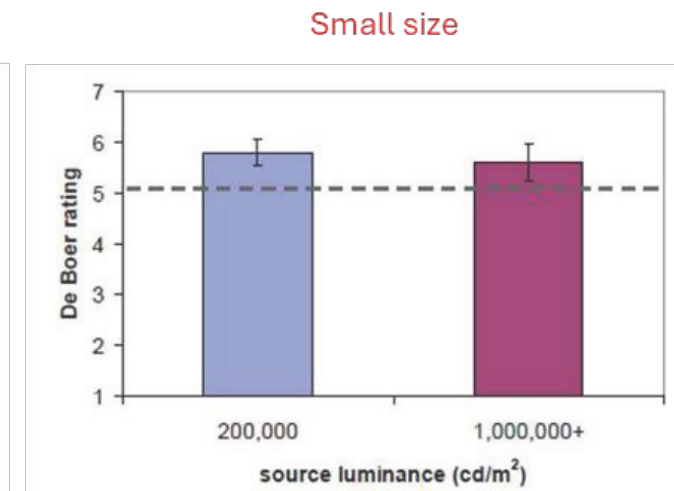
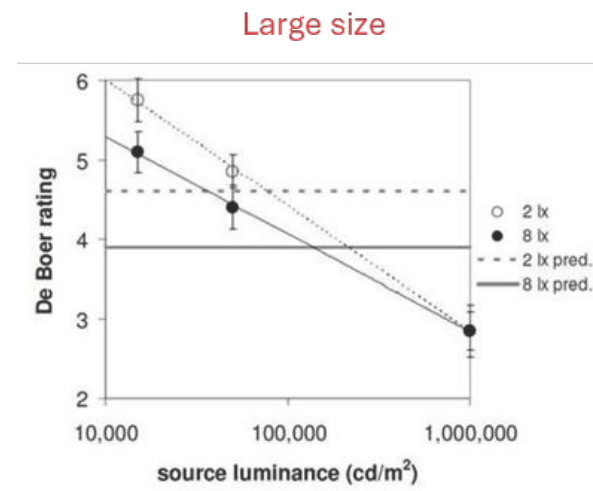
- Halogen headlights have a CCT around 3000 K
- Typical LED headlights have a CCT around 6000 K



(Bullough and Liu 2019)

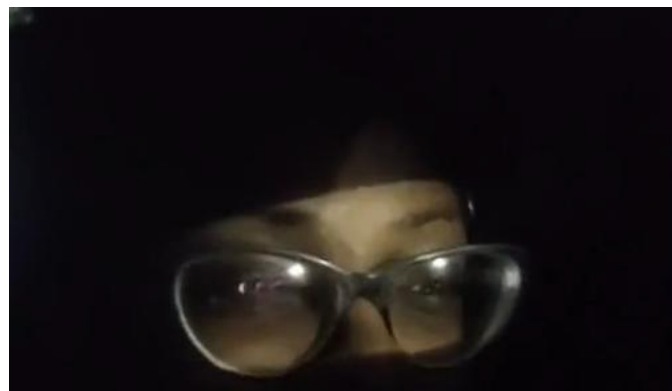
# Headlight Luminance and Size

- A smaller headlight **aperture size** corresponds to a higher **luminance** for the same **luminous intensity**
- A large headlight (8 cm diameter) must be within 15 m to be **large** enough for increased luminance to significantly increase discomfort glare



(Bullough and Sweater Hickcox 2012)

# Oncoming versus Rearview Mirror Glare?

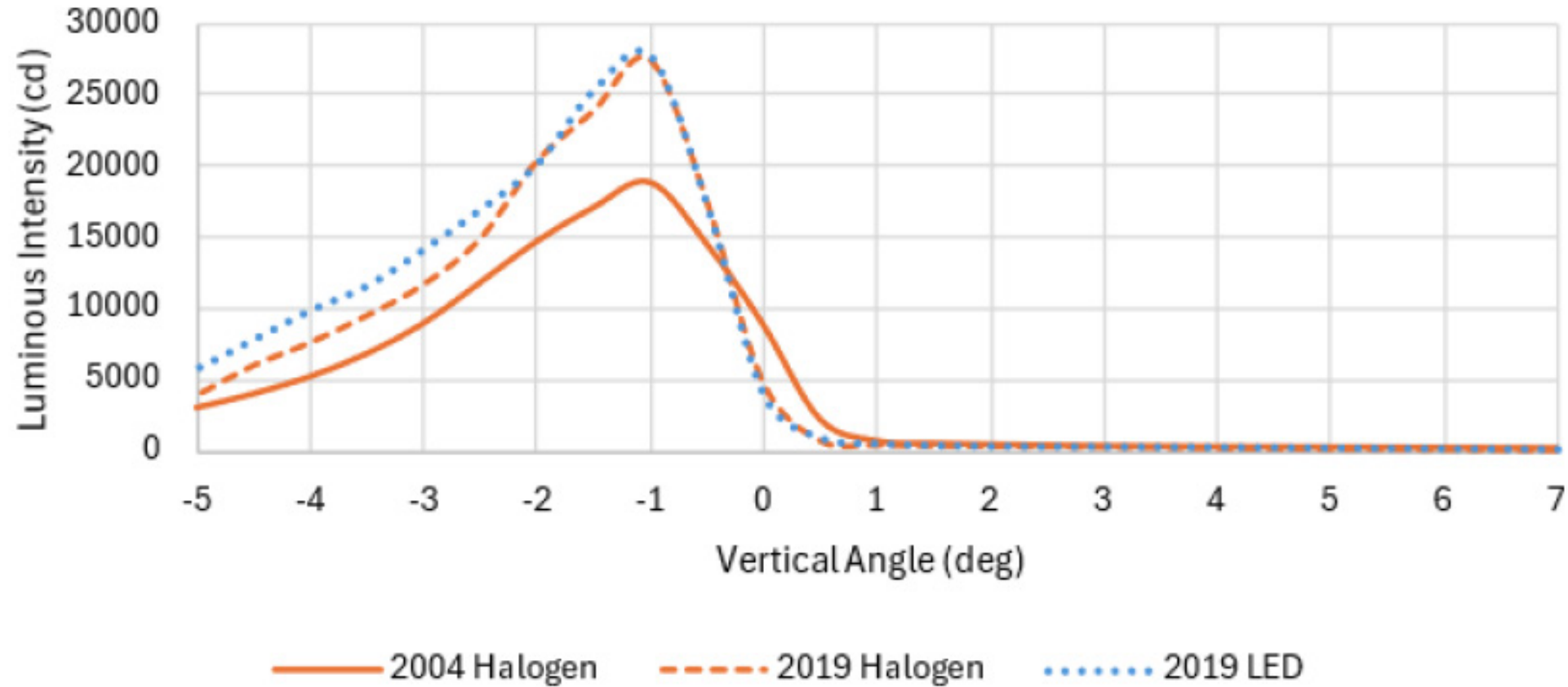


When the car behind you turns on their high beams to blind you, But you turn your rear mirror up to reflect their light back to them



# Headlight Photometric Distribution

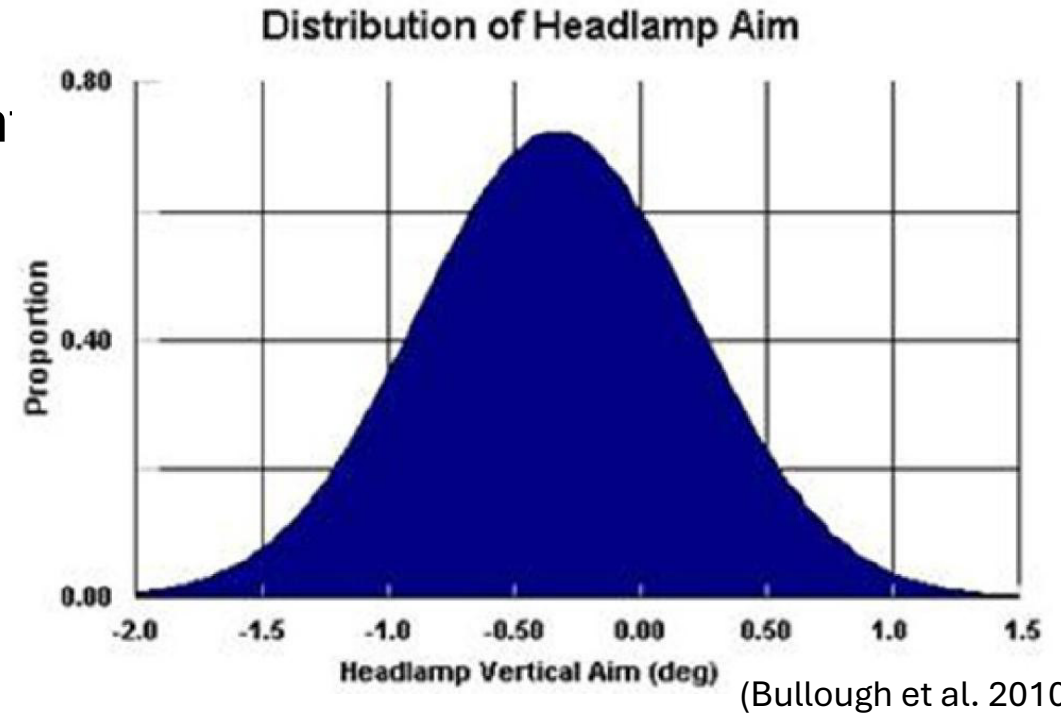
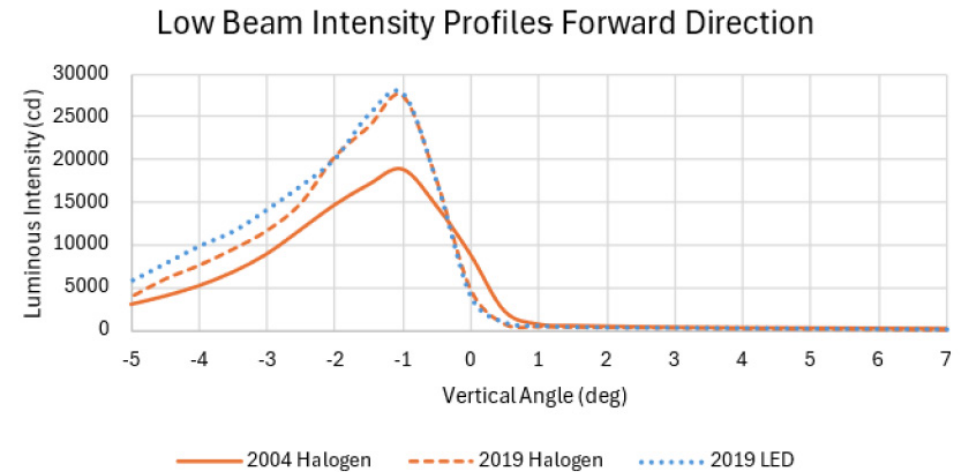
## Low Beam Intensity Profiles Forward Direction



(Schoettle et al. 2004; Flannagan 2019)

# Headlight Aim

- Headlight aim has frequently been cited as the most important factor contributing to glare (and visibility) (Perel 1985; Sivak et al. 1998; Akashi et al. 2008)
- Headlight aim has consistently been poor (a 2008; Flannagan 2011) <sup>13</sup>
- Even small amounts of upward misaim (or upward orientation along vertical curves, uneven surfaces, and loaded vehicles)



# Influence of Headlight Safety Ratings?



- Rating systems such as the Insurance Institute for Highway Safety (IIHS) may have influenced headlight performance (sharper cutoff, higher maximum intensity)



- Tested headlight aim has also improved:
  - 2016: Vertical aim range was  $0.9^{\circ}$  ( $0.65^{\circ}$  down to  $0.25^{\circ}$  up), hardly any @  $0^{\circ}$
  - 2022: Vertical aim range was  $0.55^{\circ}$  ( $0.31^{\circ}$  down to  $0.23^{\circ}$  up), 25% @  $0^{\circ}$

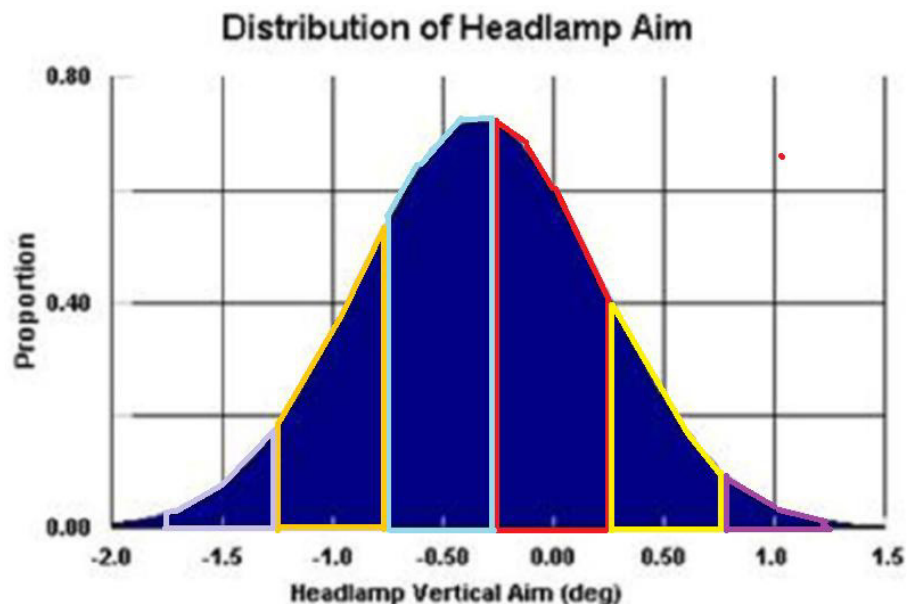
# What Could Be Done?



- Geometry: Upper limit for headlight mounting height on all vehicles including pickup trucks and SUVs? (**see images above**)
  - Would address disability, discomfort and recovery
- SPD / Color: Upper limit for CCT of LED headlights (3000K, 4000K)?
  - Would address discomfort only (but is very recognizable) and would require thoughtful marketing <sup>15</sup>
- Luminance / Size: Minimum luminous aperture size?
  - Would address discomfort only (and perhaps not oncoming glare)

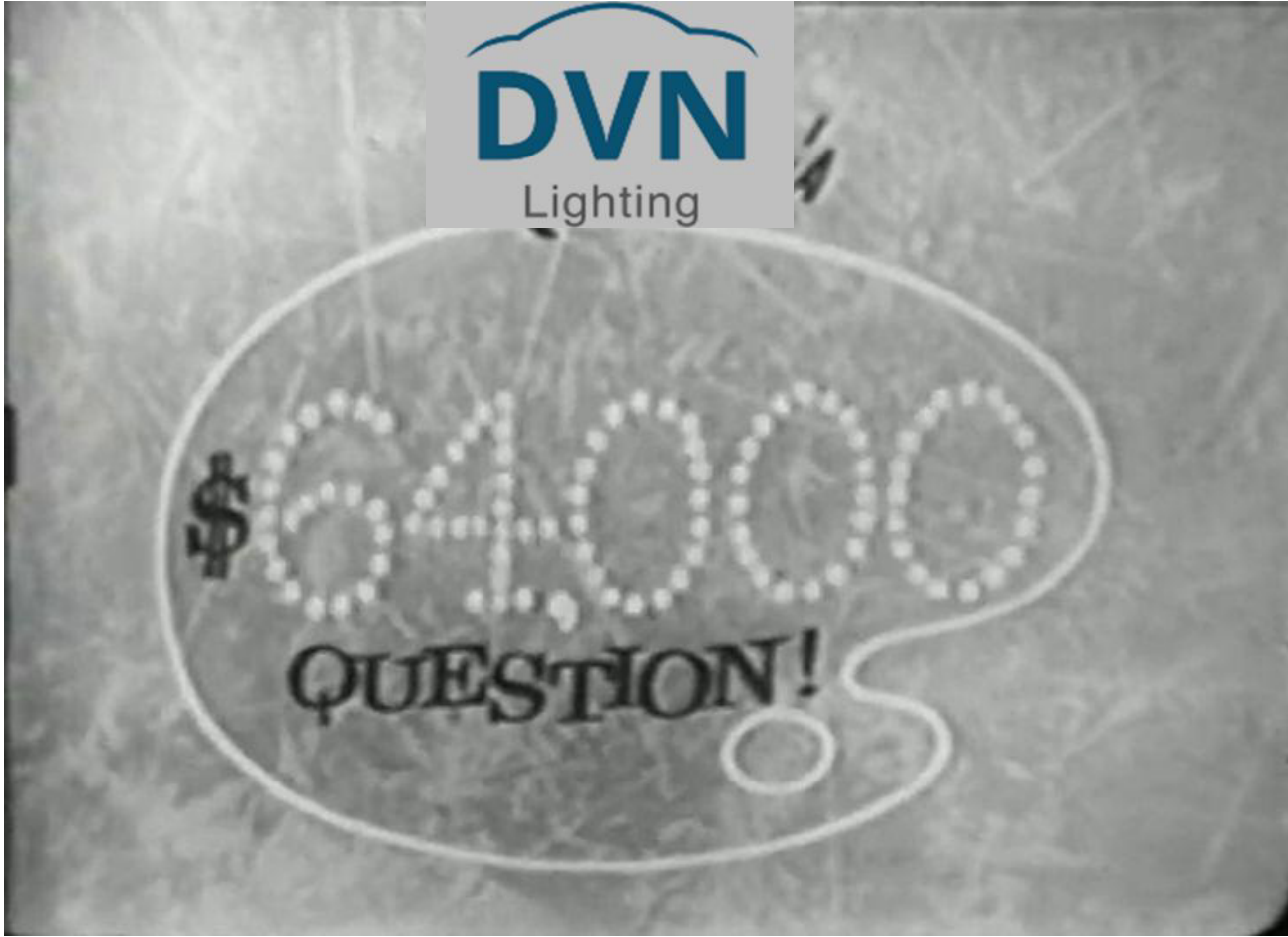
# What Could be Done? (cont'd.)

- Distribution / Aim: A Preliminary Proposal for Low-Beam Zonal Intensity Limits Below the Horizontal Cutoff



- Slices around  $-1.5^\circ$ ,  $-1^\circ$ ,  $-0.5^\circ$ ,  $0^\circ$ ,  $0.5^\circ$  and  $1^\circ$  represent relative proportion of time headlights are aimed/misaimed by about that angular value
- A “typical” halogen headlight in 2019 produced an intensity of **5000 cd** straight ahead at  $0^\circ$  (Flannagan 2019)
- Accounting for **relative frequency** of angular mis/aim ( $0^\circ=100$ ), an “equivalent” amount of glare for upward misaim angles is:
  - **+0.5°**: relative frequency=**44**, intensity for equivalent glare=**11,000 cd** @  $-0.5^\circ$
  - **+1°**: relative frequency=**9**, intensity for equivalent glare=**54,000 cd** @  $-1^\circ$
- Framework could be applied to finer angular resolution and different assumptions about misaim and “typical” or “adequate” glare performance
- A blanket upper limit for low-beam intensity (e.g., **30,000 cd**) could also be incorporated to prevent values such as 54,000 cd

# What **Should** Be Done?



# Thank You!

- Light for Transportation Safety 2024-2025 Partners
  - ams OSRAM
  - Audi <sup>18</sup>
  - Forvia Hella
  - General Motors
  - Lumileds
- Driving Vision News
  - Paul-Henri Matha
  - Daniel Stern
- SAE Lighting Committee
  - Inspiration