

# Headlamp Light Performance Evaluation

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GTB Glare and Visibility Forum

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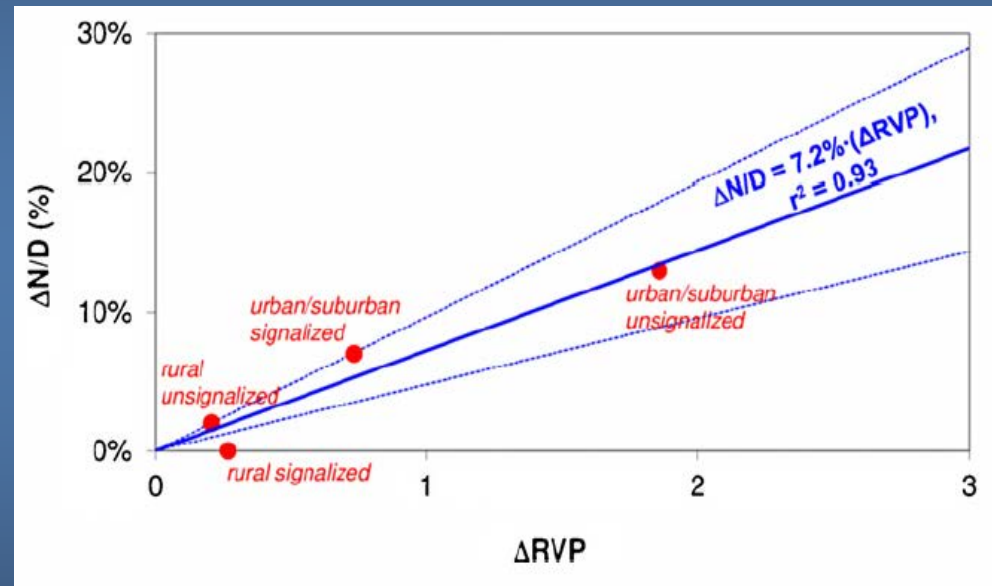
# Outline

- ◆ Lighting and safety
- ◆ Vertical aim, visibility, glare
- ◆ Vertical aim and headlight evaluations
- ◆ Low-beam, high-beam and adaptive driving beam headlights
- ◆ Outlook



# Lighting and safety

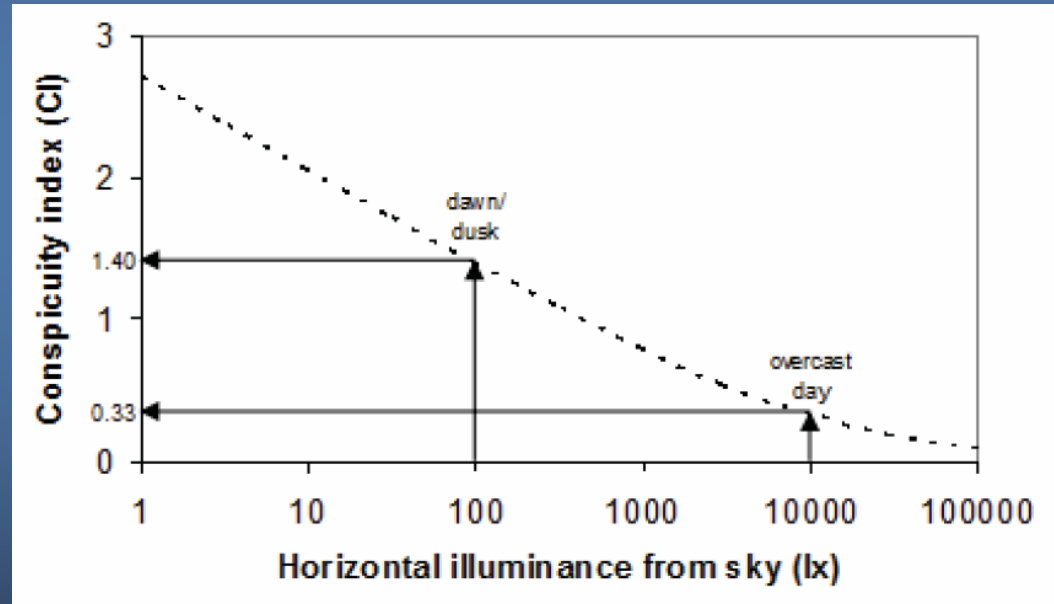
- ◆ Most roads (in the U.S.) are not illuminated (NHTSA 2007) so vehicle headlights are critical
- ◆ Visual performance from roadway lighting is directly correlated with nighttime crash reductions associated with lighting



(Bullough et al. 2013)

# Lighting and safety (cont'd.)

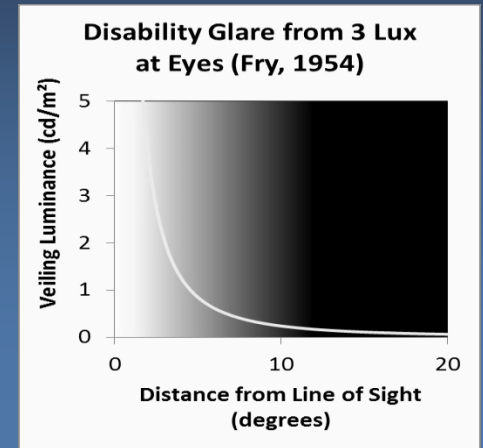
- ◆ Safety impacts of vehicle lighting are also strongly correlated with visual effectiveness (Bullough 2011)
- ◆ Low-beam headlights are 4.3 times more conspicuous during dusk/dawn than during the daytime
- ◆ Using headlights during rainy weather is 4.2 times more likely to prevent a fatal multi-vehicle crash during dusk/dawn than during the daytime



(Bullough 2011, 2012)

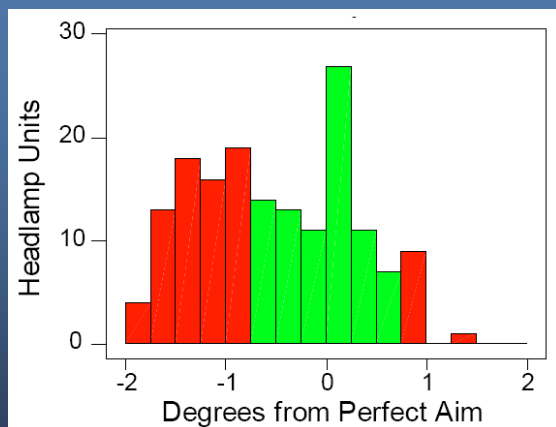
# Importance of glare

- ◆ Glare directly impacts visibility, especially near the line of sight (Fry 1954)
- ◆ Glare is a major concern of drivers and of vehicle lighting regulators
- ◆ What factor(s) influence glare from headlights?

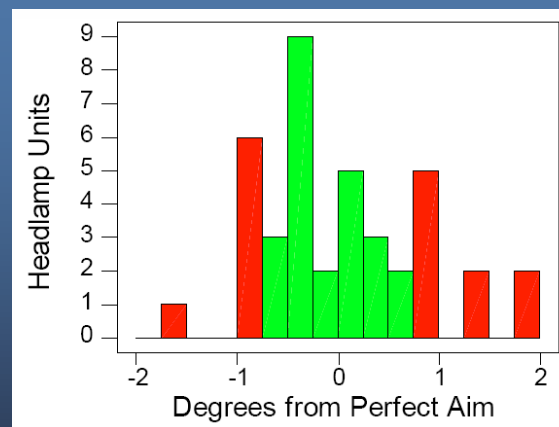


# Vertical aim

- ◆ Sensitivity analyses have consistently shown (Perel 1985; Sivak et al. 1998; Akashi et al. 2008) that vertical aim is the most critical parameter associated with visibility and glare from headlamps
- ◆ Real-world measurements (Skinner et al. 2010; Bullough et al. 2010; Flannagan 2011) have demonstrated that many vehicles have misaimed headlamps, including brand-new vehicles

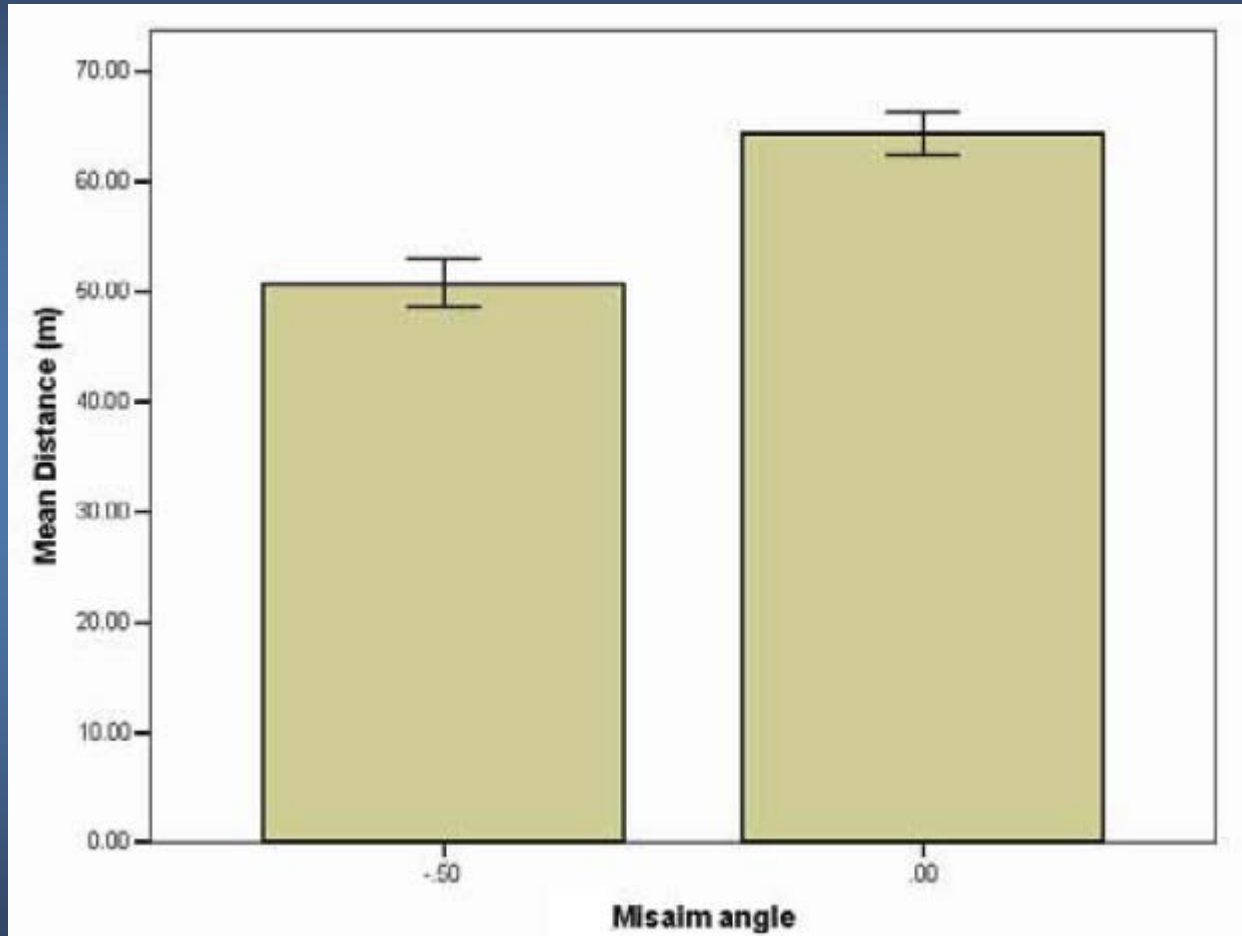


In-service vehicles



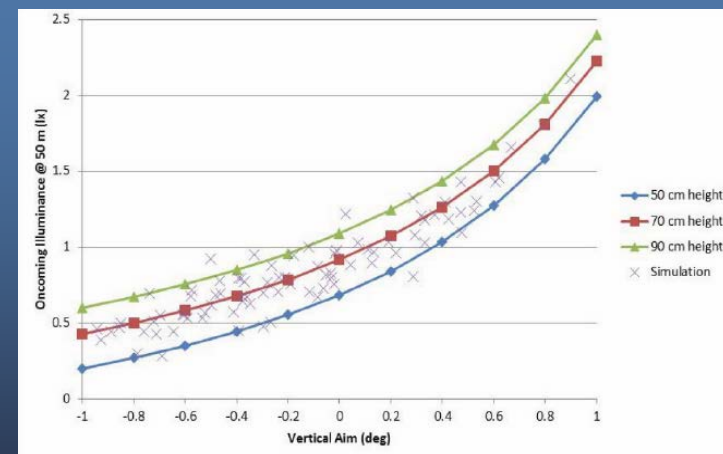
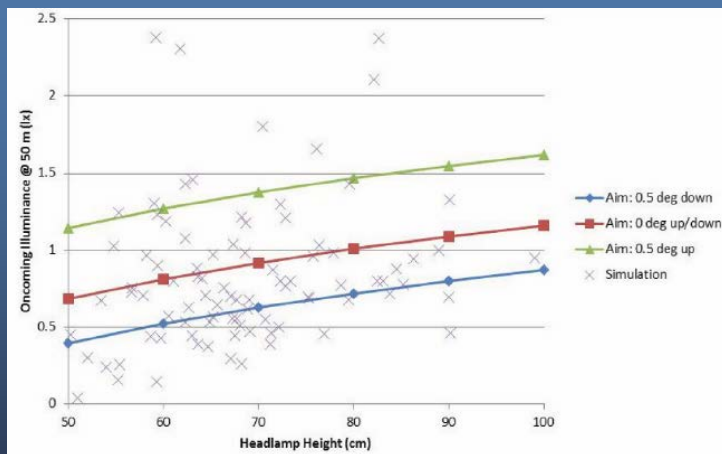
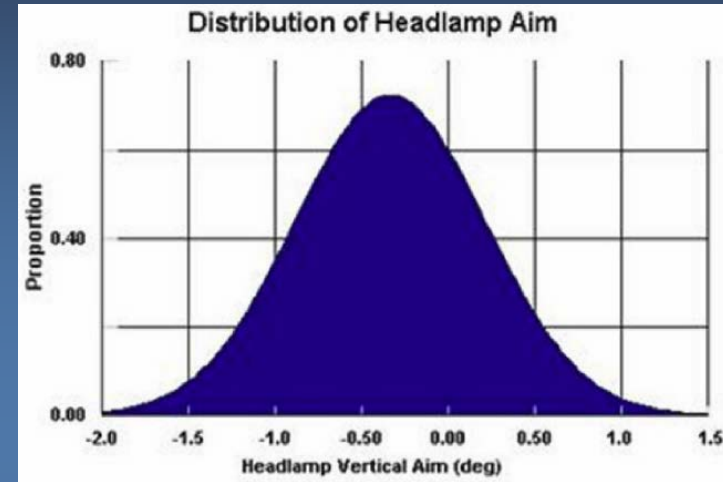
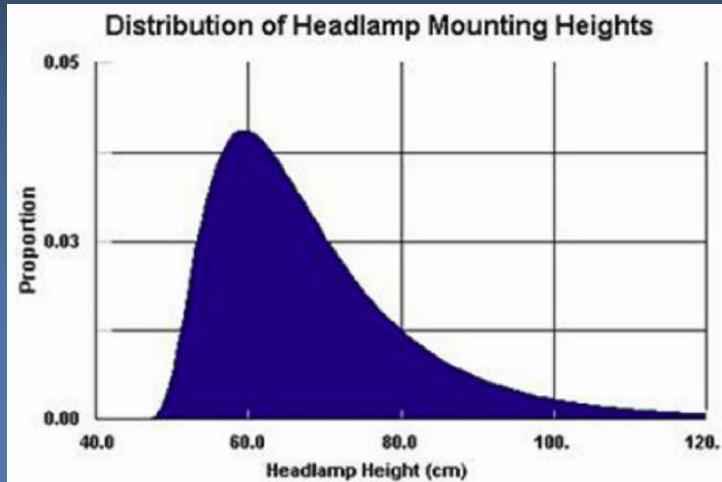
New vehicles

# Influence of vertical aim on visibility



(Akashi et al. 2008)

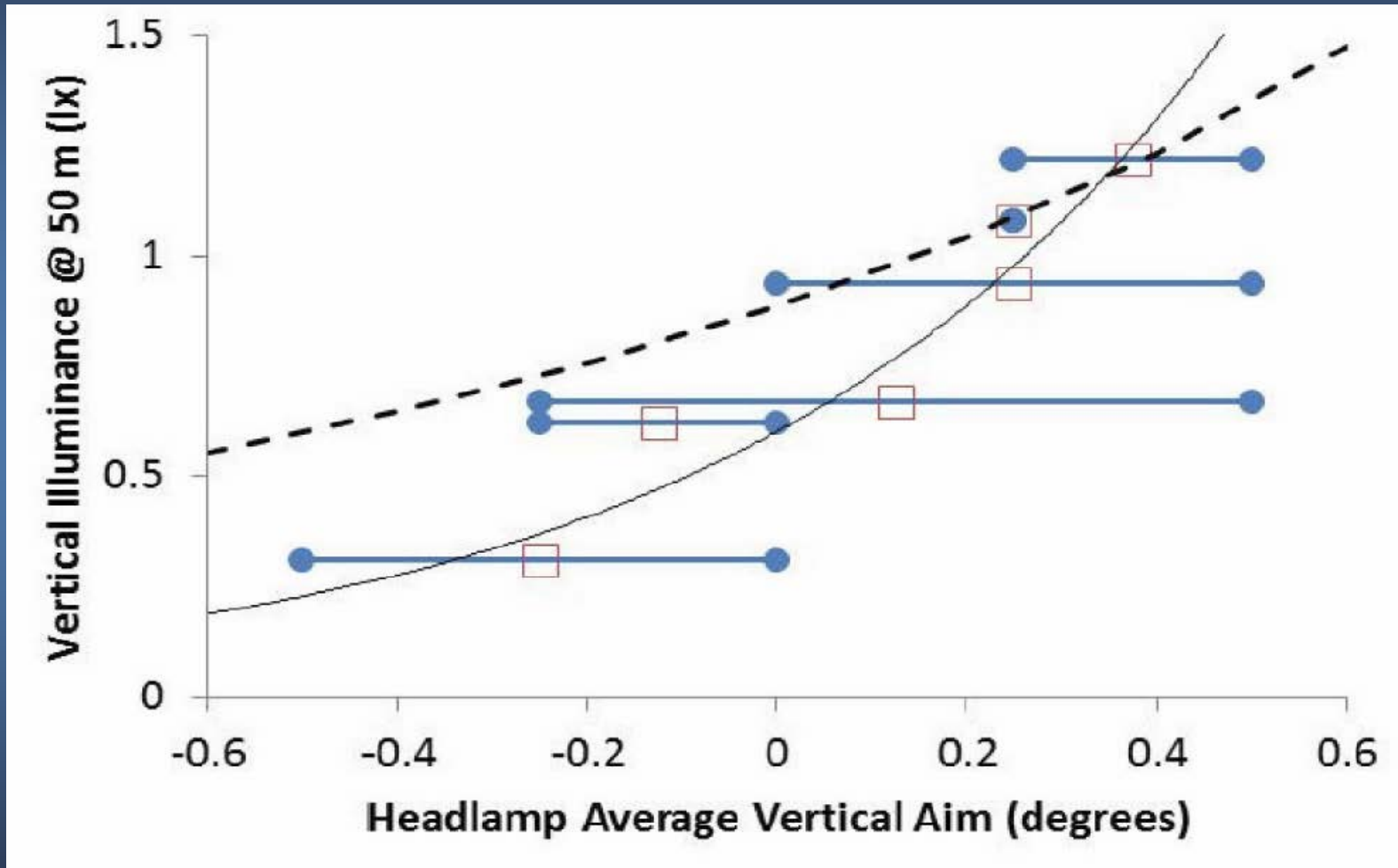
# Vertical aim (vs. mounting height) and glare



(Bullough 2013)



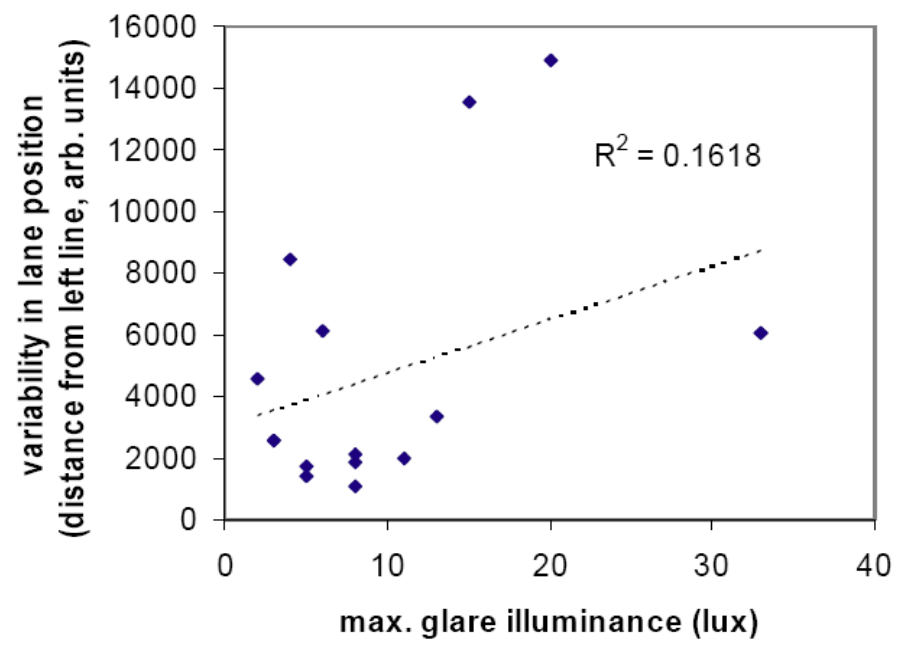
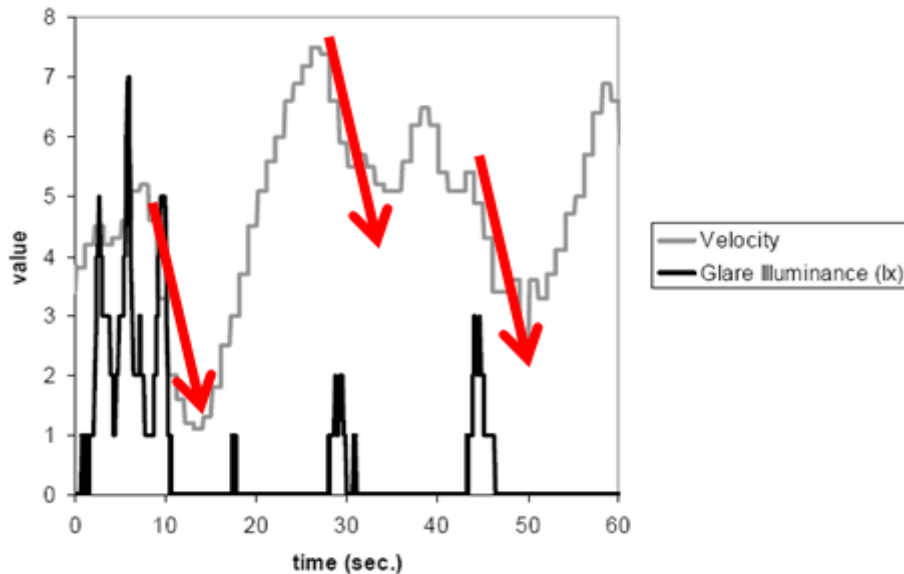
# Vertical aim (vs. mounting height) and glare



(Bullough 2013)

# Influence of glare on driving behavior

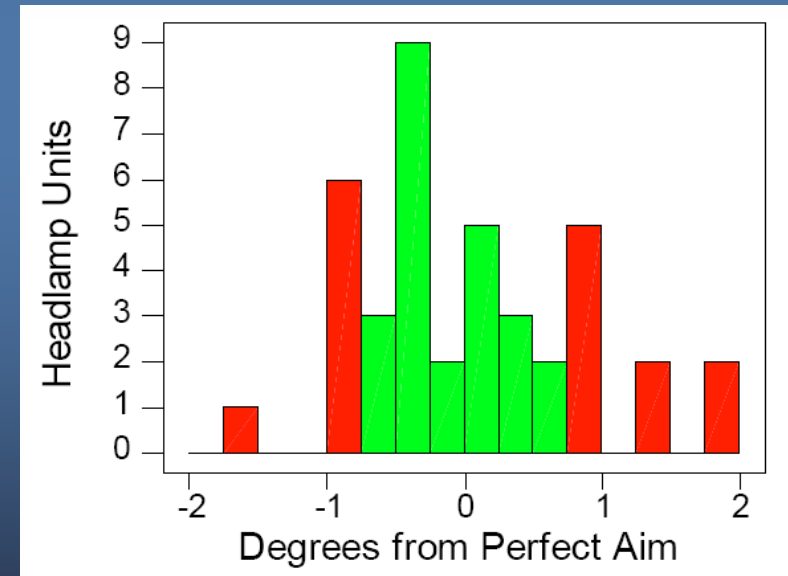
Glare illuminance and driving speed



(Van Derlofske and Bullough 2005)

# Headlight evaluation ratings

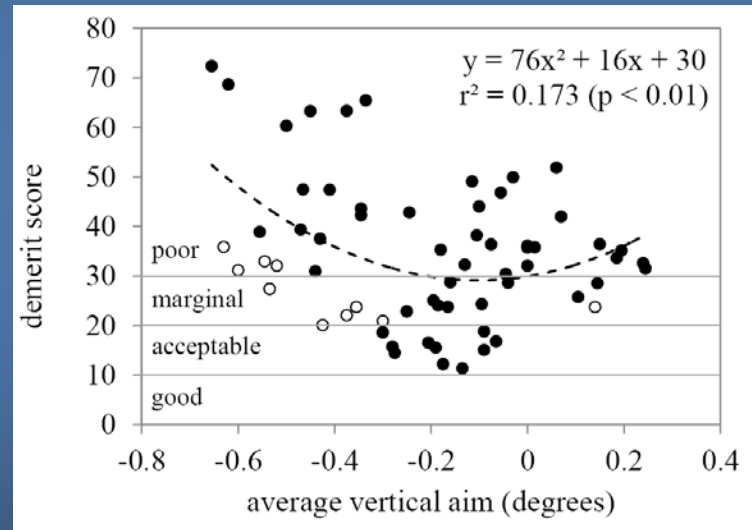
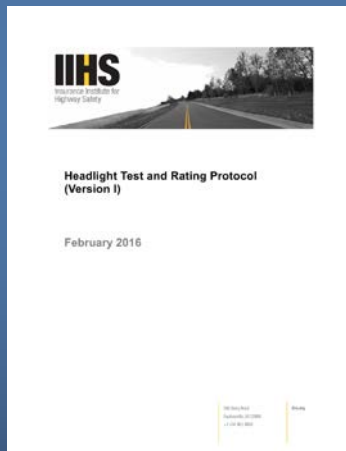
- ◆ Not all headlight evaluation and rating systems control for vertical aim (e.g., Insurance Institute for Highway Safety – IIHS)
- ◆ In the IIHS system, illuminance levels at target and oncoming driver eye locations are measured without adjusting headlight aim
- ◆ Headlights are penalized if they fail to illuminate targets or if they exceed limits toward driver eye locations
- ◆ Recall that a substantial proportion of new automobiles have misaimed headlights



(Skinner et al. 2010)

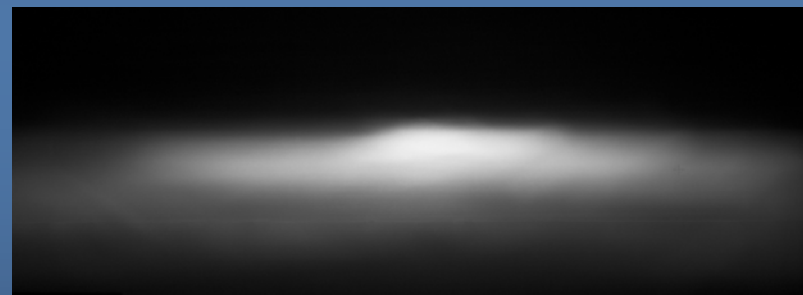
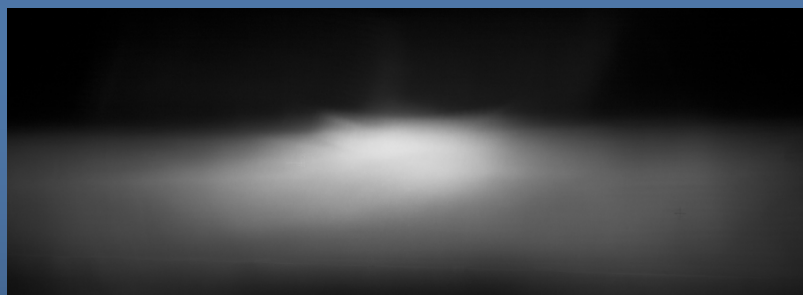
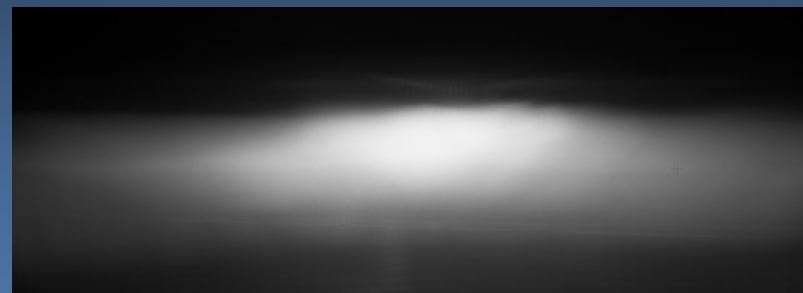
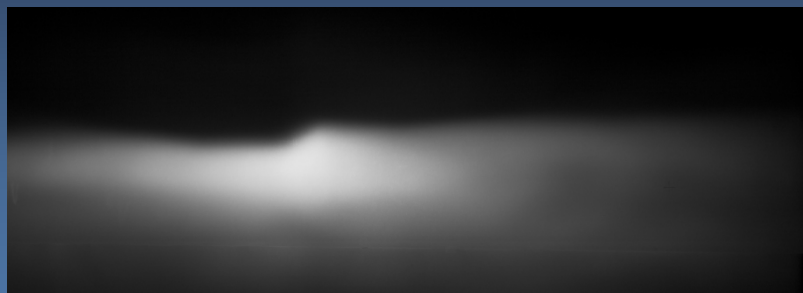
# Headlight evaluation ratings (cont'd.)

- ◆ “Demerit” scores and categories are shown for 64 headlight sets, neglecting bonuses for swiveling lights and automatic high beams
- ◆ Headlights with the greatest misaim (too low or too high) tended to be rated most poorly



- ◆ If headlights had been aimed properly, twice as many headlights could have been labeled as acceptable or good

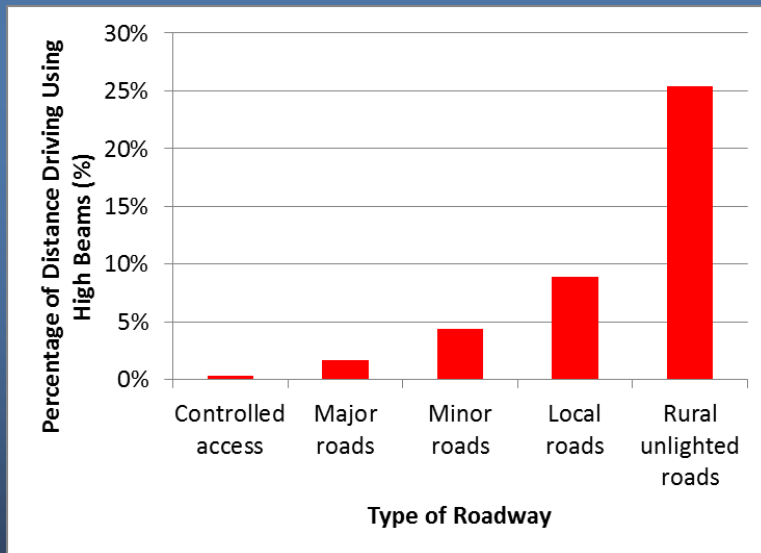
# Why the emphasis on vertical aim?



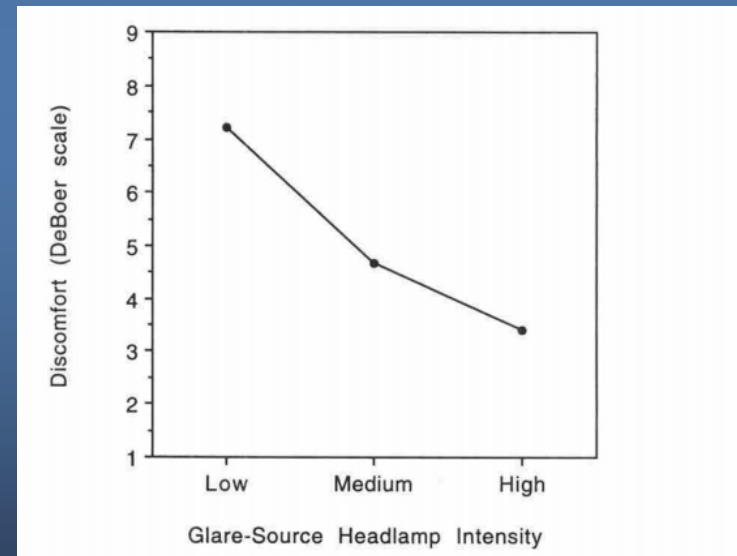
- ◆ Low beam headlights have sharp vertical cutoffs
- ◆ High beams don't, but...

# High beam use

- ◆ Driver don't often use their high beam headlights
- ◆ Even though overall visibility might be improved if everyone used high beams, discomfort glare would increase

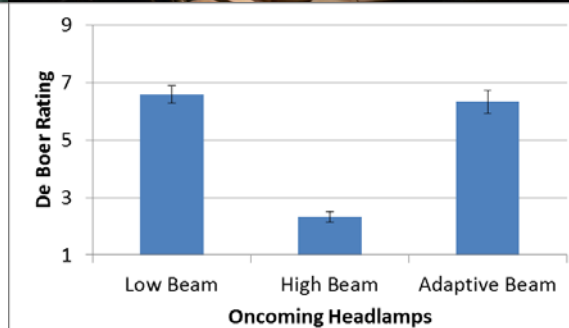
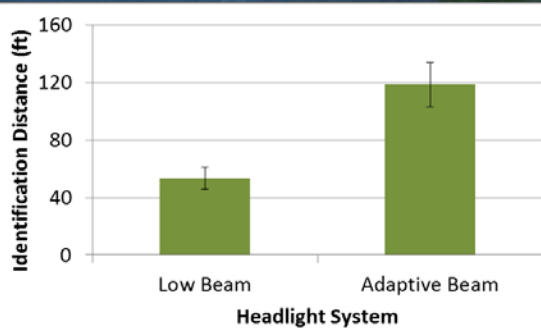
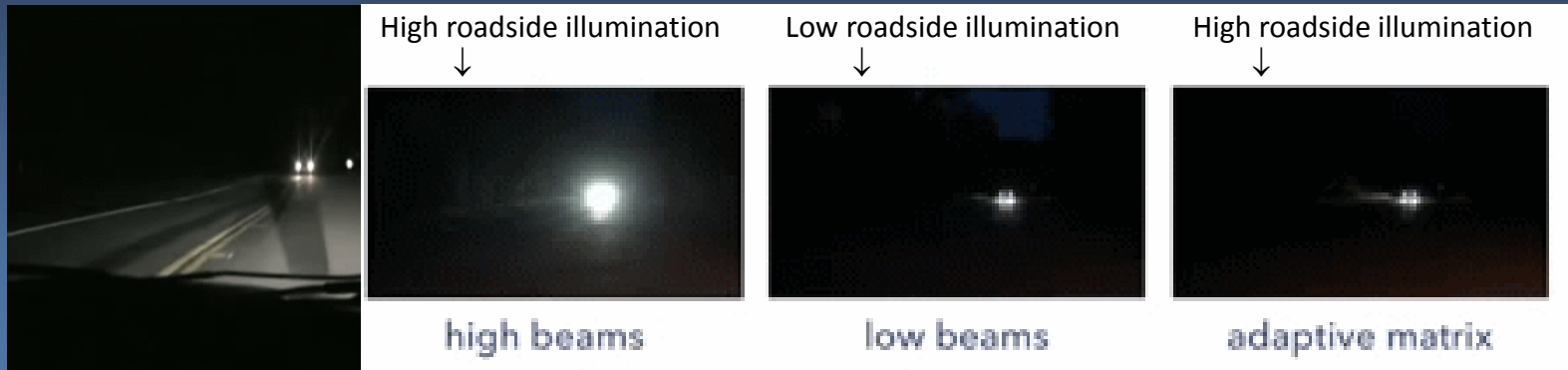


*Data replotted from Mefford et al. (2006)*



*Flannagan et al. (2000)*

# Adaptive driving beam (ADB) headlights



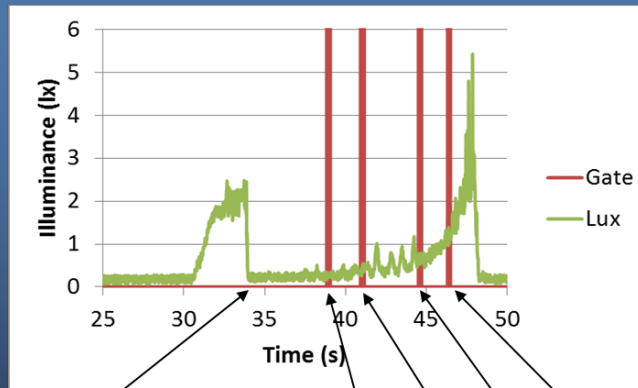
- De Boer Rating Scale
- 9 Unnoticeable glare
  - 8
  - 7 Satisfactory
  - 6
  - 5 Just permissible
  - 4
  - 3 Disturbing
  - 2
  - 1 Unbearable

Adaptive driving beam (ADB) systems might reduce visibility-related nighttime crashes by 6%-7% based on visual performance improvement (Bullough 2014)

From Bullough et al. (2016)

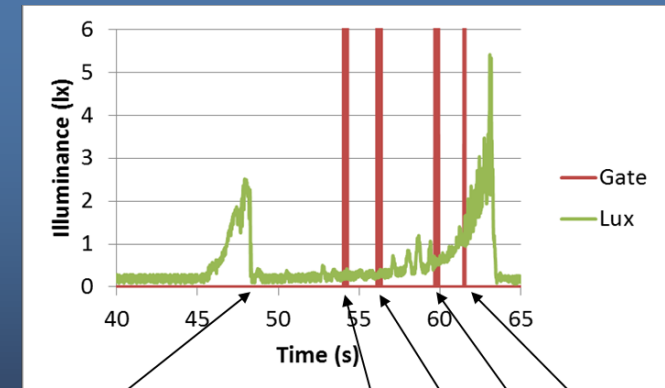
# Evaluating ADB/dynamic headlight performance

- ◆ Field tests of an ADB vehicle were made along a flat, straight road using draft procedures for SAE J3069
- ◆ Measurements were feasible and repeatable



ADB activates

155m 120m 60m 30m



ADB activates

155m 120m 60m 30m

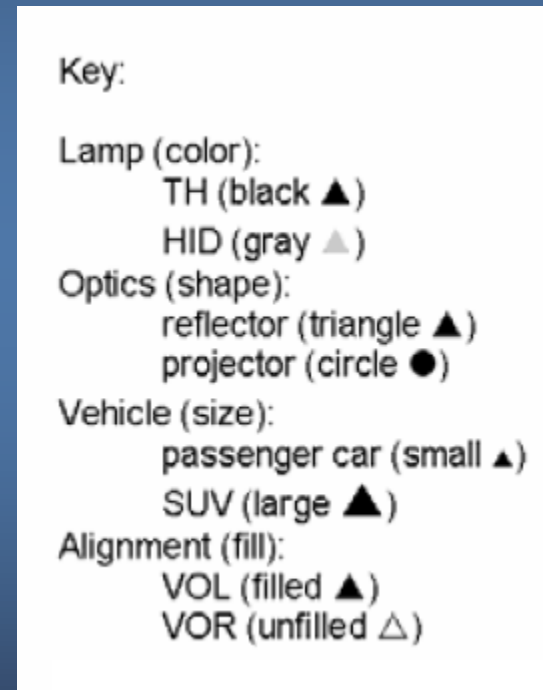
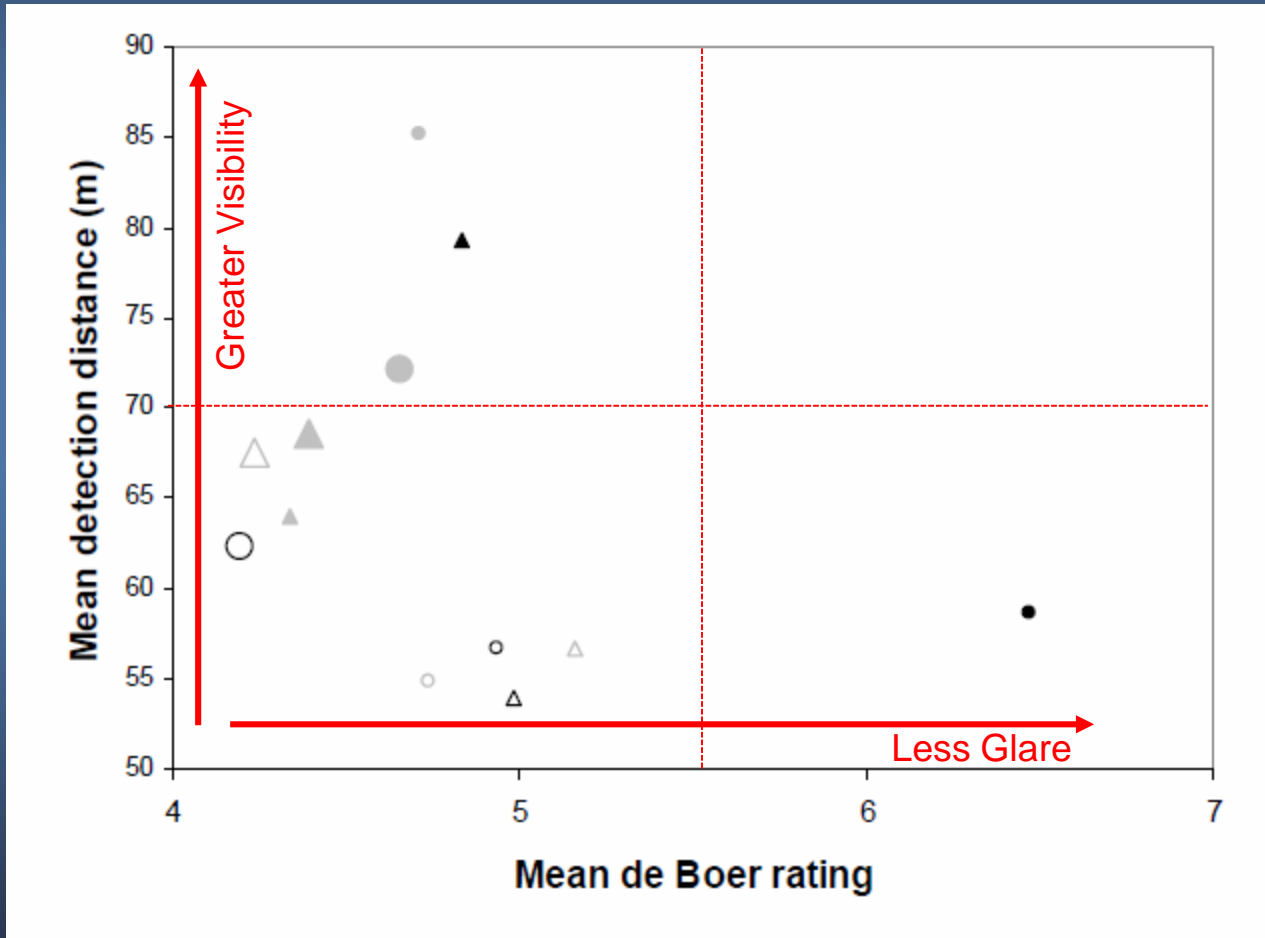


# Possibility of self-adjusting/self-calibrating ADB headlight systems

- ◆ ADB headlights work in conjunction with a camera to interpret the scene in front of a vehicle
- ◆ A “matrix” type of ADB system can control small individual portions of the beam pattern
- ◆ A calibration routine to match matrix beam elements with angular locations within the camera image (sequentially) could be developed
  - › This could ensure that variations in headlight vertical aim do not increase glare or reduce forward visibility

# Outlook

- ◆ Traditionally there has been a “trade-off” between visibility/glare



(Akashi et al. 2008)

# Outlook (cont'd.)

- ◆ Because of the visibility/glare trade-off, vertical aim has been critical to control
- ◆ ADB headlight systems can offer a way to break through this trade-off
  - › Dynamic, whole-vehicle field measurement is feasible and repeatable
- ◆ In the near-term, more rational headlight evaluation procedures are needed that account for headlight performance, not vertical misaim



# Acknowledgments

- ◆ Rainer Neumann, Geoff Draper, Gert Langhammer, Bart Terburg for invitation to participate
- ◆ Sponsors of LRC research summarized here:
  - › National Highway Traffic Safety Administration (NHTSA)
  - › Transportation Lighting Alliance (TLA: Audi, Automotive Lighting, Hella, Lumileds, OSRAM, Varroc)
- ◆ Thank you!