

Advances in Understanding the Safety Benefits of Adaptive Vehicle Lighting

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DVN Workshop: How to Save Lives in Nighttime Driving

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Icahn School
of Medicine at
**Mount
Sinai**

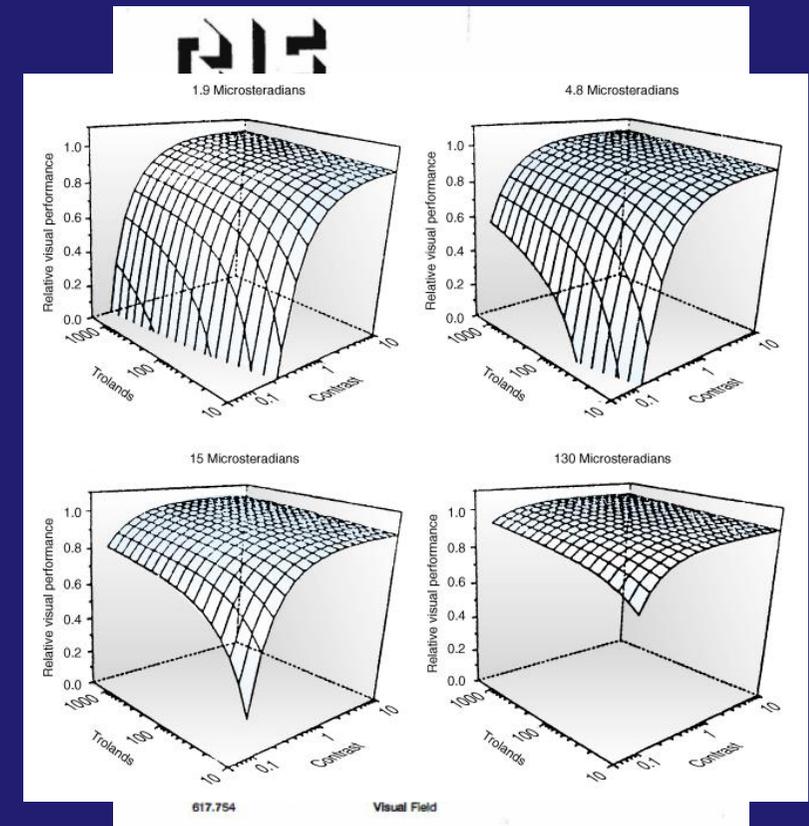
*Light and Health
Research Center*

Outline

- Relative visual performance (RVP) model
- Empirical benefits of adaptive driving beam (ADB) headlights
- Visual performance analyses – default and ADB scenarios
- Safety and other broader implications

Visual Performance in Driving

- Nighttime driving is an inherently visual task
 - “The visual sense is the source of the most important information required in the performance of the driving task.” (CIE Report No. 100, 1992)
- Visual performance characterizes the speed and accuracy of visual processing
- Relative visual performance (RVP) is influenced by:
 - Light level
 - Contrast
 - Size
 - Age (indirectly)



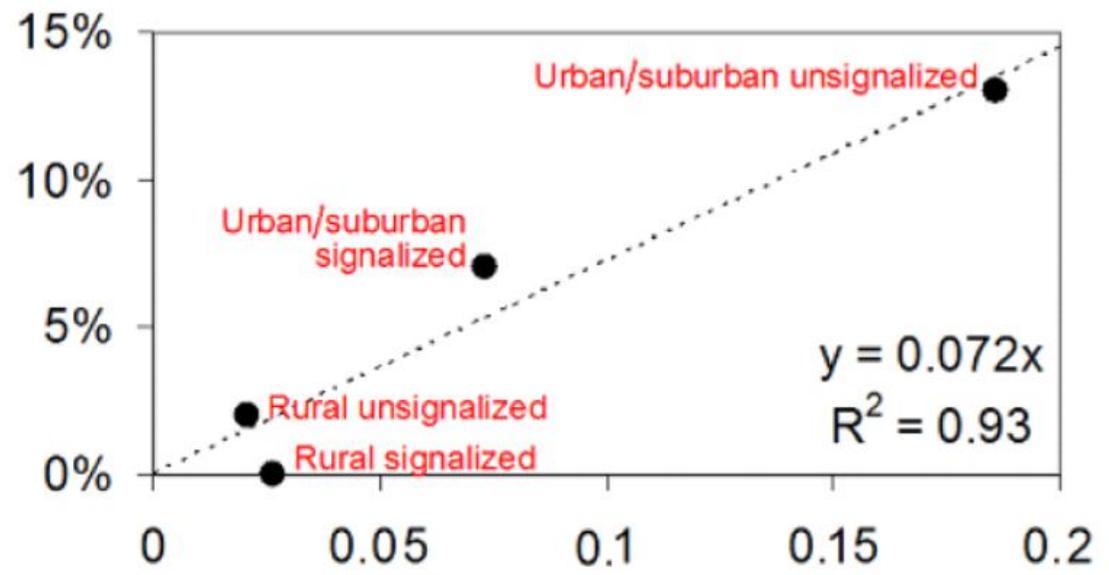
(CIE, 1992; Rea and Ouellette, 1991)

Is Visual Performance Modeling Useful?

Medium street lighting level (9 lux on road, 15 lux at intersection)

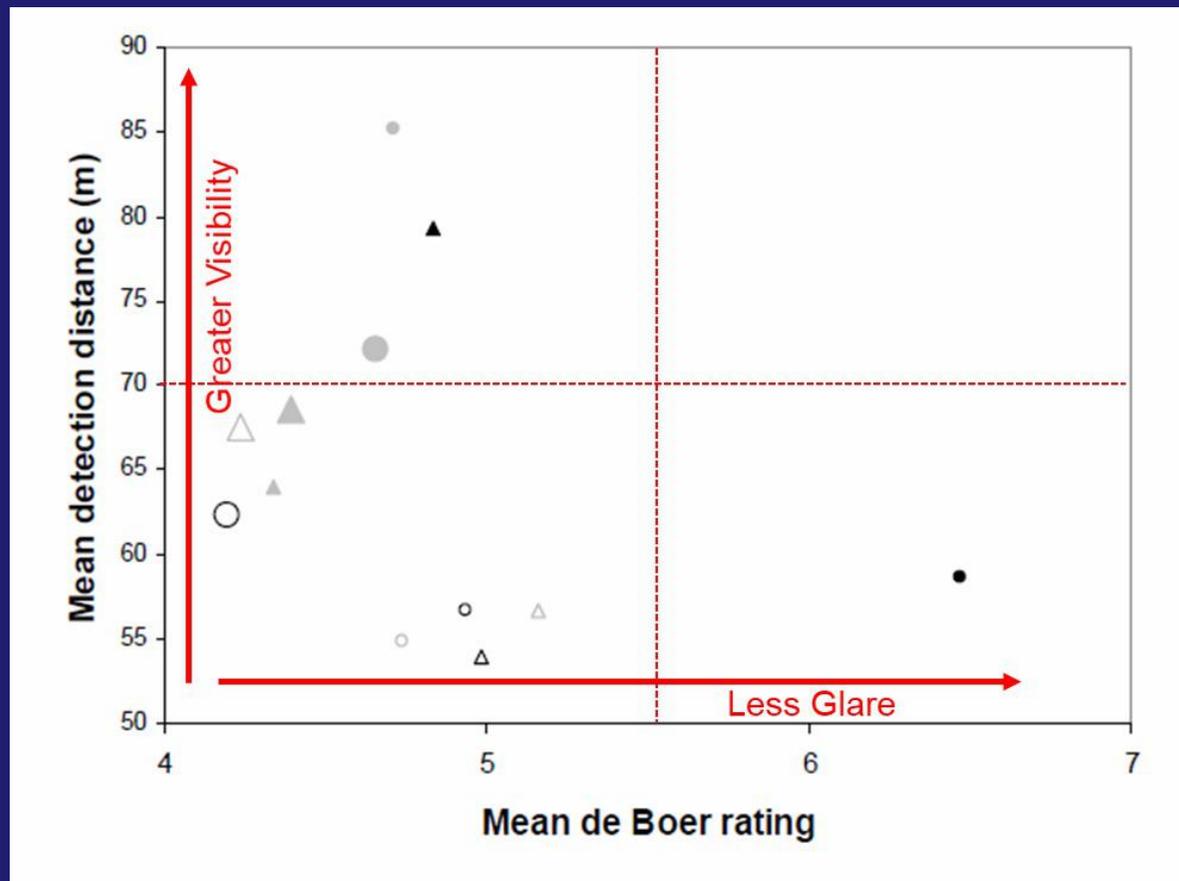
Lighting configuration	Location	Driver Age=30																Driver Age=60																			
		Ambient Illuminance = 20 lux				Ambient Illuminance = 2 lux				Ambient Illuminance = 0.2 lux				Ambient Illuminance = 0.02 lux				Ambient Illuminance = 20 lux				Ambient Illuminance = 2 lux				Ambient Illuminance = 0.2 lux				Ambient Illuminance = 0.02 lux							
		C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
0		0.91	0.91	0.92	0.92	0.71	0.71	0.81	0.81	0.99	0.99	0.73	0.73	0.99	0.99	0.73	0.73	0.88	0.88	0.91	0.91	0.99	0.99	0.73	0.73	0.99	0.99	0.73	0.73	0.99	0.99	0.73	0.73	0.99	0.99	0.73	0.73
1		0.91	0.91	0.92	0.92	0.71	0.71	0.81	0.81	0.99	0.99	0.73	0.73	0.99	0.99	0.73	0.73	0.88	0.88	0.91	0.91	0.99	0.99	0.73	0.73	0.99	0.99	0.73	0.73	0.99	0.99	0.73	0.73	0.99	0.99	0.73	0.73
2		0.92	0.92	0.93	0.93	0.72	0.72	0.82	0.82	0.99	0.99	0.74	0.74	0.99	0.99	0.74	0.74	0.89	0.89	0.92	0.92	0.99	0.99	0.74	0.74	0.99	0.99	0.74	0.74	0.99	0.99	0.74	0.74	0.99	0.99	0.74	0.74
3		0.93	0.93	0.94	0.94	0.73	0.73	0.83	0.83	0.99	0.99	0.75	0.75	0.99	0.99	0.75	0.75	0.90	0.90	0.93	0.93	0.99	0.99	0.75	0.75	0.99	0.99	0.75	0.75	0.99	0.99	0.75	0.75	0.99	0.99	0.75	0.75
4		0.93	0.93	0.94	0.94	0.73	0.73	0.83	0.83	0.99	0.99	0.75	0.75	0.99	0.99	0.75	0.75	0.90	0.90	0.93	0.93	0.99	0.99	0.75	0.75	0.99	0.99	0.75	0.75	0.99	0.99	0.75	0.75	0.99	0.99	0.75	0.75
5		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
6		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
7		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
8		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
9		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
10		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
11		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
12		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
13		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
14		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
15		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
16		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
17		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
18		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76
19		0.94	0.94	0.95	0.95	0.74	0.74	0.84	0.84	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.91	0.91	0.94	0.94	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76	0.99	0.99	0.76	0.76

Nighttime Crash Reduction (%)



Nighttime Crash Safety Increase in RVP Value

The Visibility / Glare “Tradeoff”



Key:

Lamp (color):

TH (black ▲)

HID (gray ▲)

Optics (shape):

reflector (triangle ▲)

projector (circle ●)

Vehicle (size):

passenger car (small ▲)

SUV (large ▲)

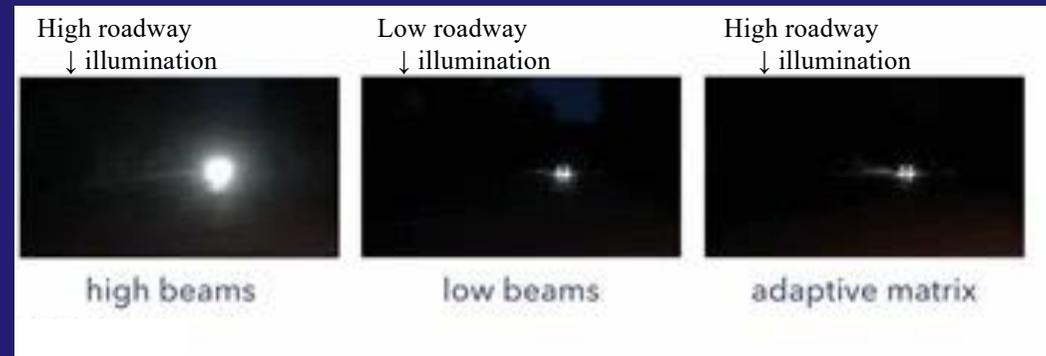
Alignment (fill):

VOL (filled ▲)

VOR (unfilled △)

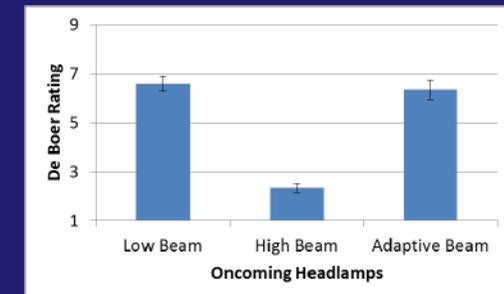
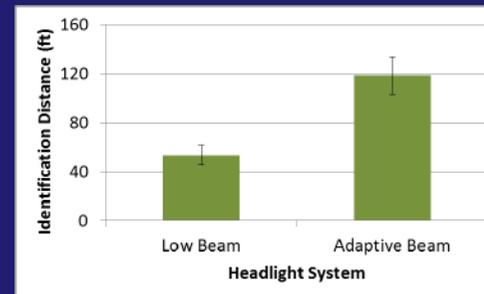
(Akashi et al. 2008)

Averting the Tradeoff: Adaptive Driving Beam



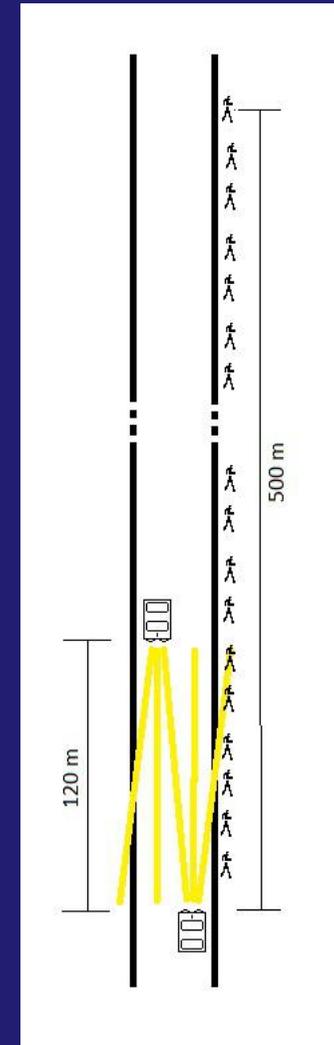
- Empirical evidence:
High beam visibility
with low beam glare

(Bullough et al. 2016)



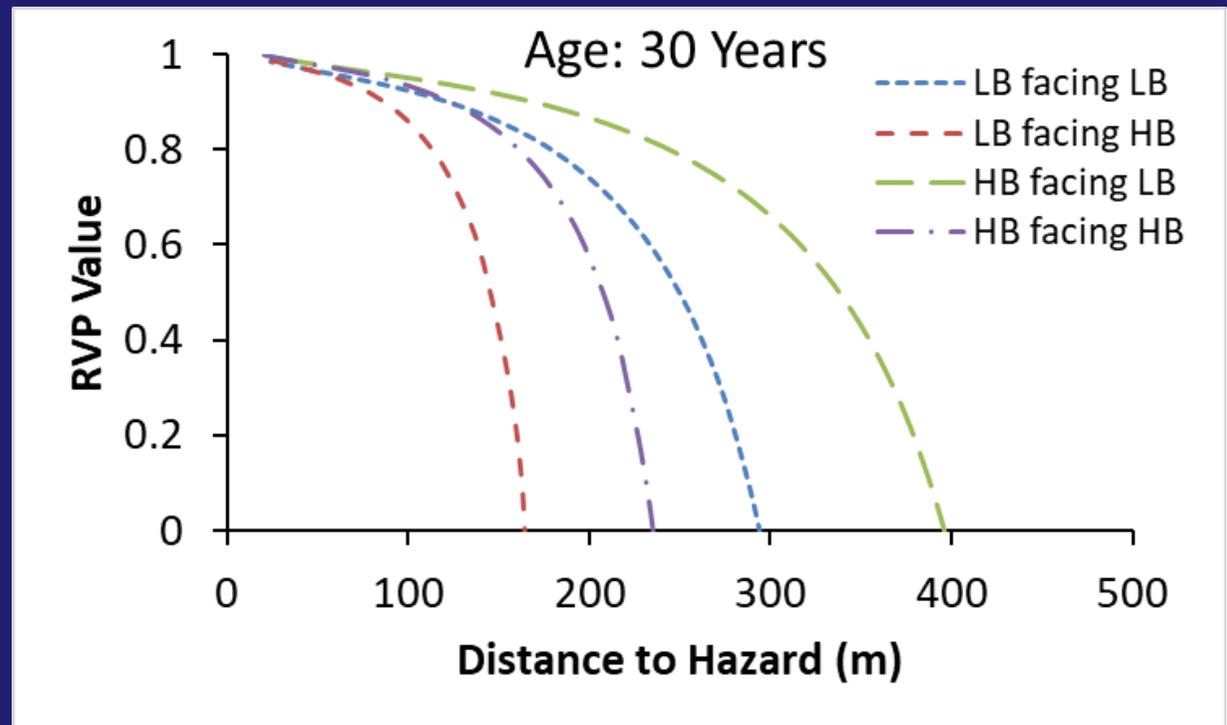
Analysis Method

- Investigate impacts of forward and opposing headlight intensity
 - Default: Low vs. low beams, ADB scenario: High vs. low beams
 - For driver ages of 30 or 60 yr
 - Oncoming distance: 120 m
- Visibility target: “Child-sized” pedestrian (1 × 0.5 m, $\rho=0.2$) between 20 and 500 m away
- Visibility model: Relative visual performance (RVP) model



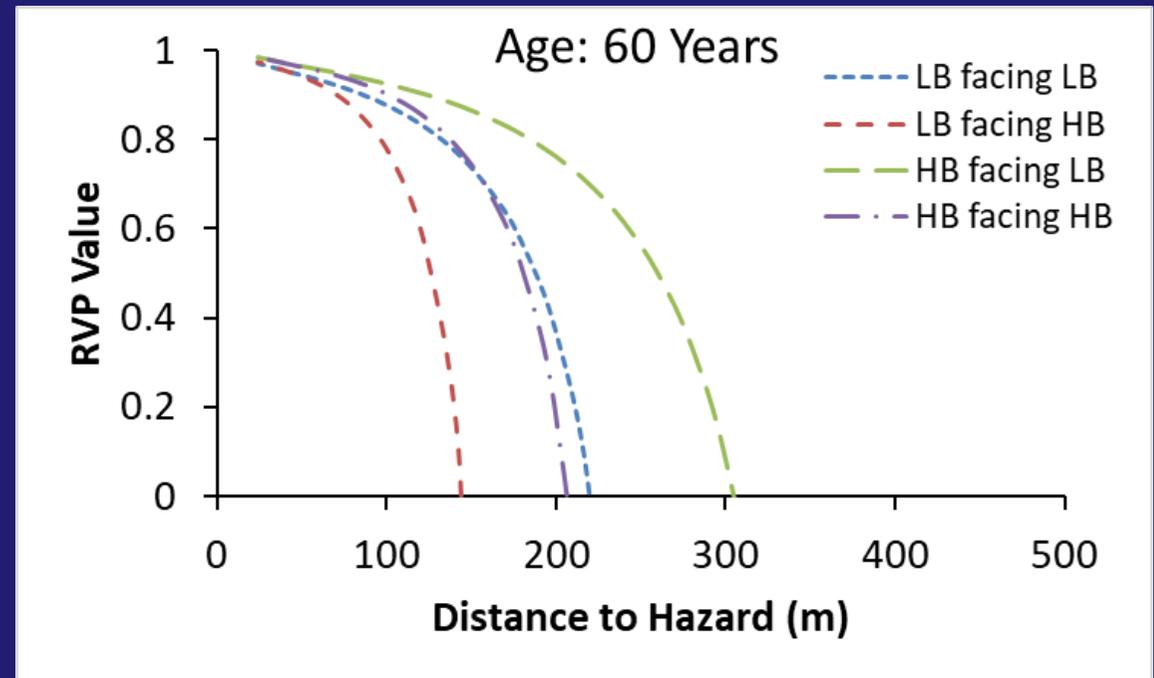
Results: Younger Drivers

- Best performance: Using high beams / facing low beams (corresponds to all-ADB scenario)
- Worst performance: Using low beams / facing high beams
- Low vs. low beams outperformed high vs. high beams



Results: Older Drivers

- Shorter threshold visibility distances than for younger drivers
- Rank order is unchanged
- Low vs. low beams performed similarly as high vs. high beams



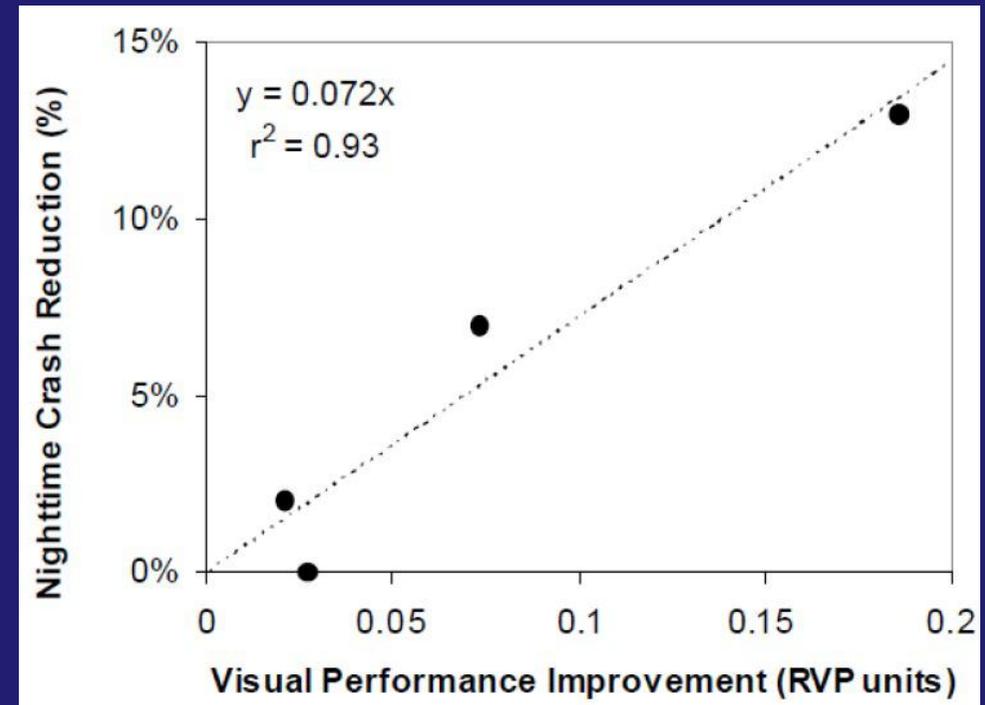
Discussion

- For four lighting conditions:
 - Low vs. low beams (most likely “default” scenario)
 - High vs. low beams (analogous to “all-ADB” scenario)
 - Low vs. high beams
 - High vs. high beams
- Scenarios modeling universal ADB headlight use result in highest RVP values and longest threshold visibility distances
- What is RVP improvement for default and ADB scenarios at minimum stopping distances for asphalt pavement at 120 km/h?

Scenario	RVP (driver age: 30 yr)	RVP (driver age: 60 yr)
<i>Default (low vs. low beams)</i>	0.833	0.671
<i>ADB (high vs. low beams)</i>	0.906	0.842
<i>ΔRVP value</i>	0.073	0.171

Discussion (cont'd.)

- Based on the transfer function between visibility improvements associated with lighting and nighttime crash frequency, the potential nighttime pedestrian crash reduction under the ADB scenario is:
 - **5.3%** for 30 year olds
 - **12.3%** for 60 year olds
- Similar range for safety benefit estimated by Bullough (2014)



(Bullough et al. 2013)

Summary

- Empirical results and analytical predictions are consistent with each other and with previously published literature (e.g., Flannagan et al., 2000)
 - Analysis method extended to hazard detection (Bullough, 2014) and visual acquisition of raised pavement markers (Barrette and Pike, 2019)
- Evidence points to improved visibility expected to result in a reduction in nighttime crashes similar in magnitude to that observed from roadway lighting, but without the same magnitude of energy use or light pollution



Thank You!

Light for Transportation Safety Partnership

Members: Audi, Hella, Lumileds, Marelli, OSRAM, Varroc

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