Spectral Sensitivity in Night Driving: Dependence on Adaptation, Location, Task, and Whatnot

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UMTRI

UMTRI Overview

- A multidisciplinary research institute within the University of Michigan
- Founded in 1965 by a major donation from vehicle manufacturers
- Currently, a mix of government and industry funding, total $14 million annual research
- Staff of 140 with research expertise on all aspects of driving road vehicles: safety, sustainability, driver experience

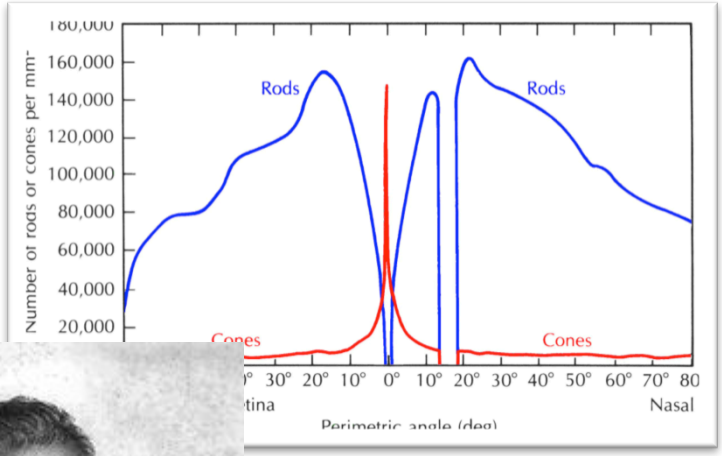
SAFETYPILOT

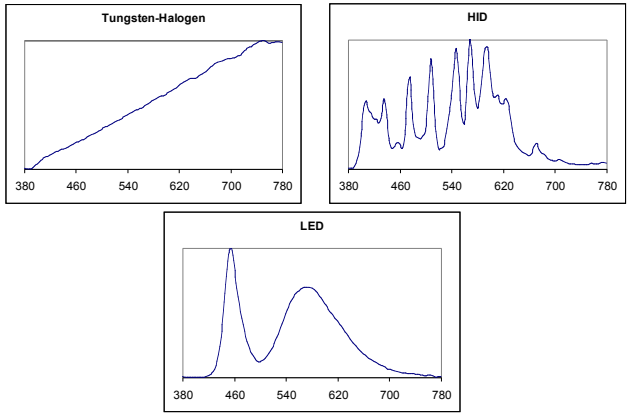
UMTRI

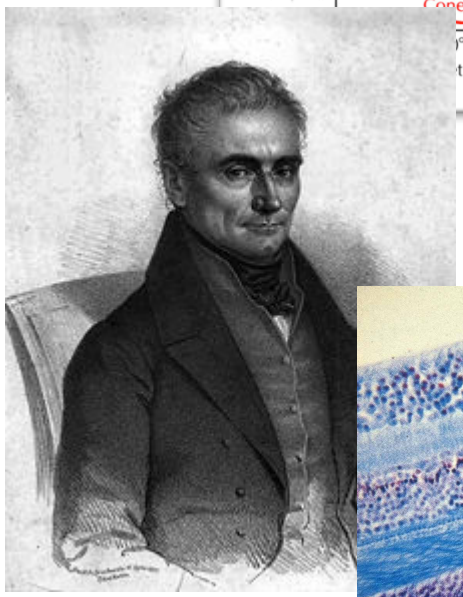
DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

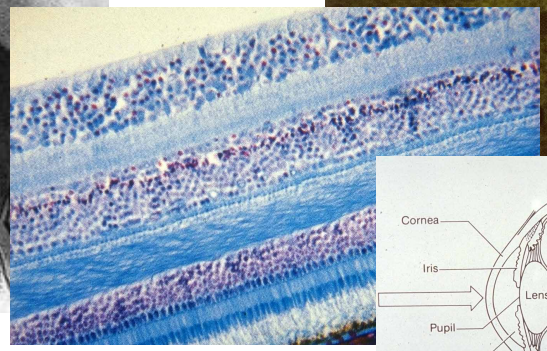
- Dedicated Short Range Communications (DSRC) in about 3000 vehicles
- Two road corridors
- One-year deployment and data collection

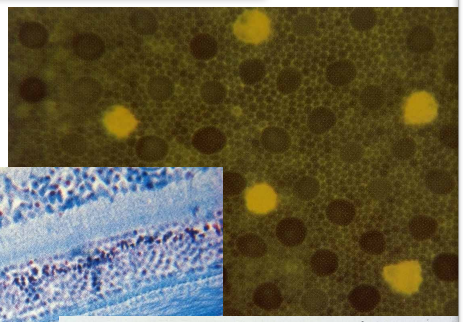
Effects of Color in Night Driving?

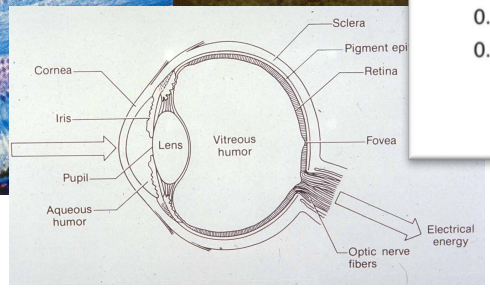


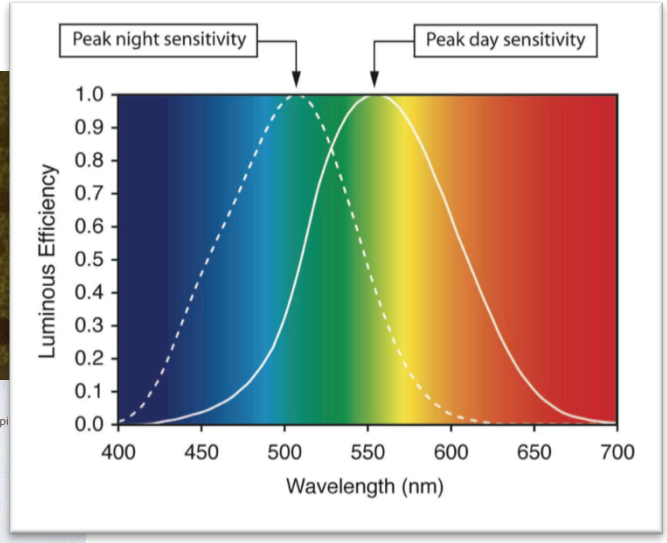








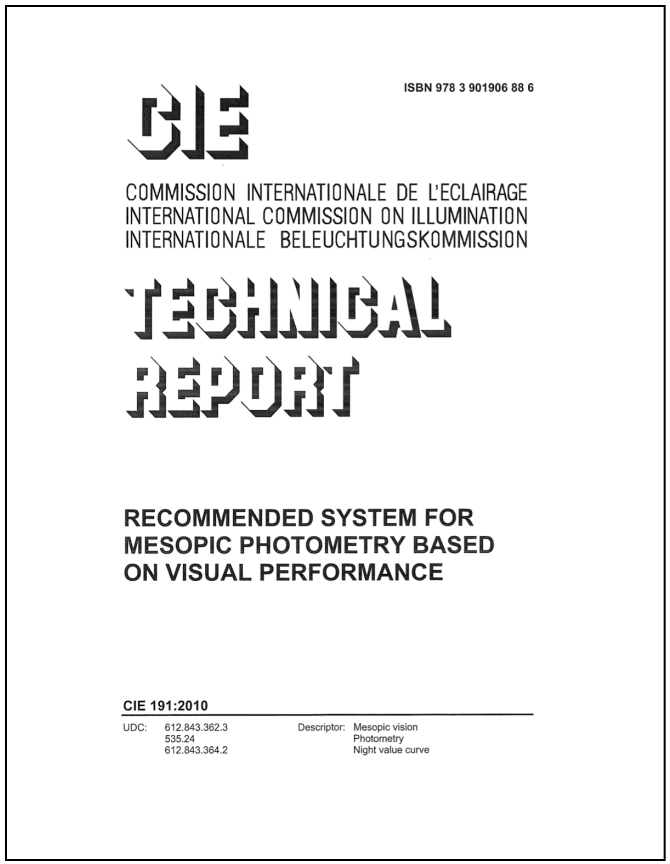




Some recent statements on headlamp color (ISAL 2011)

- “LED threshold detection appears to be significantly weaker than Halogen.” – *Hamm*
- “. . . the special white-bluish light color [of LED headlamp sources] is well appreciated by the human eye.” – *Neumann*

Mesopic photometry: CIE 191 (2010)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CIE

COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

TECHNICAL REPORT

RECOMMENDED SYSTEM FOR MESOPIC PHOTOMETRY BASED ON VISUAL PERFORMANCE

CIE 191:2010

UDC: 612.843.362.3 535.24 612.843.364.2

Descriptor: Mesopic vision Photometry Night value curve

"The recommendation is based on . . . the most important visual tasks and the range of visual conditions typically encountered when these tasks are considered in the context of night-time driving, which is considered as a key representative example of a mesopic lighting application."

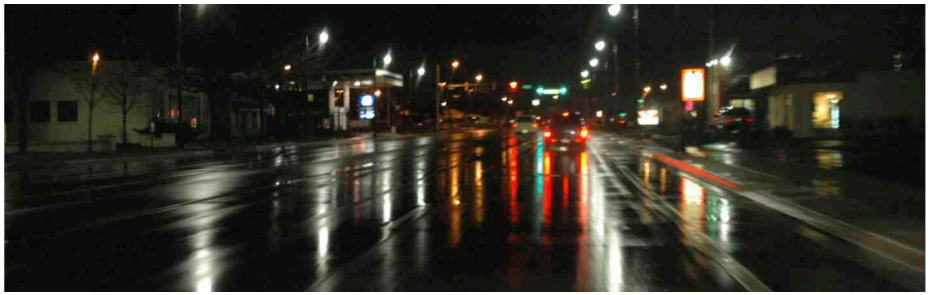
"The recommended system has been developed based on studies involving peripheral vision, where rods and cones both contribute to the visual response. This difference in visual performance as a function of target eccentricity may have implications for applications such as road lighting design. For example, different specification criteria may be necessary in situations where there is a different weighting of on-axis and peripheral visual information to process. These points will require careful consideration within the various specification organisations (highway agencies etc.)."

A differing view: "Happily, for practical purposes, scotopic vision is of interest only in wartime, and mesopic photometry is of little use in engineering problems."
LeGrand, 1972

Uchida & Ohno, 2012

- Adaptation luminance mainly depends on local luminance
- Adaptation fields can be defined from
  - Critical task points
  - Eye fixation

    These depend on application
- Imaging luminance meter or spot luminance meter should be employed to avoid too many special optics for each adaptation field



Driving Tasks and Failures (Crashes)

- Seeing the roadway to steer
- Seeing and avoiding unmarked obstacles (pedestrians)
- Seeing other vehicles (with lights and retroreflectors)
- Reading signs
- Etc.

- Preview: The critical safety issue for headlighting is pedestrian detection.

People overdrive low beams

- Perel, Olson, Sivak, & Medlin (1983): Safe speed with low beams is 70 km/h [45 mph].
- Burgett, Matteson, Ulman, & Van Iderstine (1989): Maximum speed for which adequate light is achievable is 40 mph [64 km/h].

The selective degradation hypothesis

According to this point of view, visual processes can be dissociated into at least two subsystems. "Focal" vision is mediated primarily by the central retina and subserves form perception (identification), while "ambient" vision is mediated primarily by the peripheral retina and provides information regarding spatial localization. . . . Thus, there should be relatively little degradation of performance of the ambient system with lowered illumination. . . . In contrast with the relatively high performance of the ambient system, the performance of the focal (form identification) system is seriously degraded under low illumination.

(Leibowitz & Owens, 1977)

The selective degradation hypothesis

Since the major tasks of driving [i.e., dynamic spatial orientation, staying on the road] are relatively unimpaired by reduced illumination, the driver does not anticipate and is not prepared to deal with stimuli for which the focal system suffers a selective deficit. In effect, the driver is unjustifiably reassured by the high performance level of the dynamic spatial orientation system and is unaware of a loss in focal visual abilities. Since the visual deficit is only partial and of consequence only for low-probability stimuli, the driver is unaware of the loss of function and does not take the necessary precautions.

(Leibowitz & Owens, 1977)

Types of crashes and likely visibility countermeasures

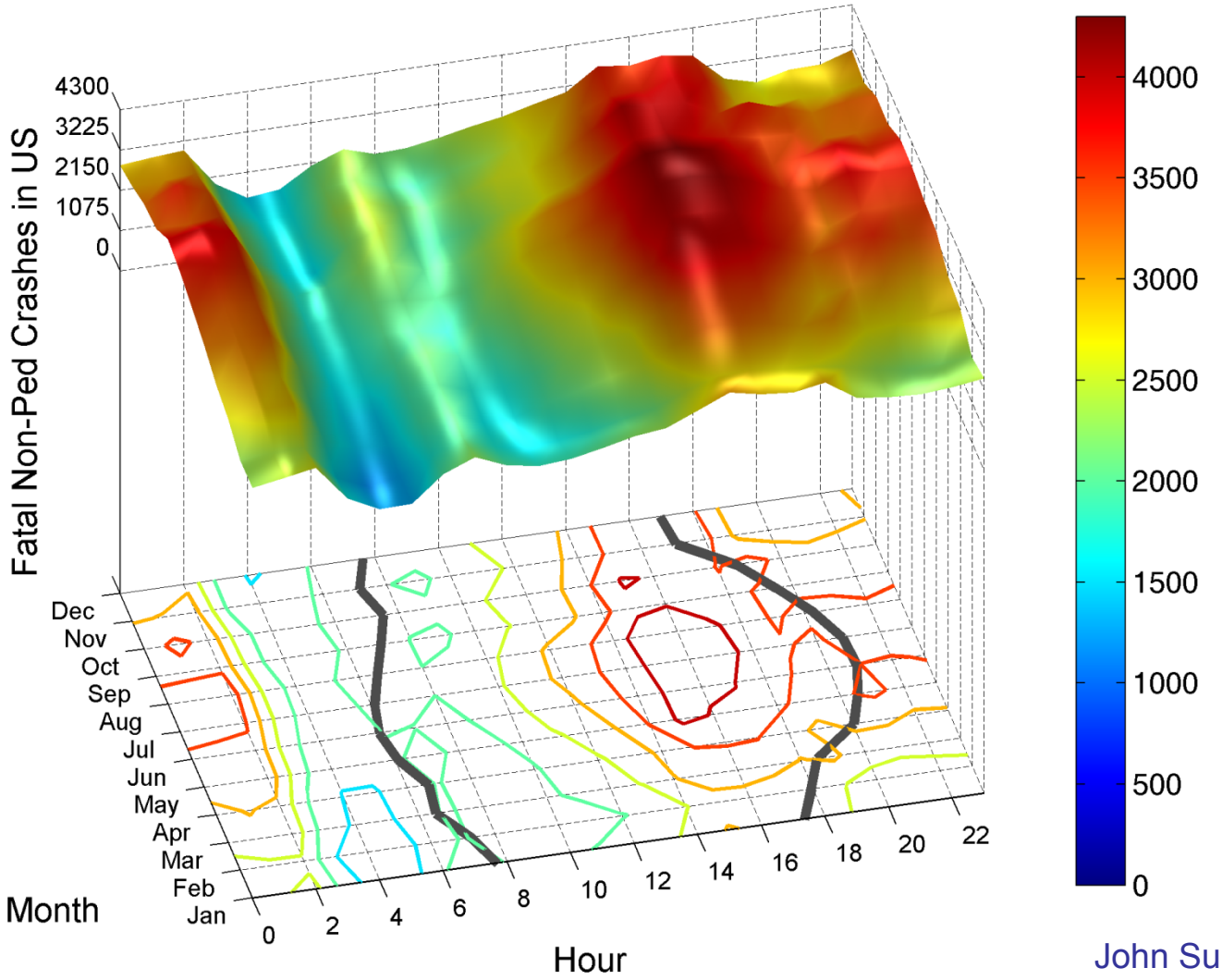
- Multi-vehicle crashes (any visibility solution is likely to involve signaling and marking lamps, or retroreflectors, rather than headlamps)
- Single-vehicle crashes (a visibility solution might involve improved headlighting)
  - Road departure
  - Pedestrian

Analysis of nighttime risks

Cause of risk	Worse at night	Addressable by improved vision
Light	x	x
Alcohol	x	
Fatigue	x	
Etc.	x	

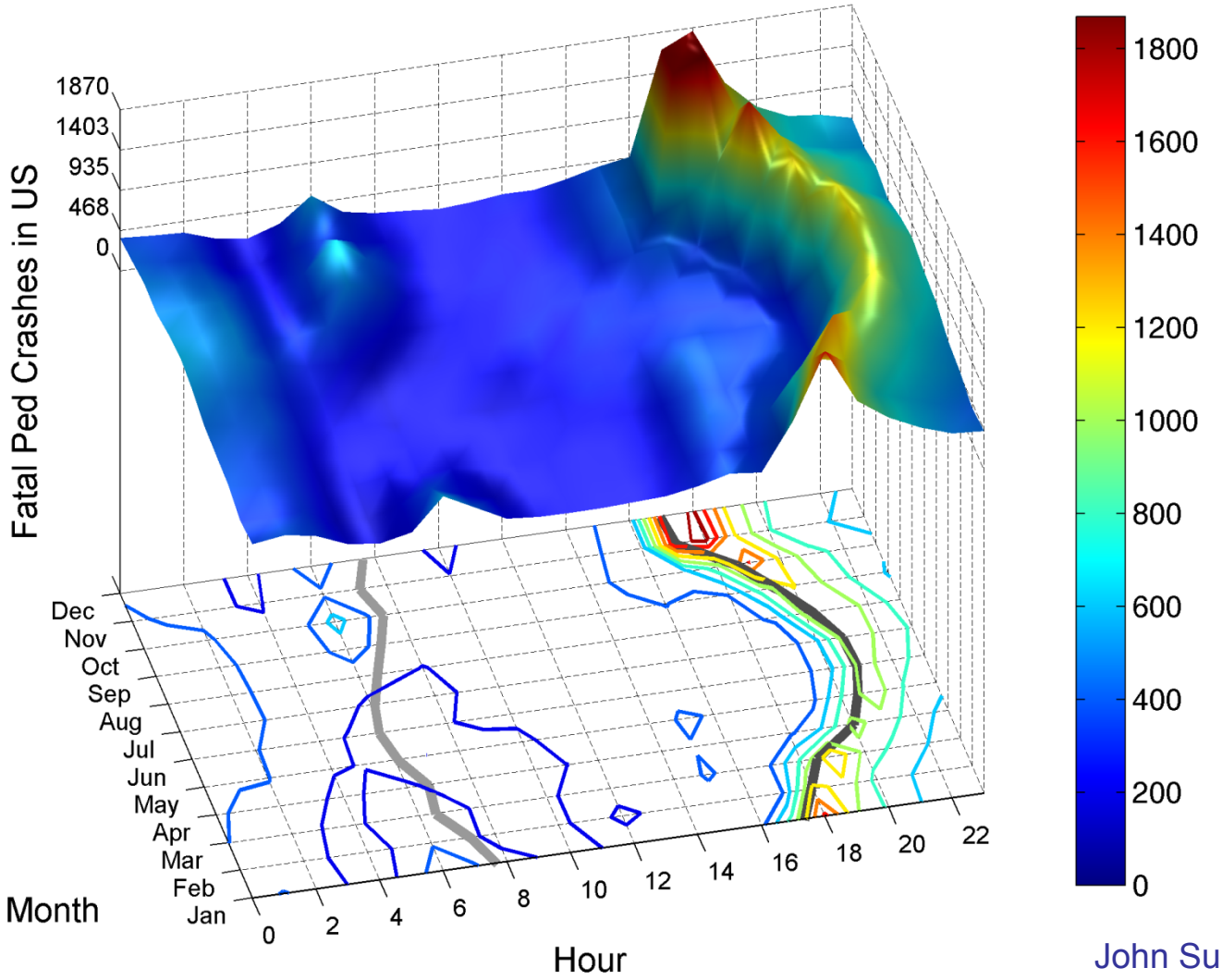
Twenty-plus years of studies of the effects of darkness on crash risk

All vehicle occupant deaths United States, 1987-2003



John Sullivan, UMTRI

All pedestrian deaths
United States, 1987-2003



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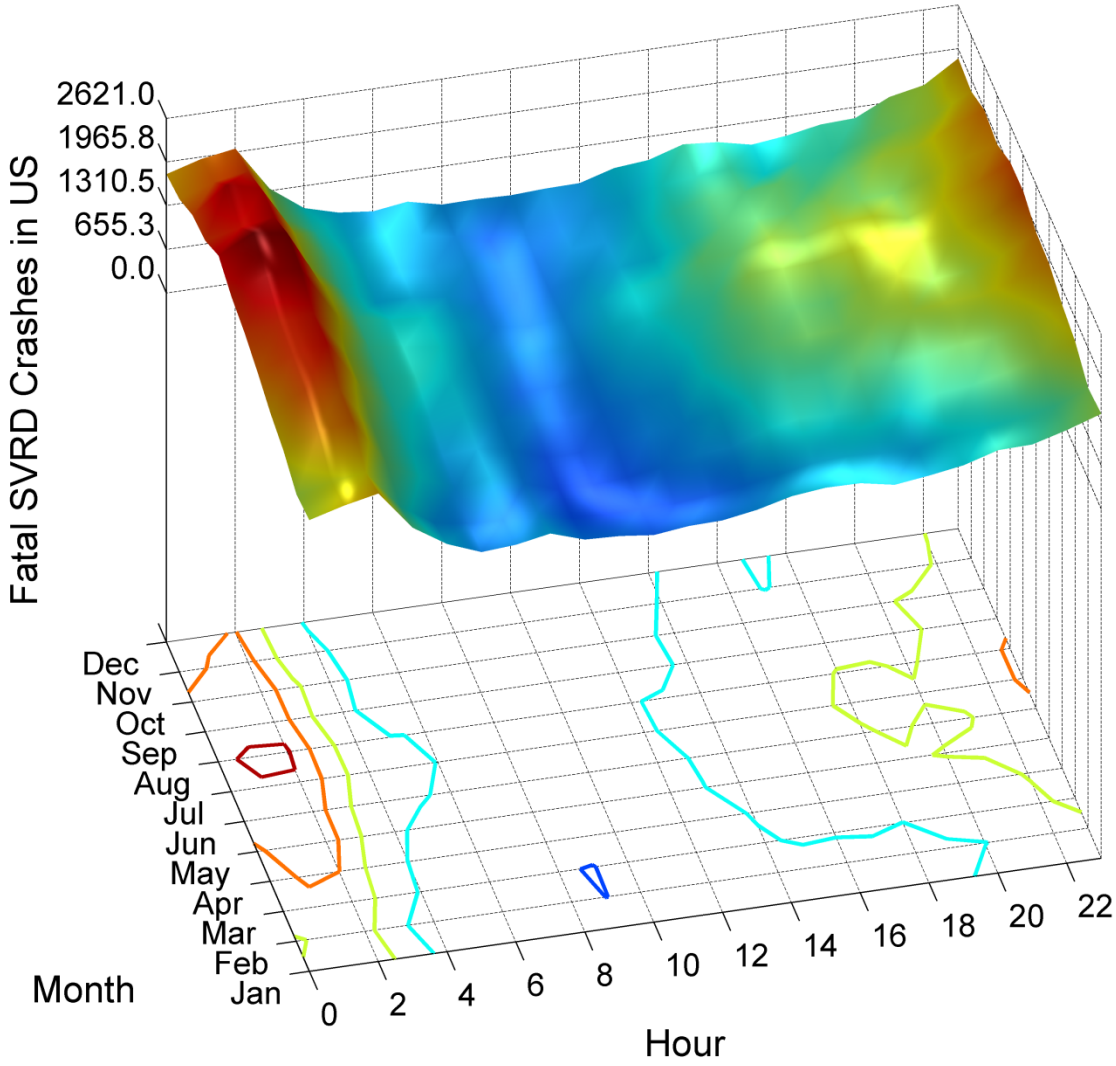
Road-departure vehicle occupant deaths United States, 1987-2003



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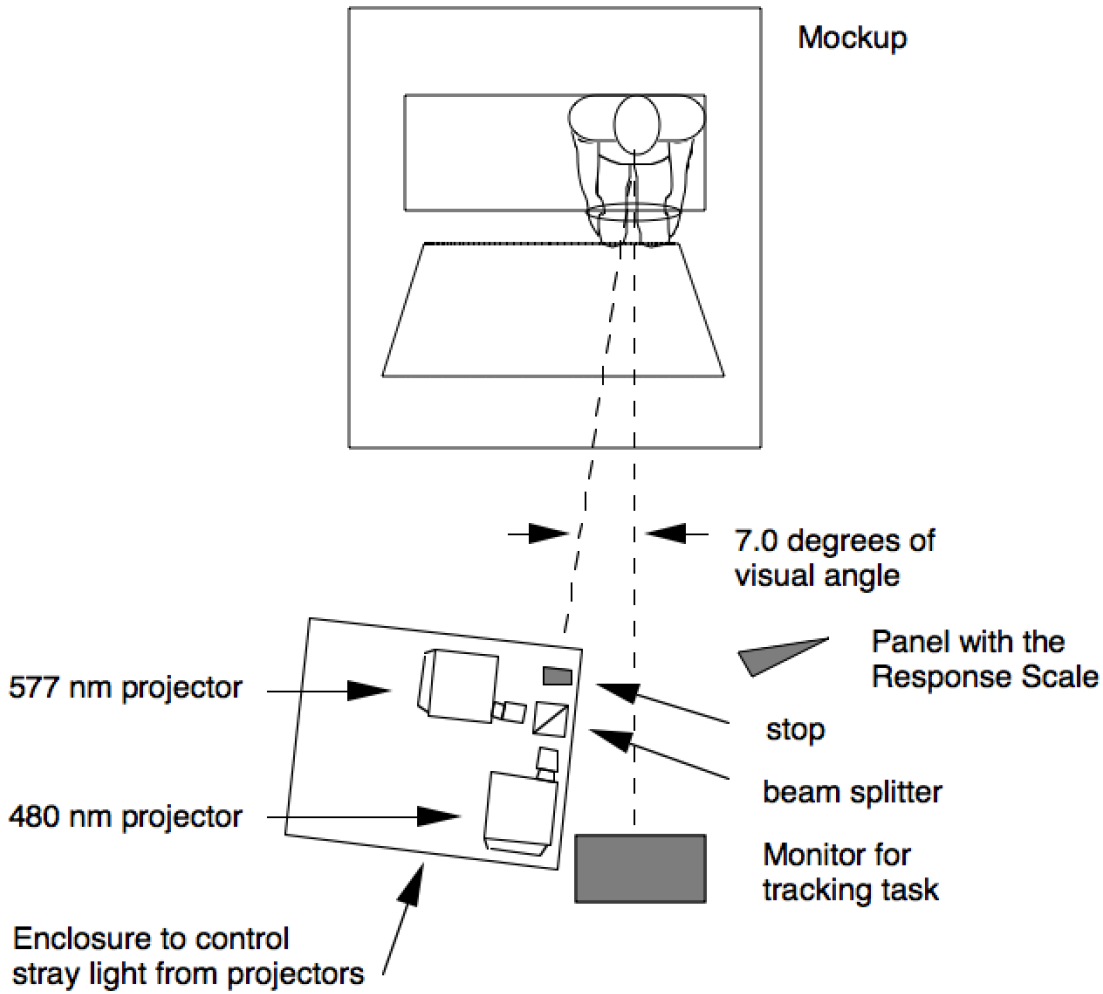
Ancient study of a Purkinje shift in discomfort glare (Flannagan, Sivak, & Gellatly, 1991)



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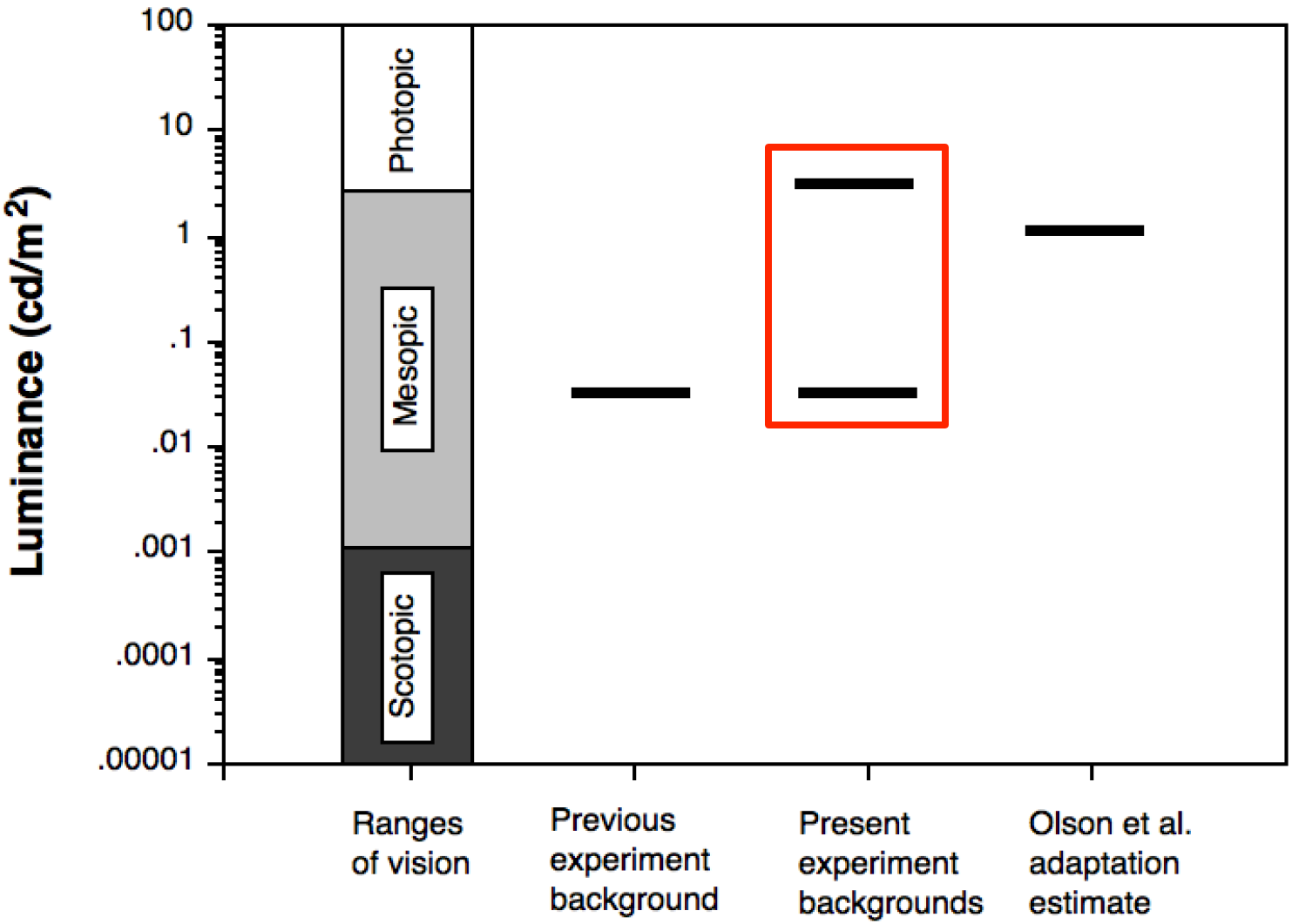

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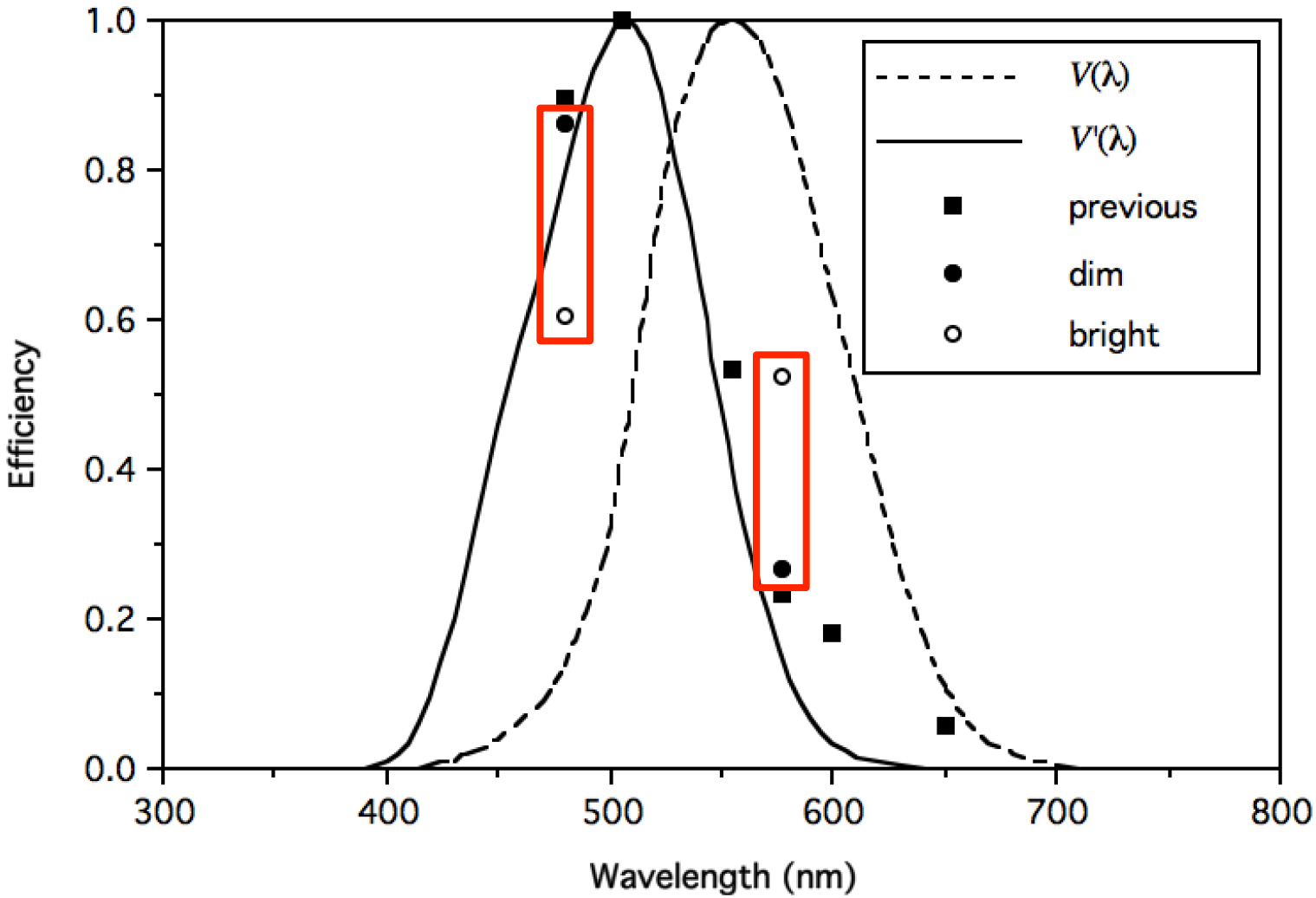
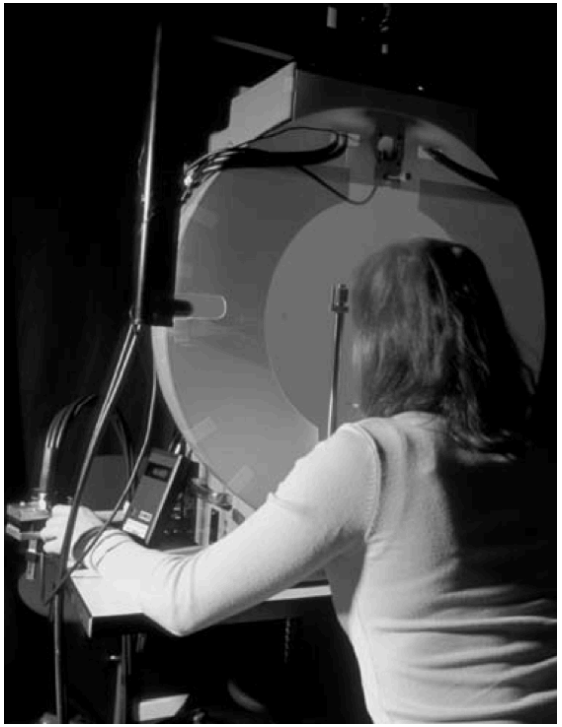
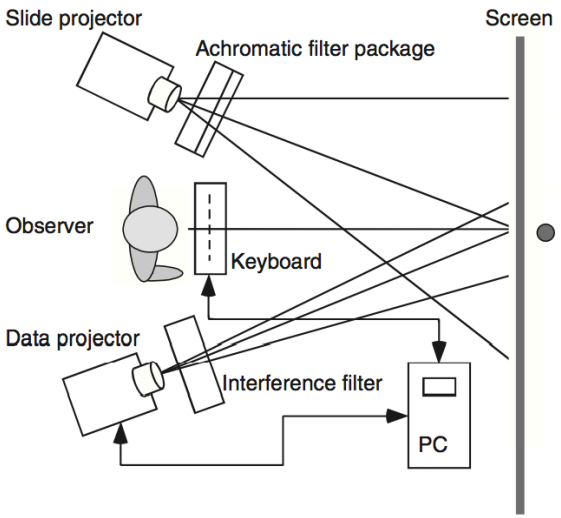
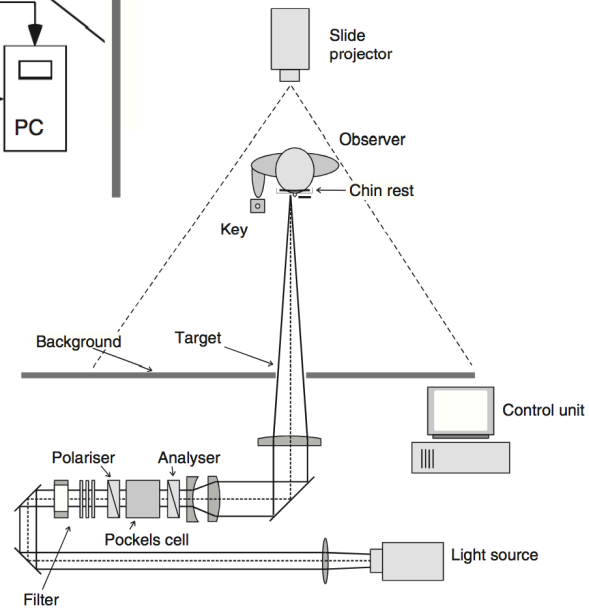


Research contributing to CIE 191 (EC MOVE project)

- Laboratory studies:
  - Uniform visual fields
  - Simple tasks

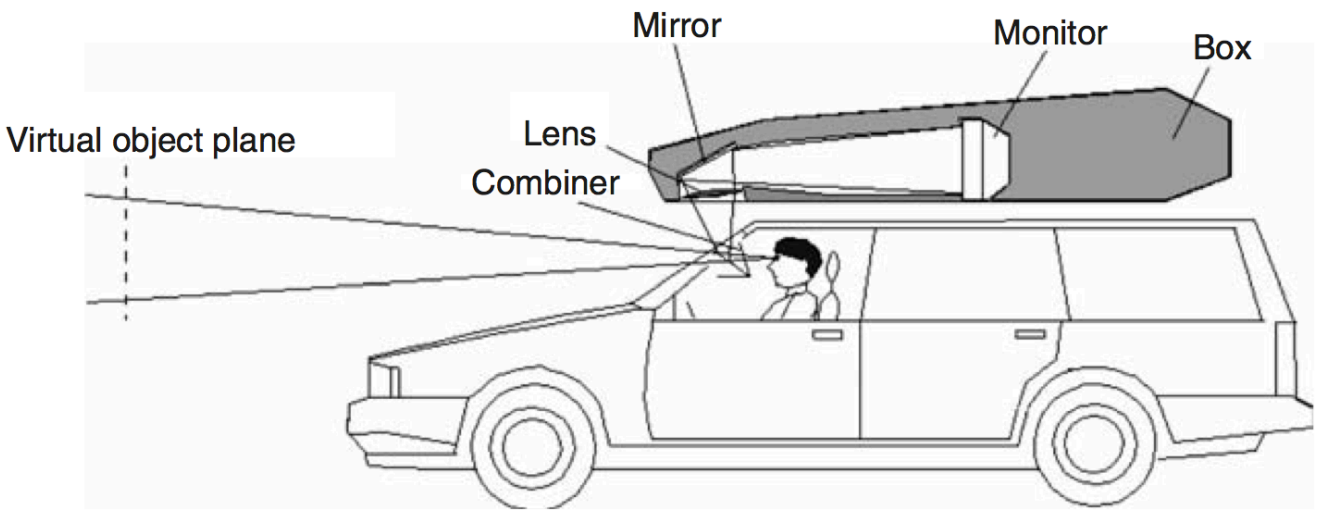






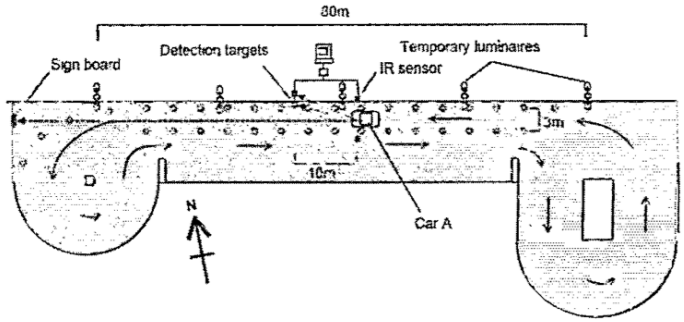
Research contributing to CIE 191 (EC MOVE project)

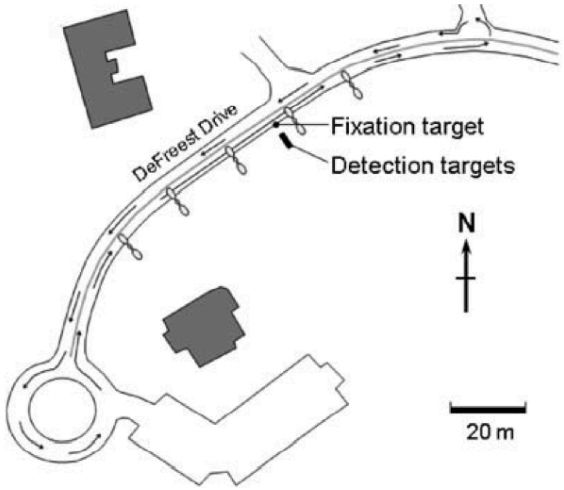
- Driving studies:
  - One simulator study
    - **three uniform areas (road, roadside, sky)**
    - **range of light 3.25:1**
  - One driving study (30 km/h, test track)



Outdoor driving studies (Akashi et al., 2002, 2007)

- Parking lot or closed road section
- Driving at 20 MPH
- Single fixed location of target



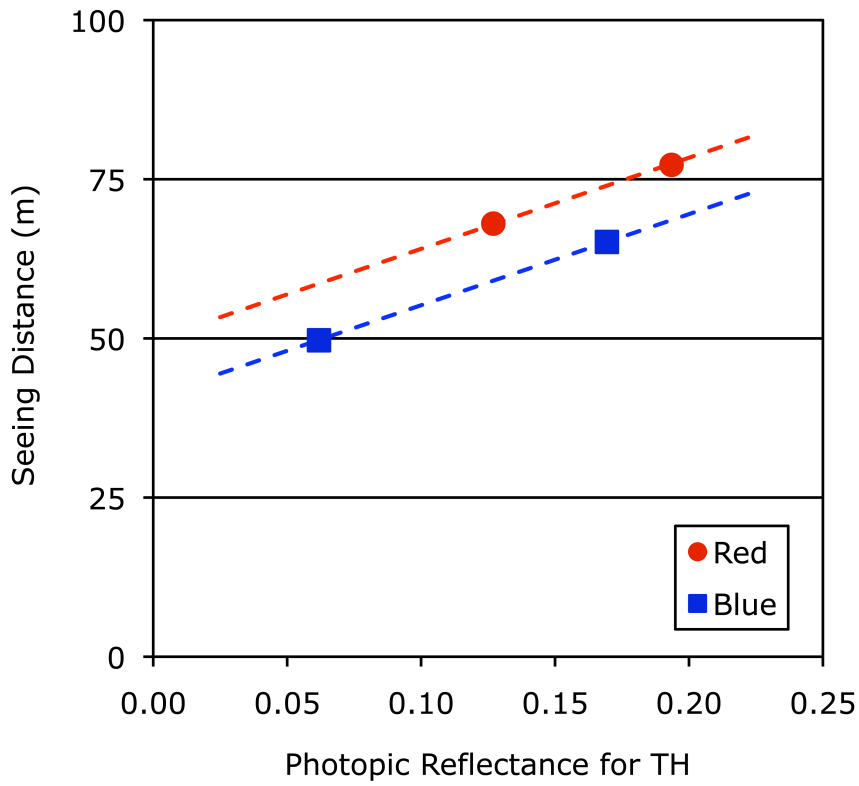


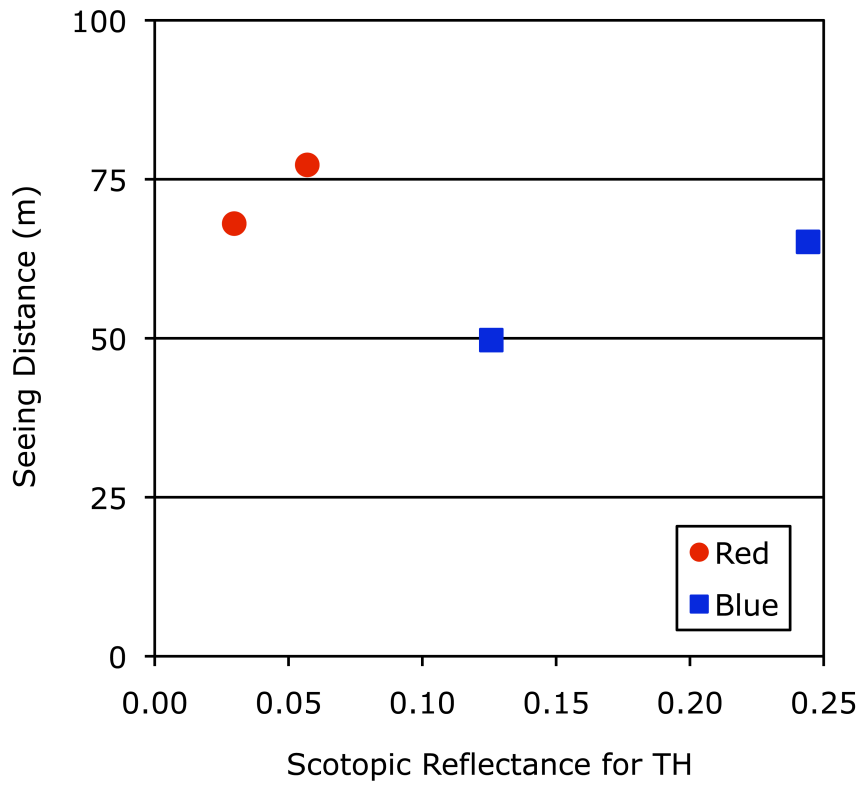
"All subjects performed better on the second night than on the first night. On the first night, most subjects seemed to be unable to pay attention to the peripheral targets . . . Because the subjects had to do a lot of tasks such as driving the car along the lane, keeping the speed constant, and reading aloud the number on the sign board." Akashi & Rea (2002)

The Blue Man study

- Public roads, at night
- Typical tungsten-halogen headlamps
- Pedestrians about once per 2 km – uncertainty was more than in many studies, but less than in real driving.
- Pedestrians wore all blue or red clothing (light and dark versions of each)
- Measure is pedestrian detection distance
- If rods contribute, blue pedestrians will be seen further

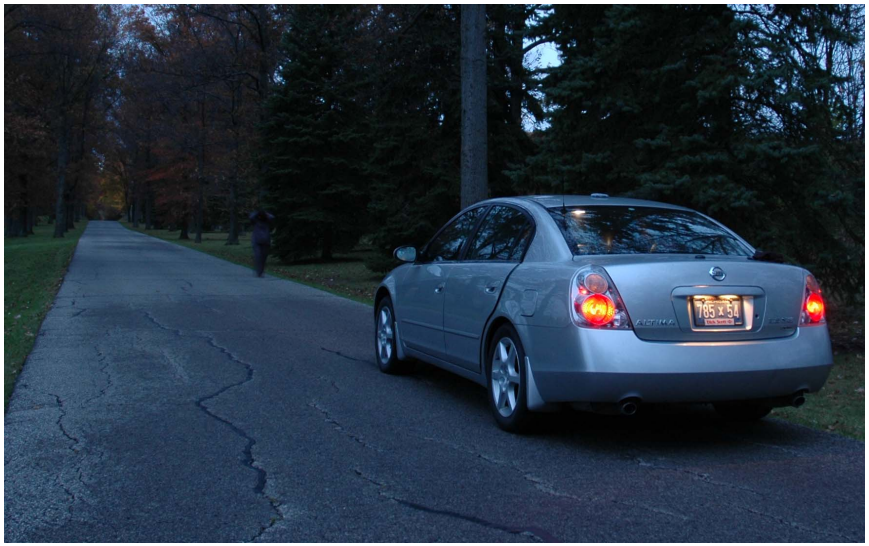
Blue Man results

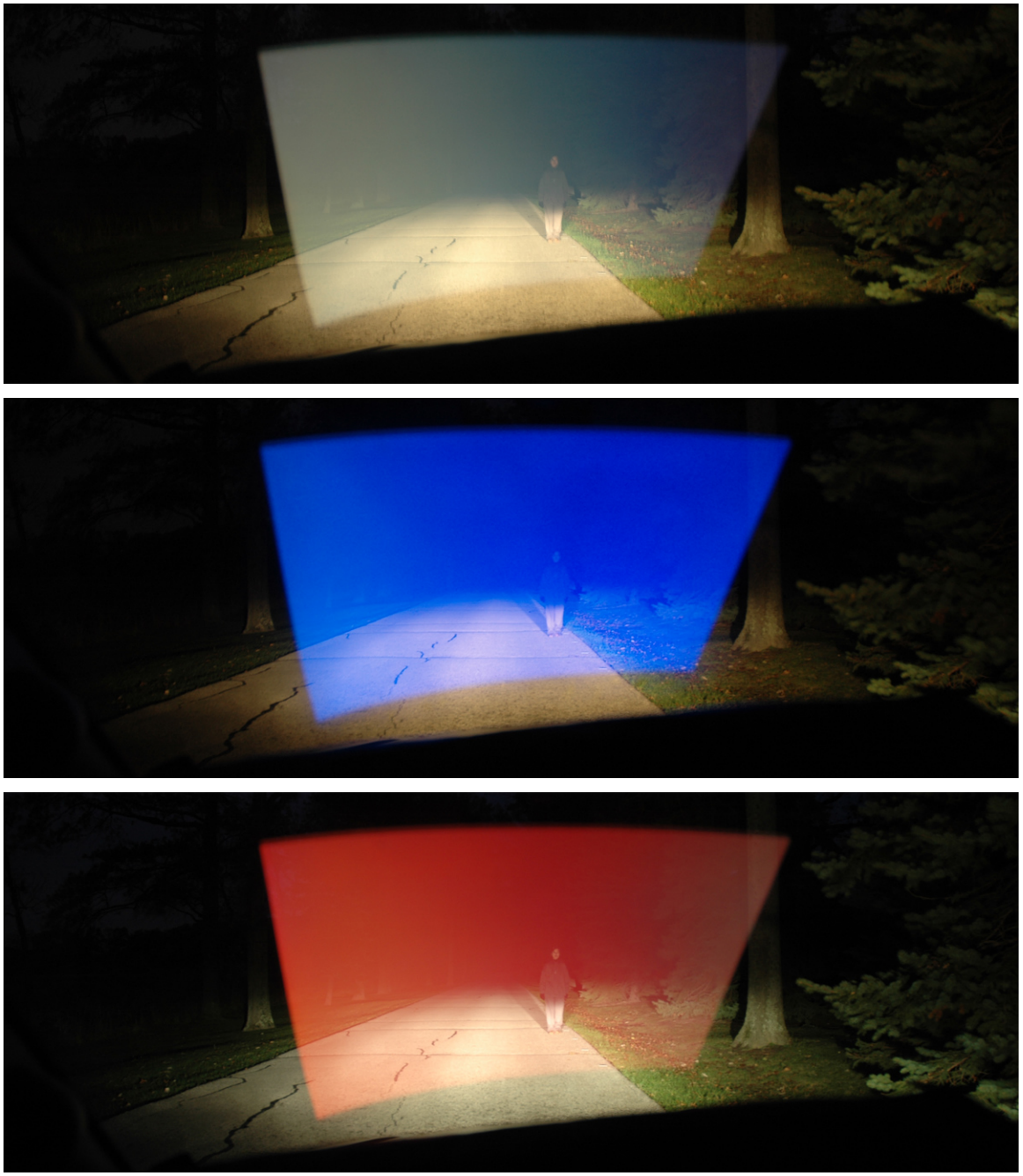




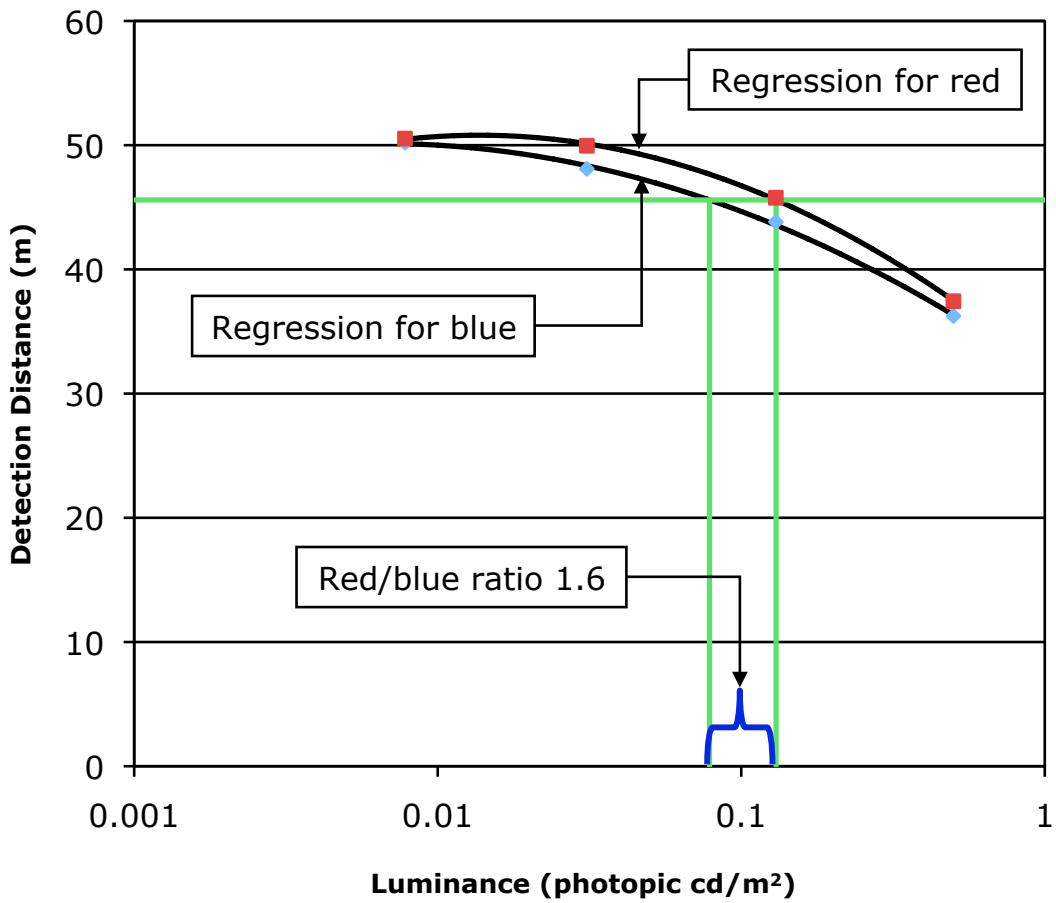
A study with both photopic and mesopic visual performance

- Static setup on closed road at night
- Two tasks:
  - Pedestrian detection through reflected luminance
  - Brightness rating of the reflected luminance

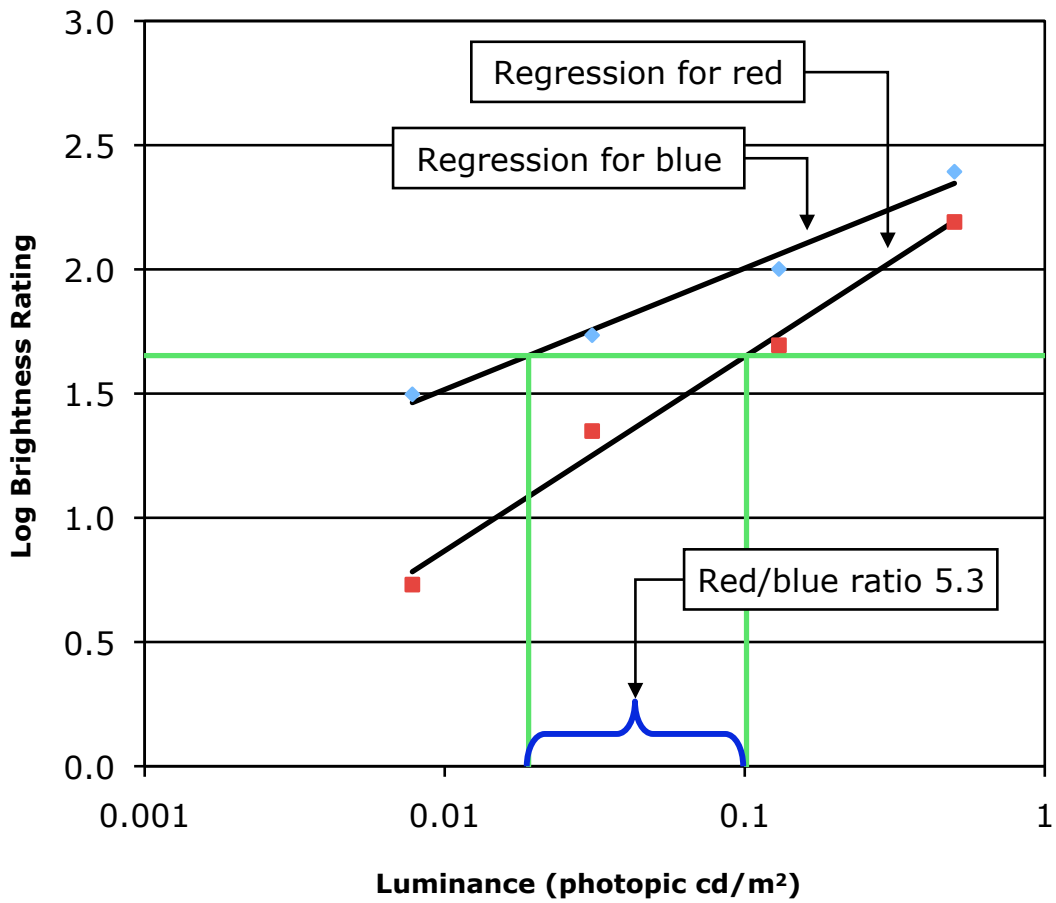




Effects of color and luminance on detection distance



Effects of color and luminance on brightness rating



Rod contributions to night driving?

- For headlighting, for the task most critical for safety (pedestrian detection) rods seem to make little or no contribution
- Headlamp photometry should be photopic
- Fixed roadway lighting has very different geometry and should be further investigated
- Rod vision seems to be involved in many subjective visual experiences (brightness, glare, etc.)

Thank you