Methods to Monitor Nighttime Visibility and Headlight Glare on the Road

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19th Biennial TRB Visibility Symposium

Blacksburg, VA, May 12-14 2009

Framework

- French project
  - Participant: Lighting & Visibility research Team at LCPC
  - Sponsor: MEEDDAT (French DOT), T.O. #05MT6039
  - Objective: develop a nighttime visibility index for secondary roads
- California project
  - Participant: Visual Detection Lab at UC Berkeley School of Optometry
  - Sponsor: Caltrans (California DOT), T.O. #6603
  - Objective: develop a glare meter tool to rate headlight glare
- Collaborative project
  - CalFrance partnership
  - Share knowledge and leverage existing projects

Introduction

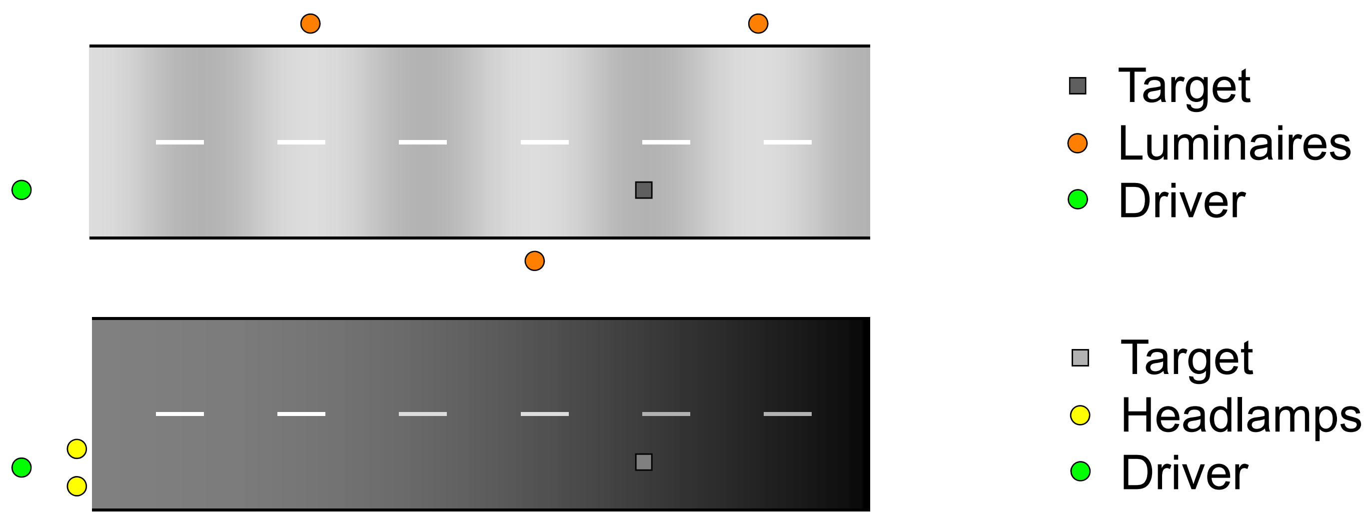
- Problem statement: nighttime driving safety
  - Fact: accident risk is higher at night than in daytime
  - Cause: low visibility
  - Solution: headlamps provide visibility, but cause glare
  - Assessment: addressed by manufacturers of lighting systems
  - Need: tools for road managers to assess the quality of service of the road
- Objectives
  - Visibility meter tool
  - Glare meter tool

Outline

- Introduction
  - Framework
  - Objective
- Nighttime Visibility Meter Tool
  - Approach
  - Implementation
  - Sample results
- Headlight Glare Meter Tool
  - Approach
  - Implementation
  - Experiments
- Integration

Visibility: Approach

- Objective
  - Assess the level of visibility offered to drivers at night on secondary roads (devoid of road lighting)
- Approach
  - Based on STV approach for road lighting
  - Can the driver detect an obstacle in time to avoid collision?



Visibility: Standard Scenario

- Driver
  - Eye height: 1.2 m
  - Age: 25 y
- Headlamps
  - Photometry: high-beam [UMTRI-2001-19]
  - Mounting height: 0.65 m
  - Separation: 1 m
  - Distance from driver: 1.8 m
- Target (obstacle)
  - Shape: square
  - Size: 0.18 m
  - Luminance factor: 8% (dark)

Visibility: Measurement System

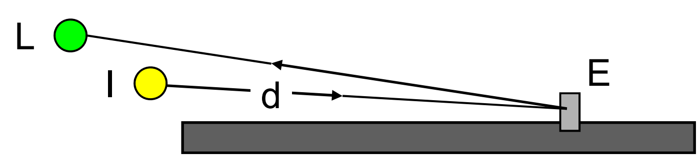
- Pavement retroreflectivity
  - ECODYN (mlpc®)
  - On-board system to monitor the visibility of the markings along the road
  - Geometry based on EN1436
    - Vision at 30 m ⇒
      1.25° lighting angle,
      2.29° observation angle.
  - Retro-reflected luminance coefficient
    - $R_L = L / E_\perp$
    - Range: from a few $mcd.m^{-2}.lx^{-1}$
      up to 2k $mcd.m^{-2}.lx^{-1}$

Visibility: Computational Model

- Target luminance
  - $L = \rho / \pi \,.\, E \approx \rho / \pi \,.\, (I_{left} / d^2 + I_{right} / d^2)$
- Pavement luminance
  - $L_b = R_L \,.\, E_\perp = R_L \,.\, (I_{left} / d^2 + I_{right} / d^2)$
- Visibility level
  - $VL = (L - L_b) / \Delta L_{th} = \Delta L / \Delta L_{th}$
  - $\Delta L_{th} = f(\Delta L, L_b, \alpha) \,.\, \Pi\, F_i(\ldots)$

    F_i: correction factors (contrast polarity, age, time, detection probability)

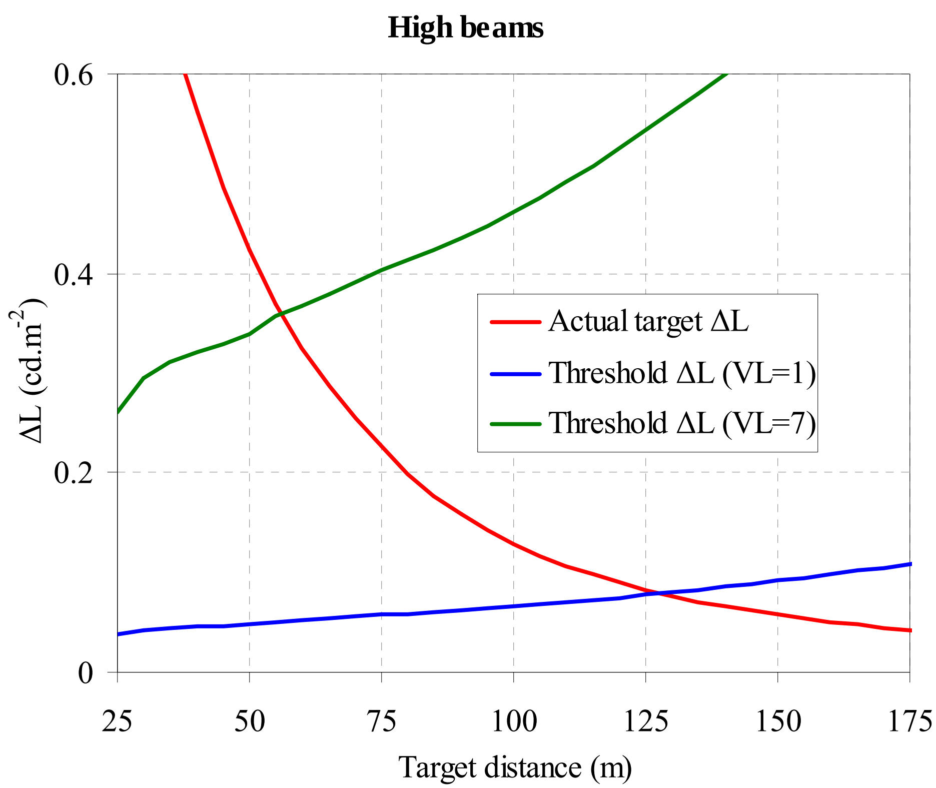
    [Adrian, 1989]



Visibility: Implementation

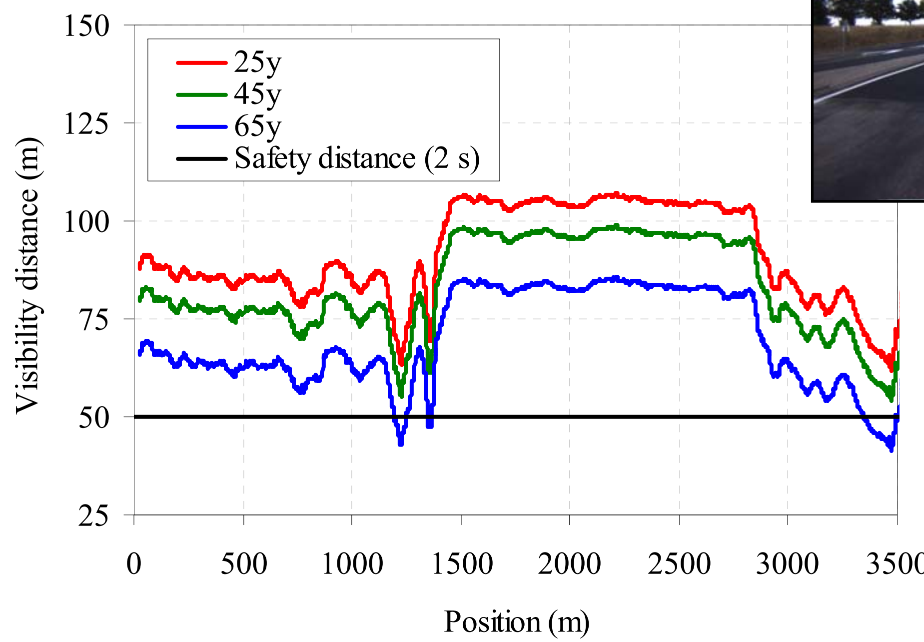
- At every point along the road
  1. Get RL value from ECODYN measurements
  2. Set headlamps at 250 m
  3. Compute VL
  4. While VL < field factor
set headlamps closer and go to 3
  5. Interpolate visibility distance
  6. Compare with « safety distance »

Visibility: Implementation



$R_L = 15\ mcd.m^{-2}.lx^{-1} \Rightarrow$ 56 m visibility distance

Visibility: Sample Results

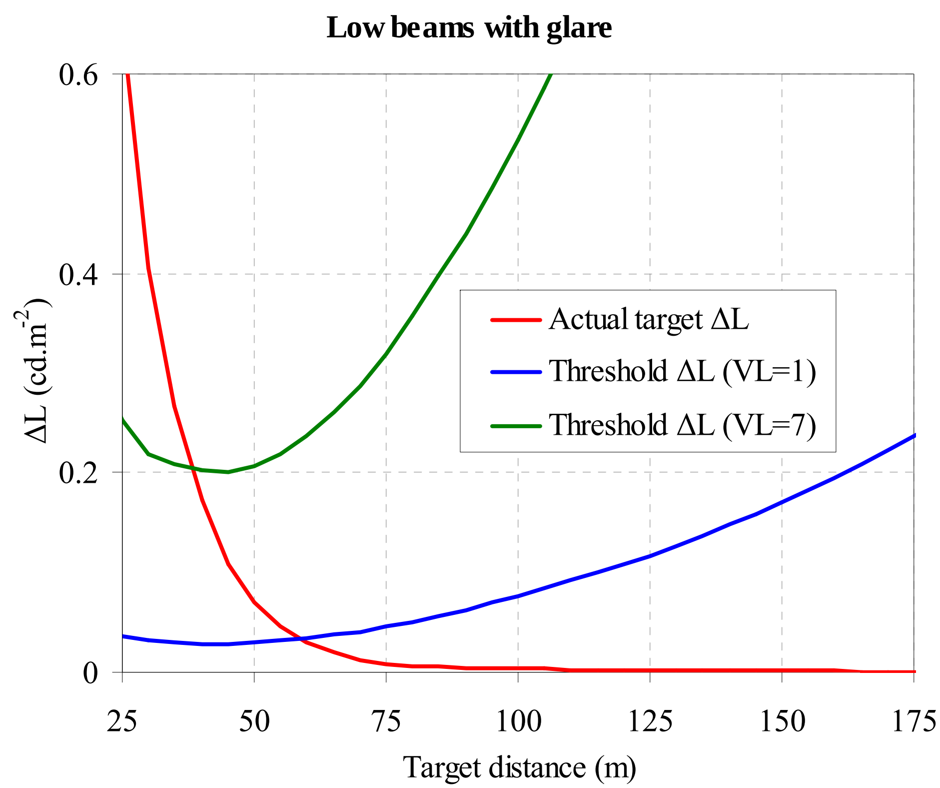


Dark colored pavement ⇒ better target visibility

Visibility: Introducing Headlight Glare

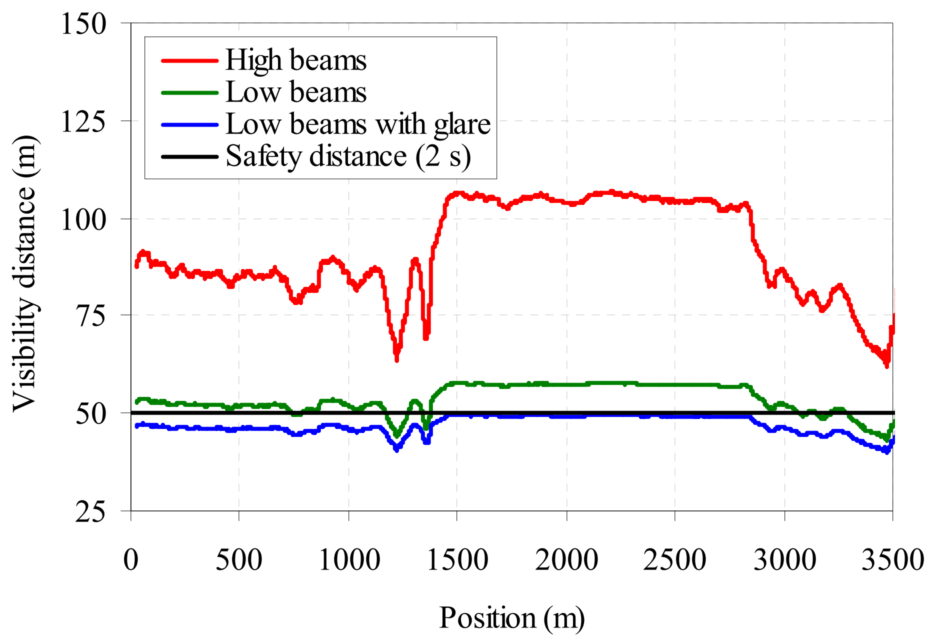
- Modified scenario
  - Same driver, same car, same road
  - Opposing vehicle ⇒ everyone in low beam
- Modified computational model
  - Use CIE Glare Formula to compute disability glare equivalent veiling luminance L_v
  - Account for L_v when computing VL

Visibility: Introducing Headlight Glare



R_L = 15 mcd.m^{-2}.lx^{-1} $\Rightarrow$ 36 m visibility distance

Visibility: Sample Results



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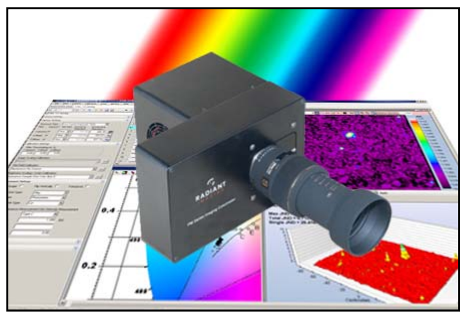
Glare: Approach

- Objective
  - Assess the level of glare from opposing vehicles in a variety of situations
- Approach
  - Capture the luminance distribution of the nighttime driving scene
  - Analyse image to locate glare sources and compute glare level

Glare: Measurement System

- Road scene luminance
  - CCD Photometer (Radiant Imaging PM-1613F-1)
  - 1020x1020 16-bit XYZ image
  - Optics ⇒ 2.28’ per pixel



Glare: Discomfort Glare

- Glare Index

  $$GI = \Sigma_{sources}\ L^a . \Omega^b / L_b^c / \theta^d$$

  L: source luminance

  Ω: solid angle subtended by the source

  θ: eccentricity

  L_b: background luminance

  a, b, c, d: model parameters

- Conversion to Glare Mark on De Boer scale

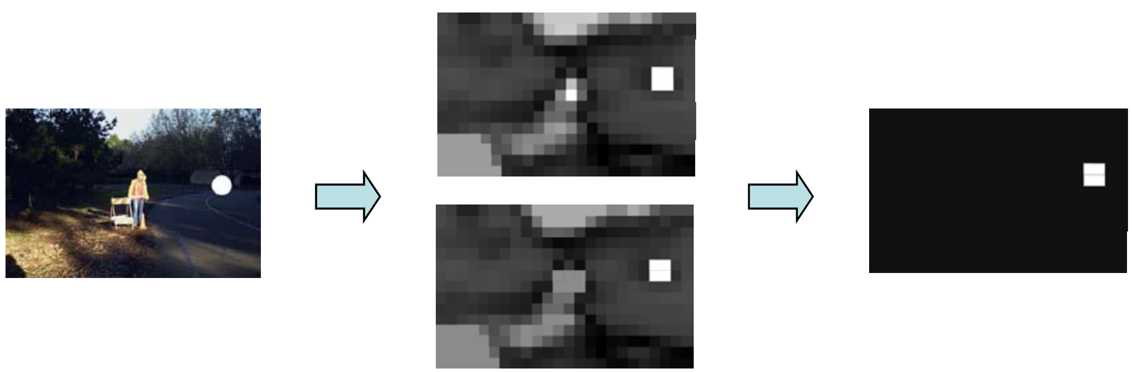
  $$GI = K . 10^{-GM/4}$$

  K: model parameter

  [Vos, 2003]

Glare: Implementation

- Set model parameters
  - Method 1: use values proposed by Vos
  - Method 2: fit values with experimental data
- Find sources and get L, θ and Ω from captured image
  - Method 1: brute force segmentation
  - Method 2: conspicuity-based segmentation

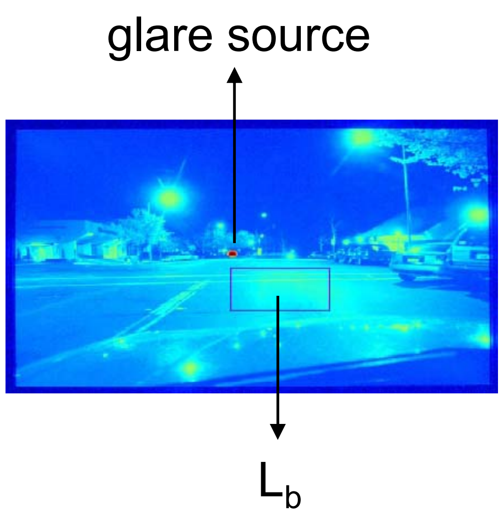


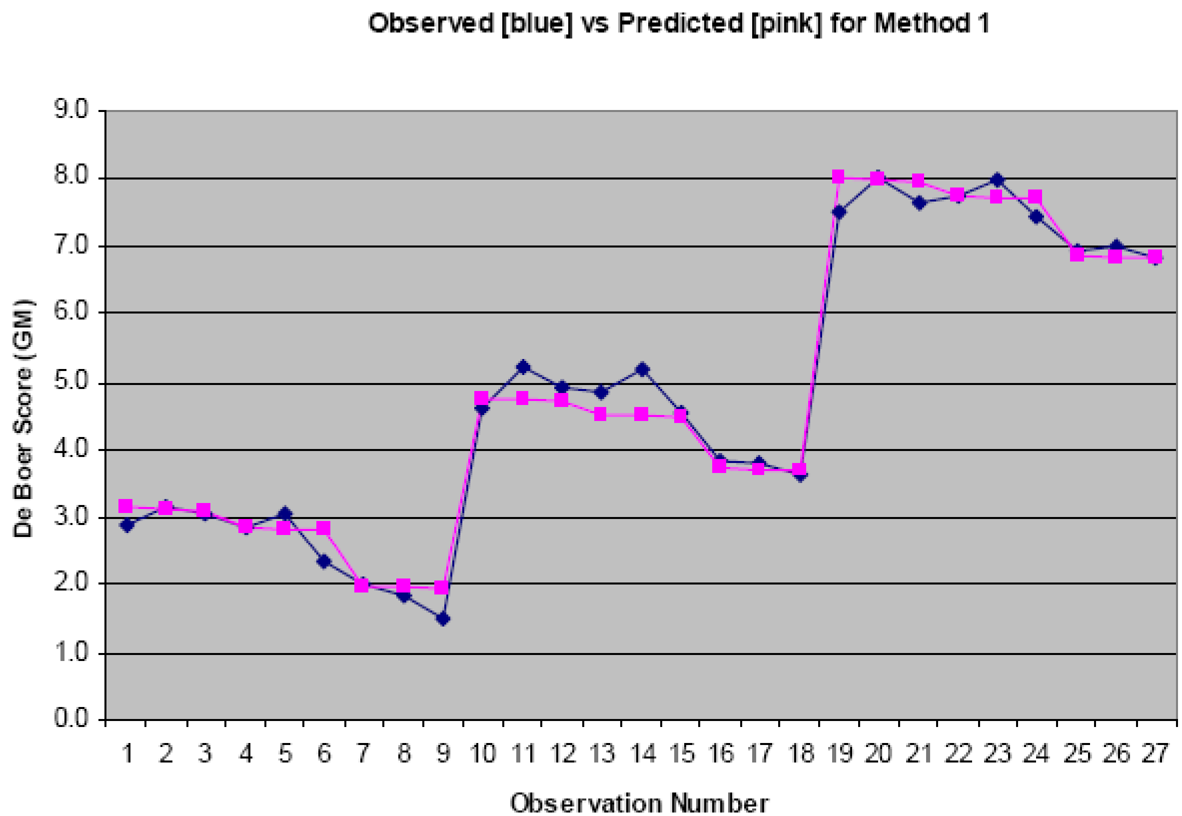
Glare: Lab Experiment

- Modalities
  - 3 types of road scenes (urban, residential, rural)
  - 3 glare source eccentricity values
  - 3 glare source intensity values
- Subjects
  - 16 observers

9 Unnoticeable
8
7 Satisfactory
6
5 Just Acceptable
4
3 Disturbing
2
1 Unbearable

Glare: Lab Experiment





RMS for Method 1: 0.27
RMS for Method 2: 0.77

Glare: Field Test

Scenario	glare source	mainline lighting	glare screen	windshield	De Boer ratings, two observers	De Boer rating predicted by Glare Meter Tool
#1	lo-beam	on	no	clean	5, 6	6.2
#2	hi-beam	on	no	clean	3, 3	3.4
#3	hi-beam	on	yes	clean	4 ½, 5	5.9
#4	lo-beam	off	no	clean	5, 6	6.2
#5	hi-beam	off	no	clean	2 ½, 3	3.4
#6	hi-beam	off	no	dirty	2, 2	3.3

Glare: Disability Glare

- CIE Glare formula

  $$L_v / E_g = 10 / \theta^3 + 5 / \theta^2 . [1 + (A / 62.5)^4]$$

  L_v: equivalent veiling luminance

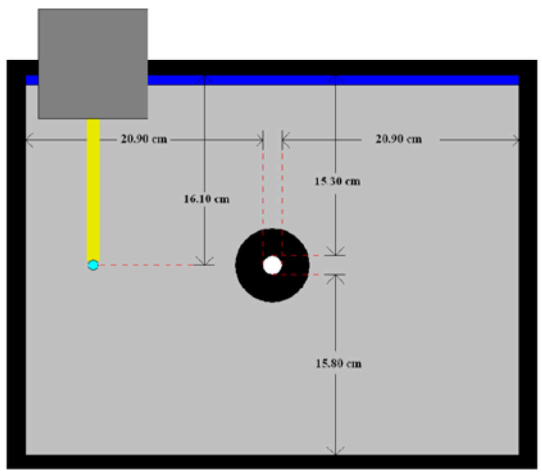
  E_g: eye illuminance from glare source

  θ: source eccentricity

  A: age
- Implementation
  - Detect glare source pixels $\Rightarrow$ L and θ
  - For every glare pixels
    - Get E_g from L
    - Add up to L_v

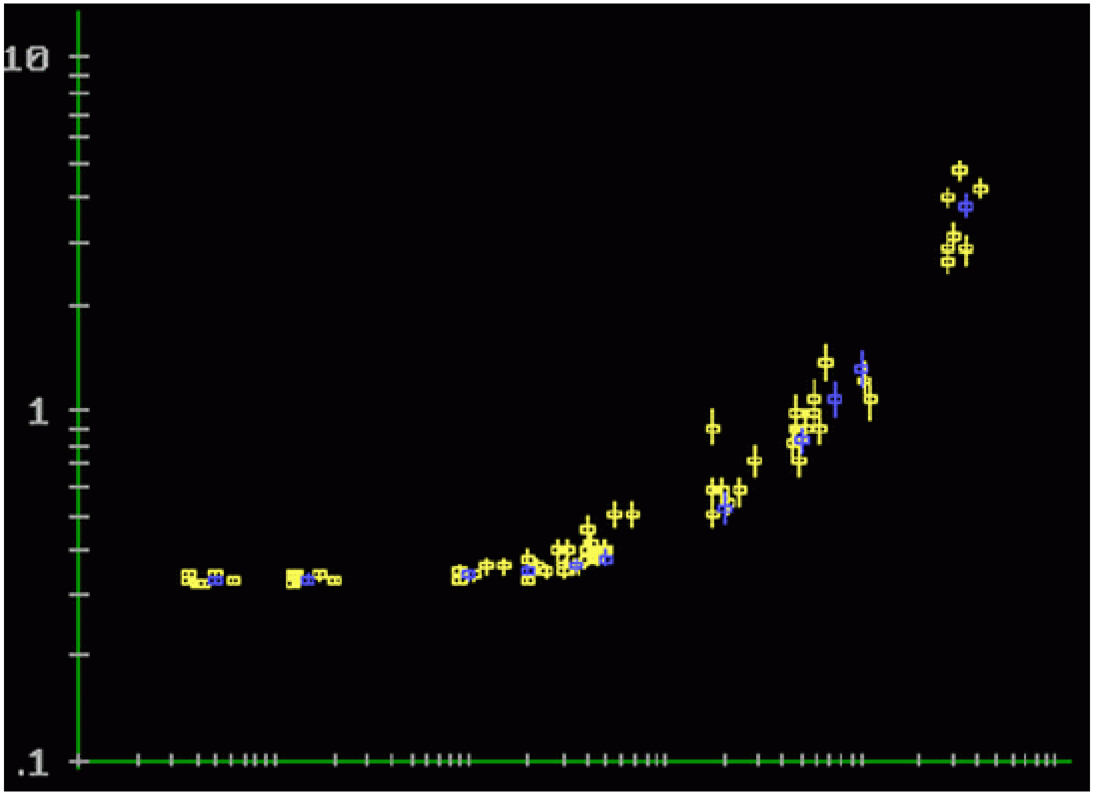
Glare: Lab Experiment

- Modalities
  - Increment grey level of disc on black background, in grey surround, until disc just detectable
  - 3 source eccentricities
  - 3 source intensities + no glare source
- Subjects
  - 16 observers



Glare: Lab Experiment

Log L_v
from subjects' responses



Log L_p
from luminance image

Conclusions

- Nighttime Visibility Meter Tool
  - Easily deployed
  - Needs to be calibrated
  - Can be improved
    - Introduce road geometry (curves, slopes)
    - Chose better contrast definition
    - Account for adaptation
- Headlight Glare Meter Tool
  - Calibrated
  - Needs stationary conditions
- Integration: complementary use of both tools
  - Locate low visibility road sections with the Visibility Meter Tool
  - Deploy the Glare Meter Tool on these sections

Nighttime Visilibility & Headlight Glare

Thank you for you attention.