A Study of Mesopic Adaptation conditions for Night Drivers using an approximation for Oncoming headlight glare

Robert L. Donofrio
Display Device Consultants LLC,
Ann Arbor, MI 48105
www.displayconsultants.com

This presentation is in part a review of our SID paper given at the SID 2007 Symposium on Vehicle Displays and Photons Oct 12-13, 2007 at the University of Michigan in Dearborn on

“Brightness Evaluation of LED Mesopic Luminaires under Dynamic Background light”

And the introduction of some additional information related to our study of Headlight glare and the Brightness evaluation of LED Automotive Dashboard Icons/Luminaires

We intend to show :

1. **that Night Driving Adaptation is in the Mesopic Region – That is , the night driving interior lighting and road sign and road lighting is in the Mesopic region.**
2. **Simulated Head Light glare can cause perceived dynamic Brightness Changes in Mesopic LED Luminaires**

Measurement of Luminance of ICONs and Alpha-numerics

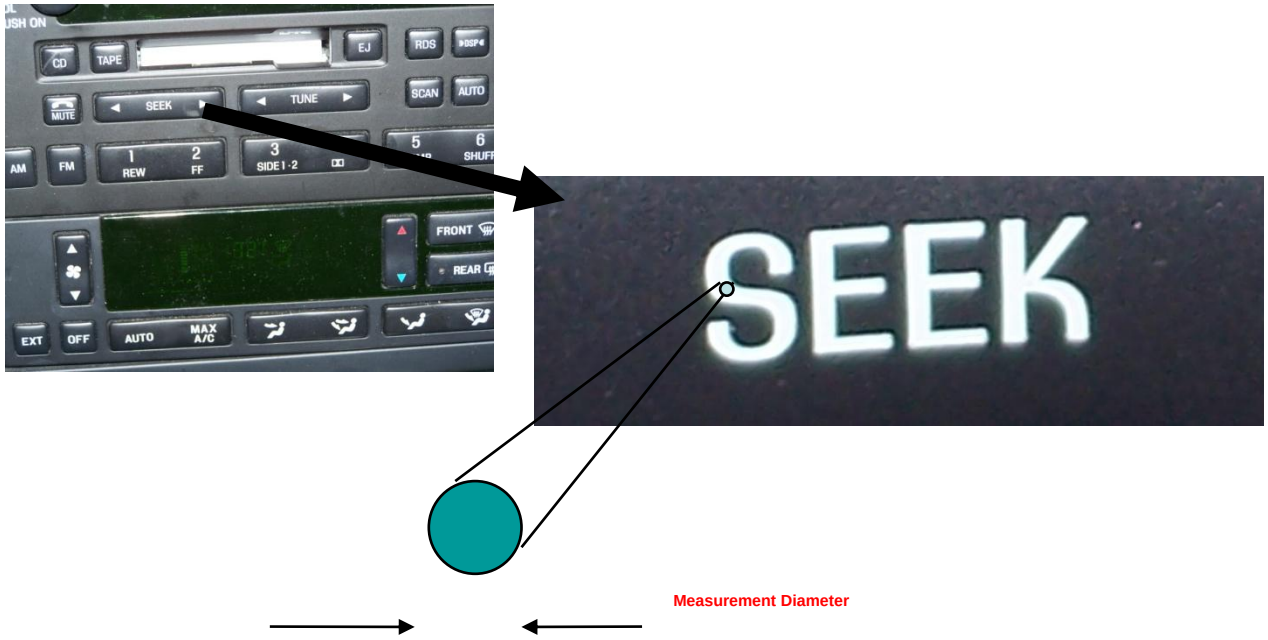
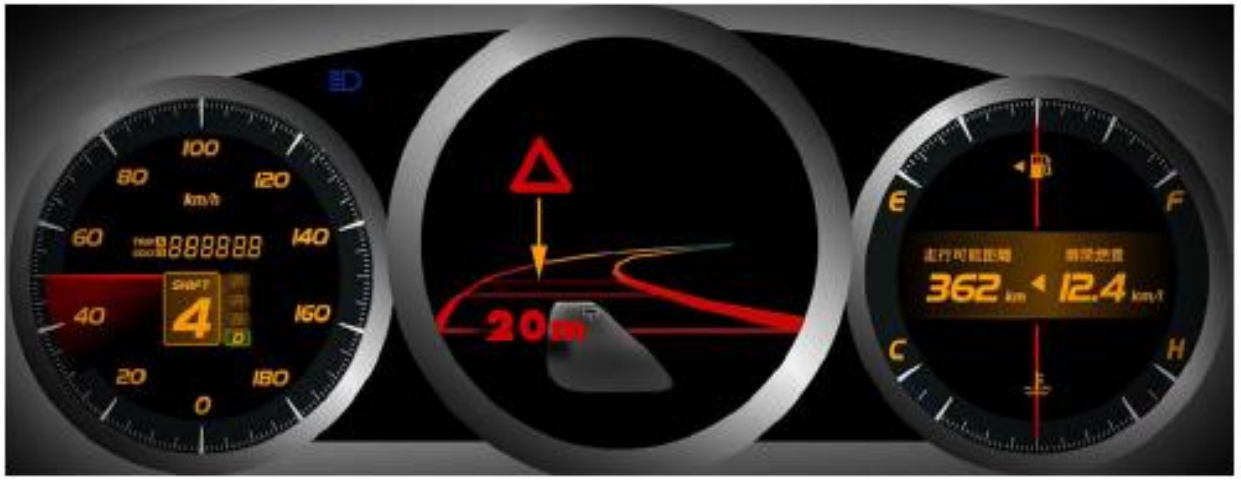


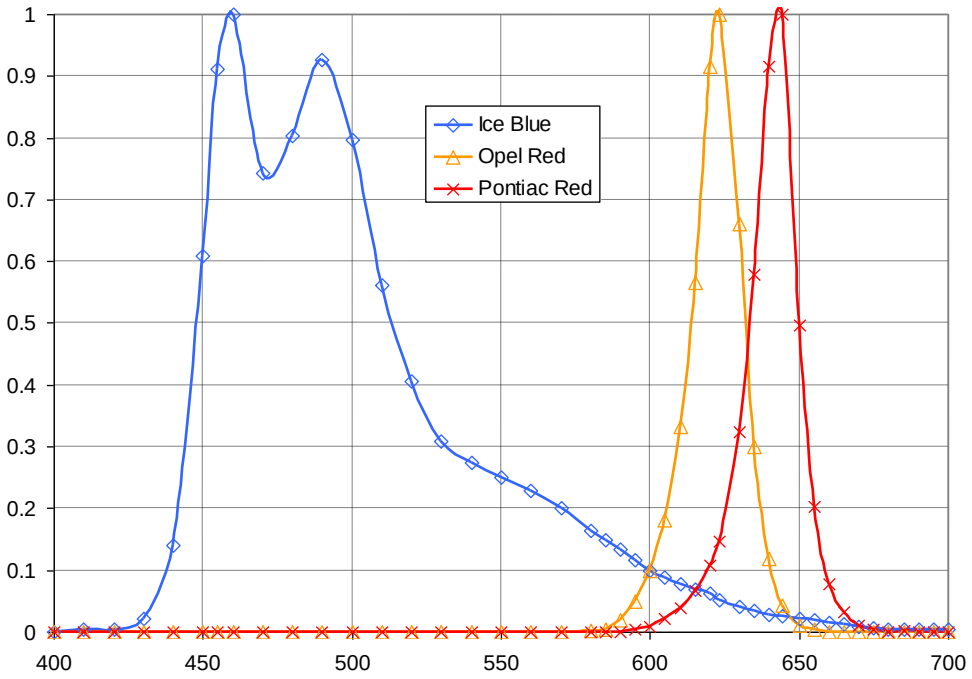
Table 1 Specifications of Minimum Display Luminance

Automaker/Supplier	Minimum Luminance (mcd/m^2)
Ford	Approx 250* for LED Ice blue color
GM	100
Chrysler (1992) audio	4,100
Chrysler (1992) Warning light	171,000 ?
Vendor (T)	1000
Yazaki	100 (as required by Customer)
VDO	100
Toyota 1988 CRT Max night driving background	600
Denso (non-dimming red)	25,000

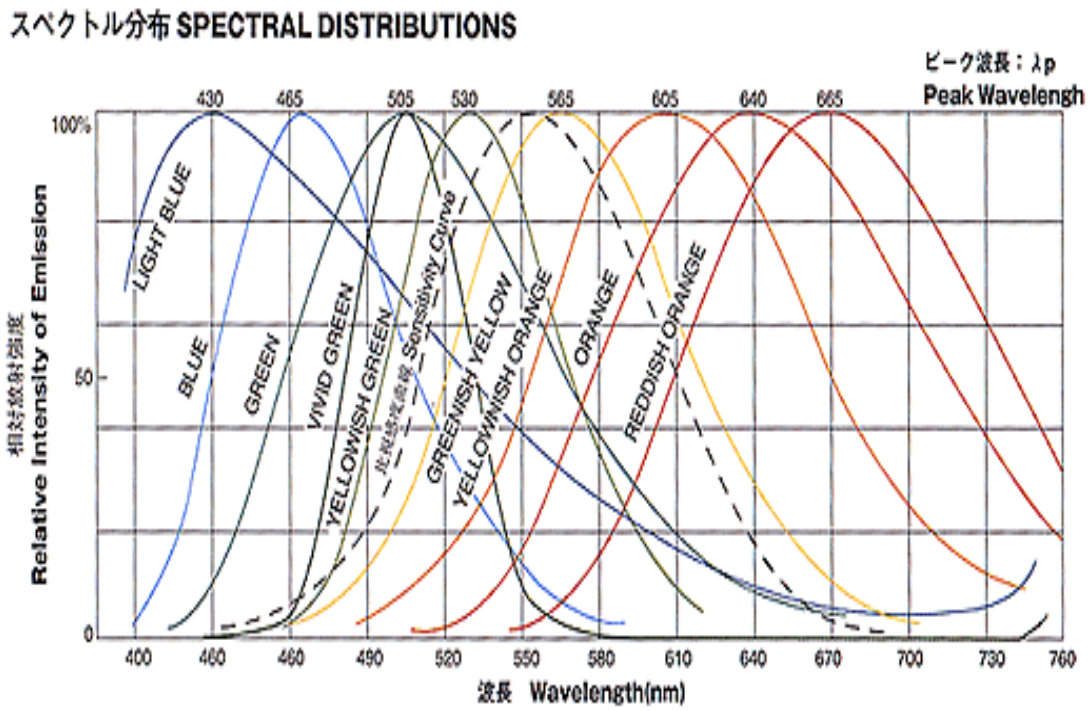

100
80
120
km/h
60
140
40
SHIFT
4
160
20
180
0
20m
E
F
C
H
362 km
12.4 km/l

Relative Spectral Distributions of LEDs

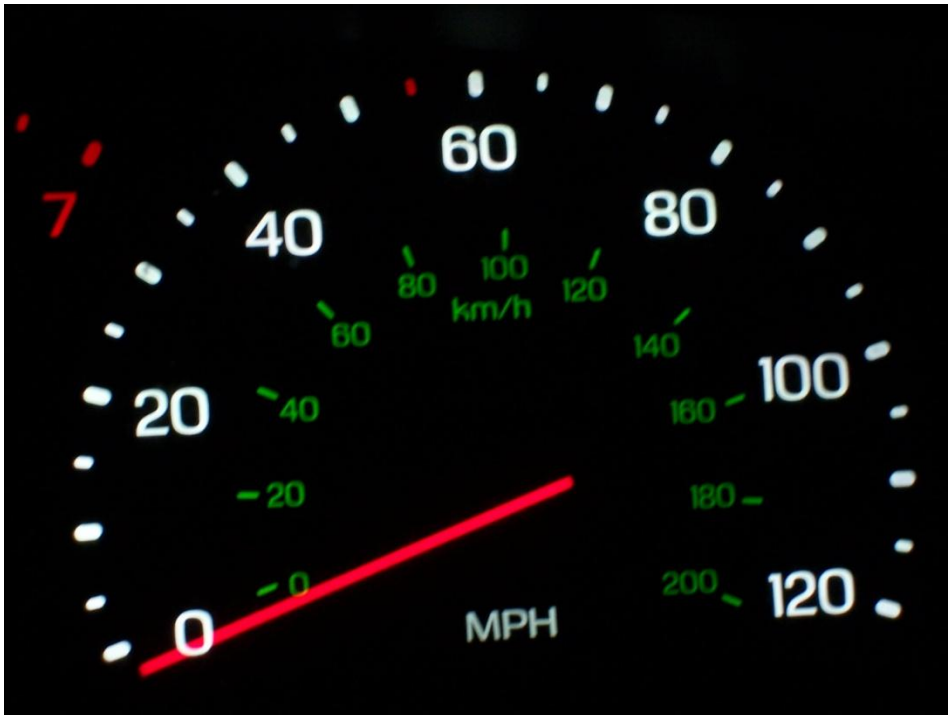
used in Automotive Icons/displays and Lighting



Relative Spectral Intensity Distributions of VFD Automotive Light Sources



Multi-colored Instrument Cluster from a 1999 Lincoln Continental



MESOPIC LUMINANCE LIGHT LEVEL INFORMATION

Wyszecki & Stiles –Color Science 1982 - CIE 1978 0.001- 3cd/m^2
Page 406 - Johnson 1937 upper limit 5 to 15 cd/m2
1999 Lewin (Lamp Color and Visibility in Outdoor Lighting) –
Roadway/Mesopic region 0.001-3.0 cd/m^2

CIE TC1 -58 Mesopic region 0.001cd/m^2 – 10cd/m^2

2003 article by Schanda etal 0.001 cd/m^2 – 3 cd/m^2

2005 MOVE (Mesopic Optimization of Visual Efficiency) HUT

- 0.01cd/m^2 – 10/cd/m^2

2006 Eloholma presentation Analysis of Performance based Mesopic Models on New Data Sets - Adaptation levels 0.003 -10cd/m^2

2006 Bullough (RPI) Light for Health and Vision, Mesopic Vision - Looks at 0.1-1.0 cd/m^2 in his study

IESNA TM-12-06 Spectral Effects of Lighting on Visual Performance at Mesopic Light Levels – luminance below 1.0 cd/m^2

From 1999 paper by Ian Lewin

In the United States of America, the recommended average luminance for major commercial roads is 1.2 cd/sq.m.

For local residential roads, the average level is 0.3 cd/sq.m. Other roadway classifications fall within this range.

A survey of actual roadway luminance values conducted in Albany and Troy, New York, USA, showed a range from 0.74 to 0.013 cd/sq.m. (or 740mcd/m^2 to 13mcd/m^2)

Pavement Luminance from 1977 SAE Article by Dr.V. Bhise

Motor Vehicle Lighting edited by G.J. Gaudaen Modeling Vision with Headlights in a Systems Context 770238 pp289.

343 mcd/m^2 ——

172 mcd/m^2 ——

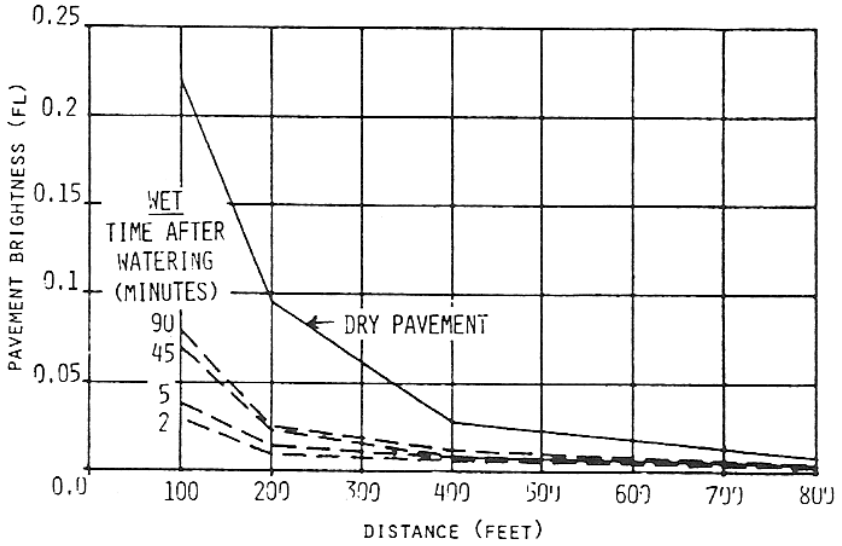


Fig. 6-15 - Effect of surface wetness and observation distance on pavement brightness

where r_s = forward reflectance at angles i, r

a. Road way lighting;
Road lines (white) - 120-600 mcd/m^2 as measured by Gamma Equip by Florida DOT (CORM 05/010/07)
Road markers are specified at about 300 mcd/m^2 on work done in Texas and those below 100 mcd/m^2 should be replaced or cleaned.

b. Roadway Pavement Markings
The reflectivity they use here is about 200mcd/m^2/Lux.

c. DDC Data
Dusk Measurements:
In 2007, we took luminance measurements on the road way by our office around dusk and measured the asphalt and line marker luminance using the CS-100 Chroma Meter. We found (as you might expect) that depending on the time of the evening the luminance changed but at one time the asphalt read 500 mcd/m^2 and the white stripe was about 1000 mcd/m^2 it was still light enough that no street lamp was turned on. Wet Asphalt luminance was about 250mcd/m^2. The grass in the lawn was down to70 mcd/m^2 and there was still light outside.

Night Driving Measurements:
2005 article of Background Luminance for Objects viewed by Night Drivers (May 2005 tech report night University of North Texas ERPI)

Roadway Luminance Chart from Ian Lewin 1999

Scotopic ← **.001 cd / sq.m.** — **Mesopic** — **3 cd / sq.m.** → **Photopic**

ROADWAY LIGHTING

STARLIGHT

INTERIOR LIGHTING

0.013 cd/m^2	**Actual Measured Roadway Range**	**0.74cd/m^2**
13 mcd/m^2		**740mcd/m^2**

We have showed that Night Driving is in the Mesopic Adaptation region

Next we will show that colored lights and materials can change relative brightness under low light conditions

History:

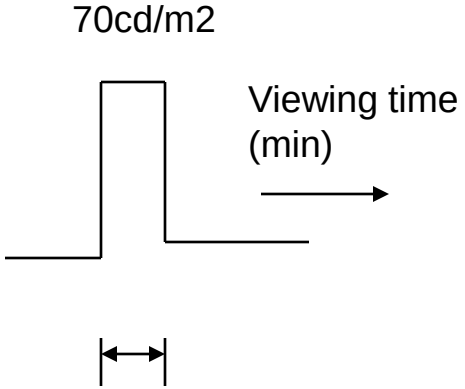
- **Purkinje (1825)**
- **Hering (1895)**
- **Kmura – Toyota (1988)**
- **Ikeda – (1989)**
- **L. Ronchi (1991) Brightness – Luminance Discrepancy**
- **Ian Lewin (1999)**
- **the author (2007)**

1988 by Kimura of Toyota

Their work was done in evaluating the night time background luminance requirements of Automobile CRT Displays. (STATIC AMBIENT LEVEL)

They *stated that at the same Photopic luminance, a white light and blue light comparison shows that the Blue Light appears brighter than the white light. In a similar fashion, comparing blue to red and green, the blue is brighter than the red but the red is brighter than the green or yellow."*

Red to Blue Visual ratios for various “luminance” levels after viewing time (from L. Ronchi Feb 1991)



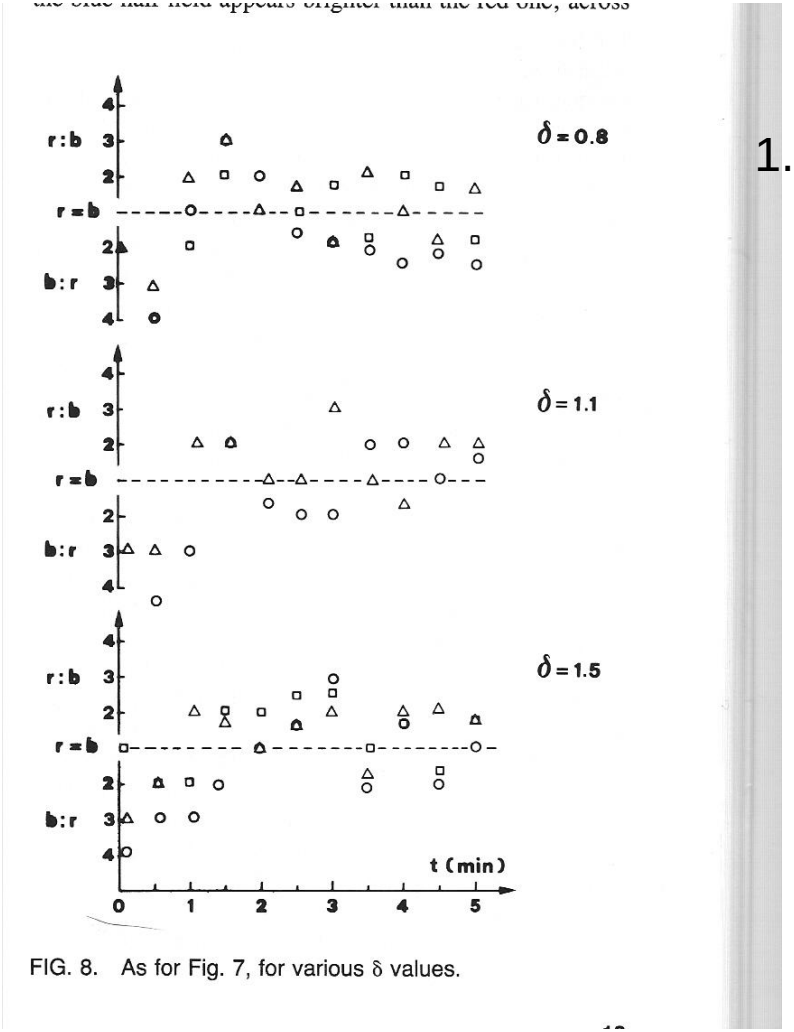


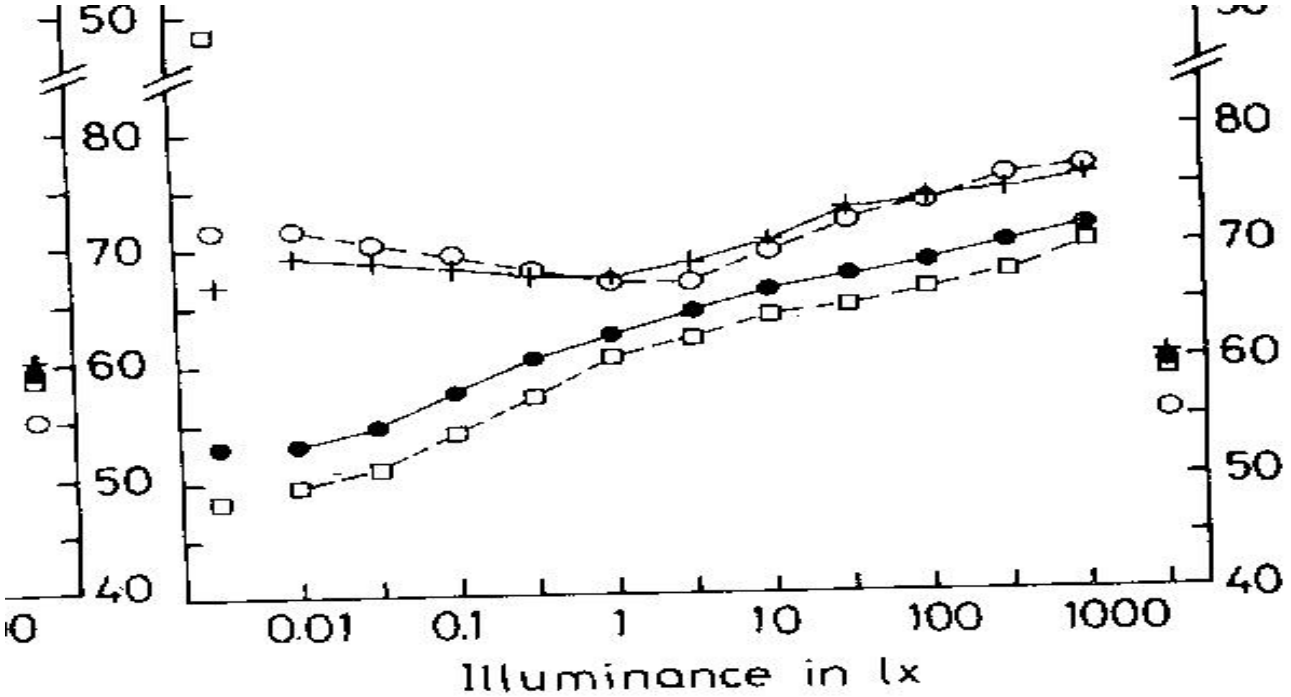
FIG. 8. As for Fig. 7, for various δ values.

1.2 cd/m2

0.6 cd/m2

0.25 cd/m2

Figure 3 1989 Ikeda study on Lightness of color test objects vs. Illuminance.



using four colored reflective test objects of colors

Blue (O), Green (+), Yellow (◊) and Red (●)

Reaction Time with Luminance Color by Ian Lewin 1999

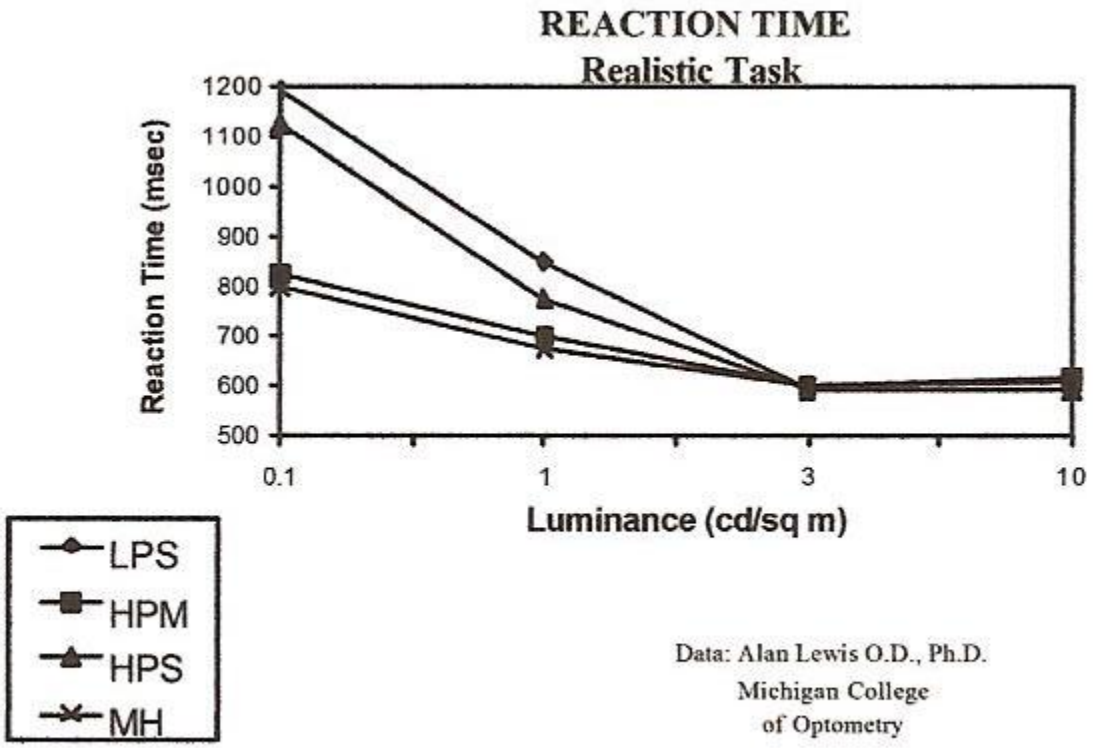


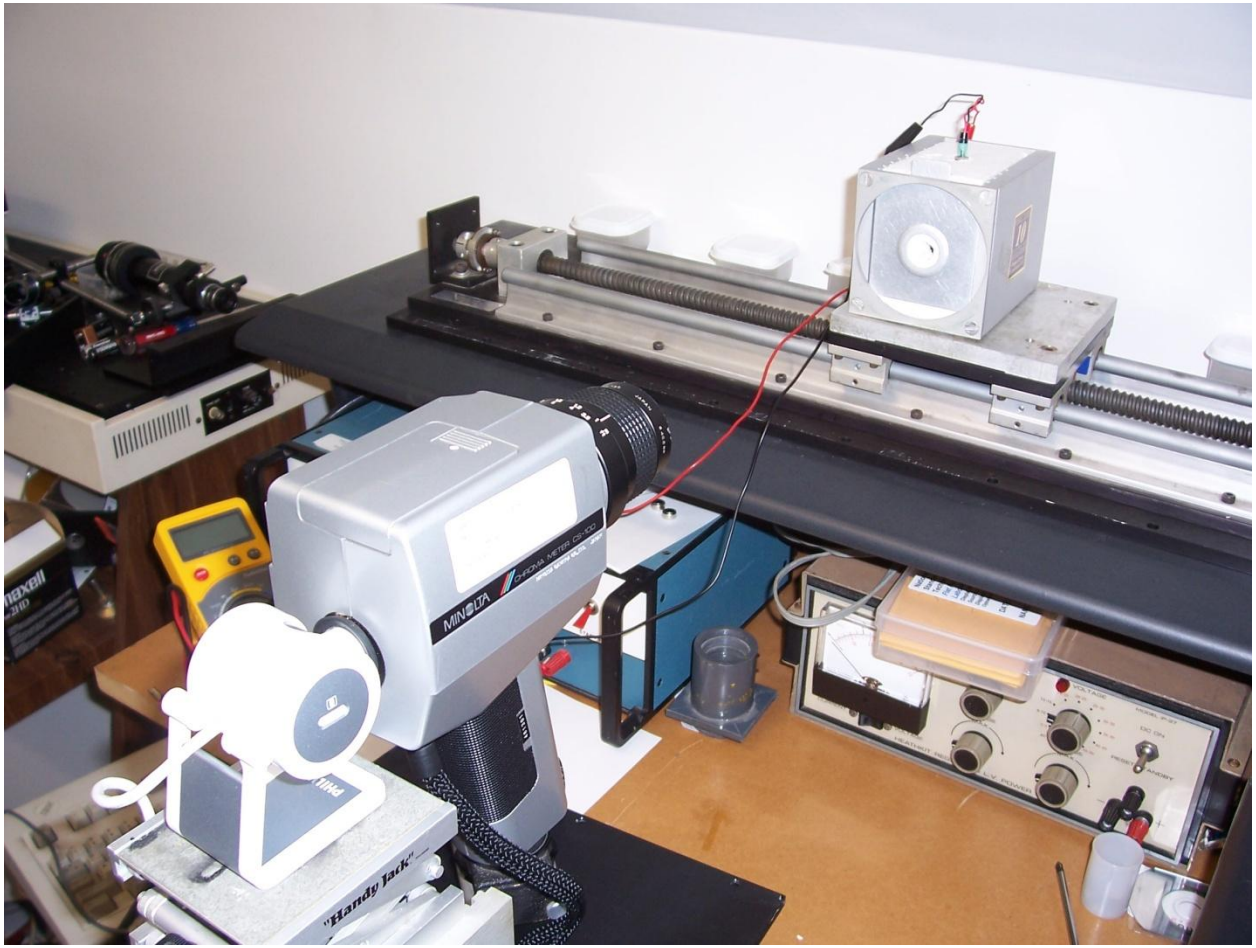
Figure 8. Reaction times measured under different light sources.

The previous data shows that a Brightness – Luminance Discrepancy exists in the Mesopic region

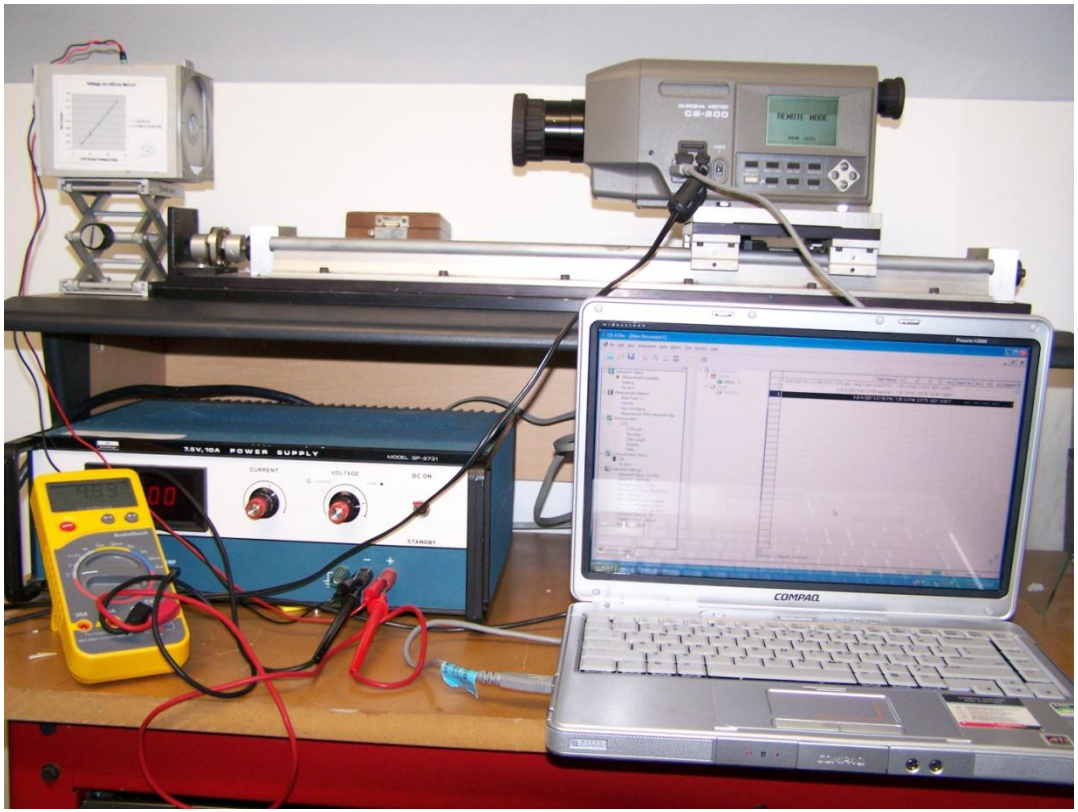
Our study on Mesopic LED brightness comparison using the Pre-adapting field as a first approximation for headlight glare.

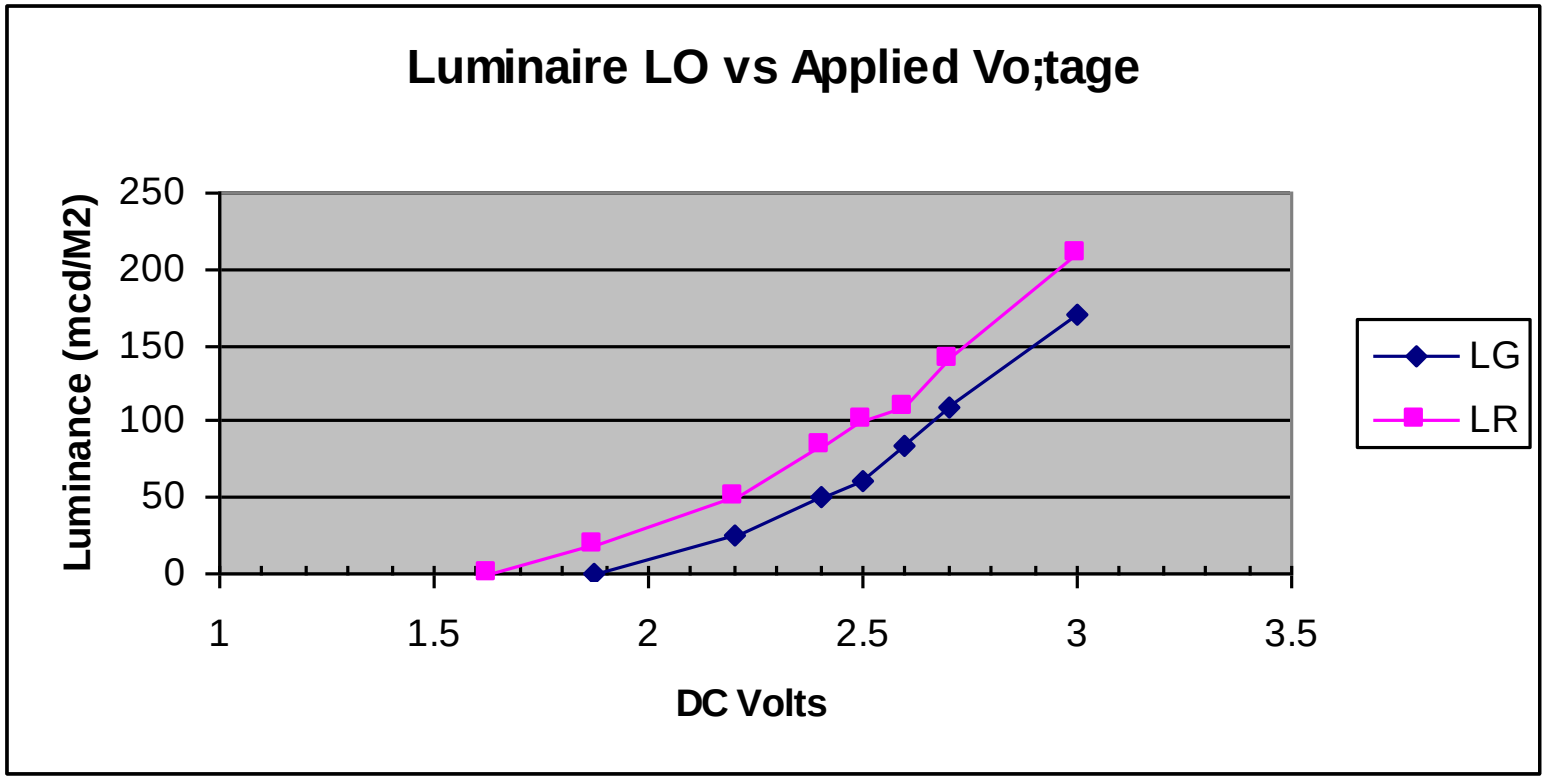
We next present our apparatus and measurement procedure

LED Luminaire being measured by CS-100 Chroma Meter

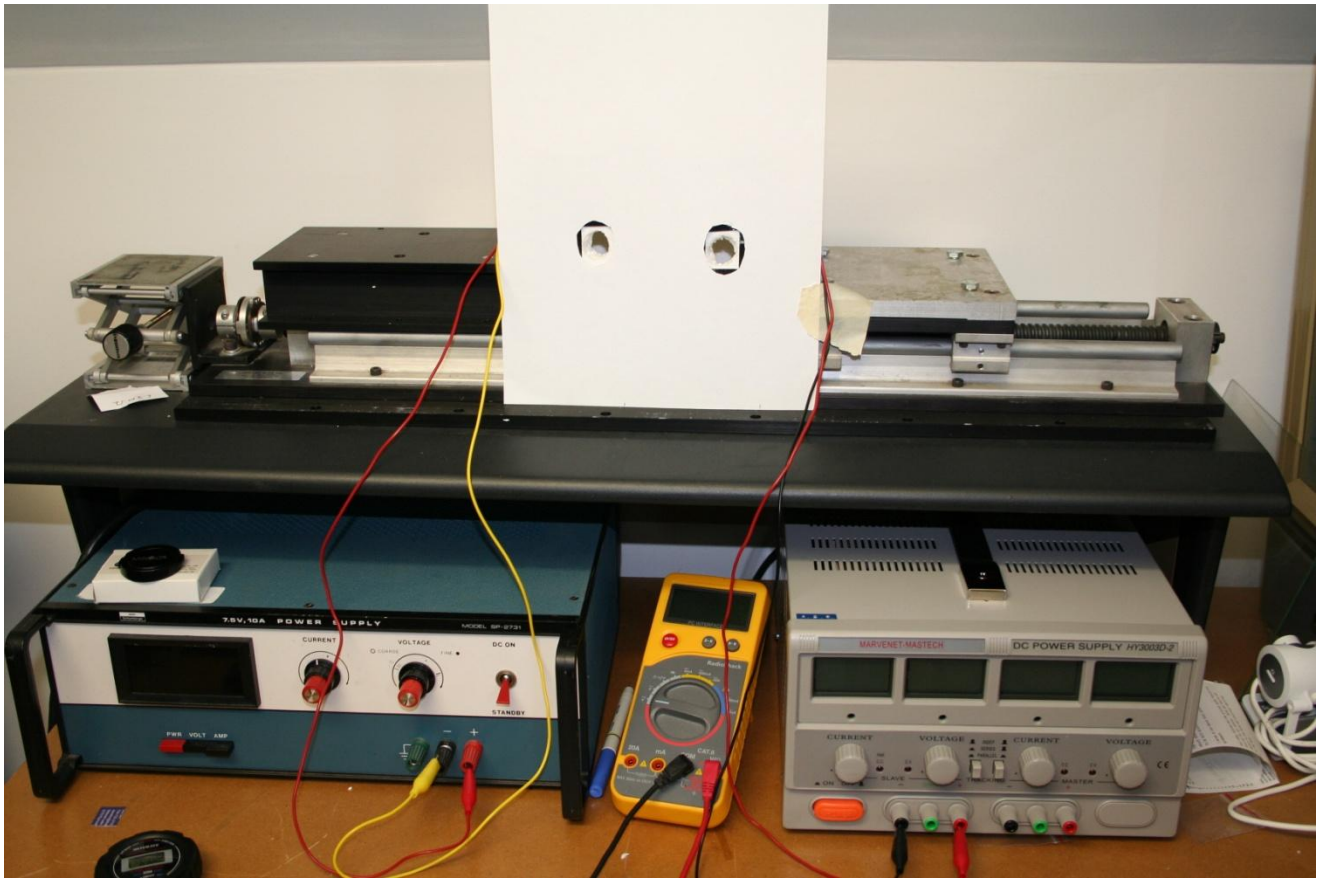


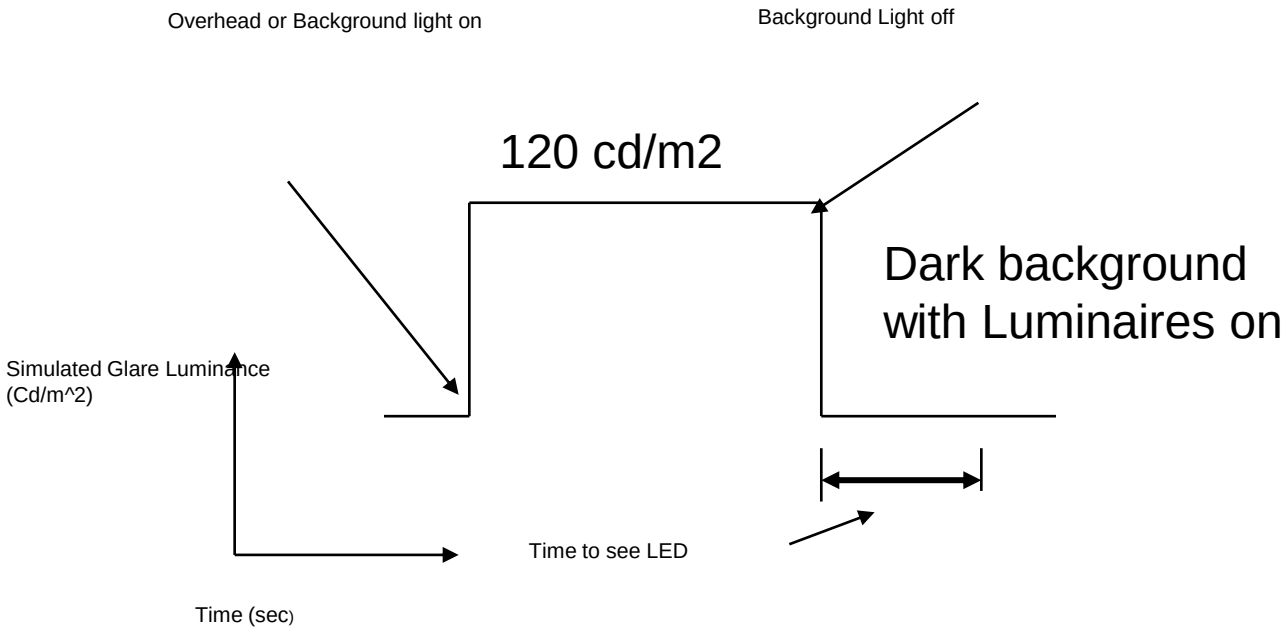
Luminaire being measured by (more accurate) CS-200




Luminaire LO vs Applied Vo;tage
Luminance (mcd/M2)
250
200
150
100
50
0
1
1.5
2
2.5
3
3.5
DC Volts
LG
LR

Test set up to visually evaluate Green & Red LED Luminaires with White Poster board to simulate Glare condition



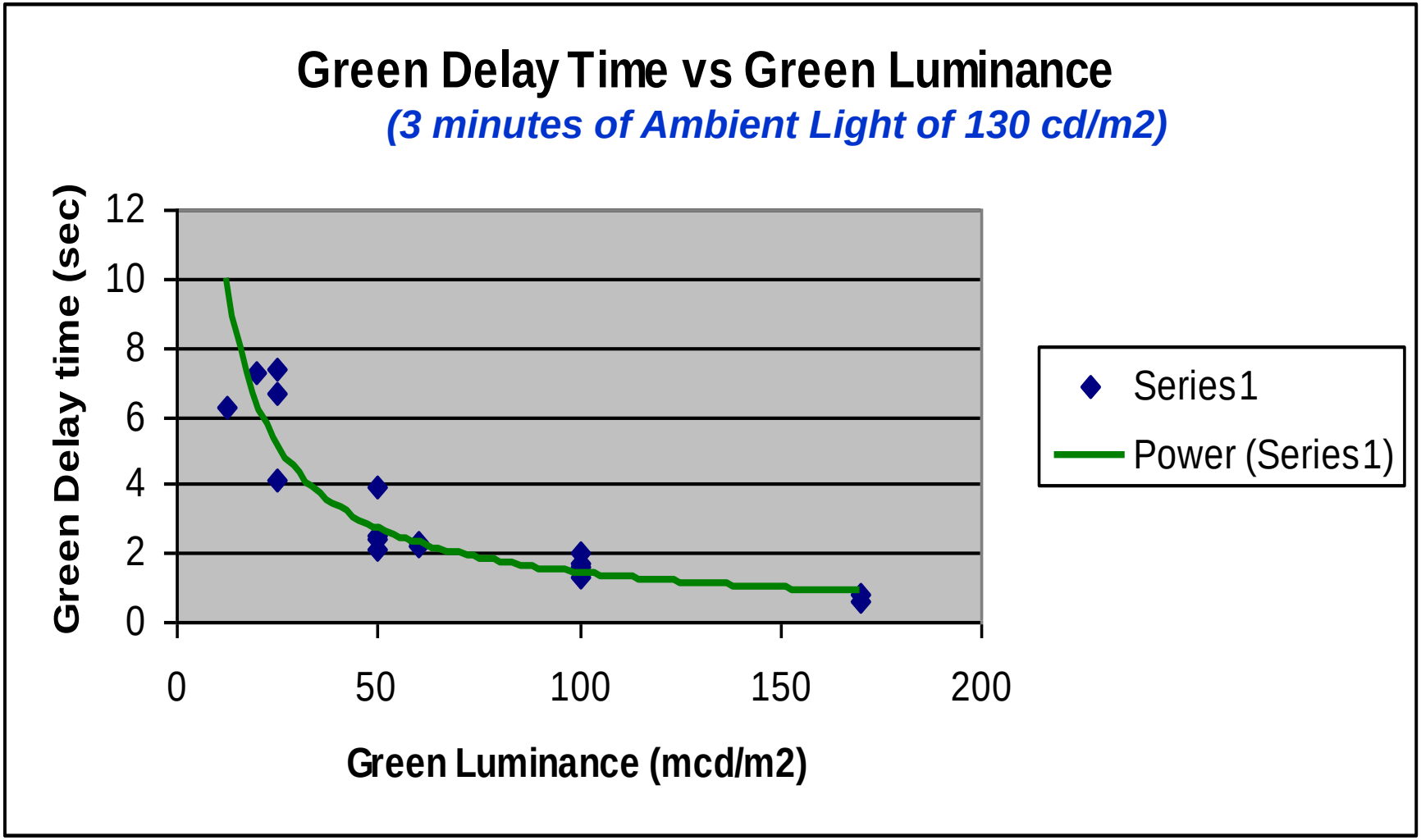

Overhead or Background light on
Background Light off
120 cd/m2
Dark background
with Luminaires on
Simulated Glare Luminance
(Cd/m^2)
Time to see LED
Time (sec)

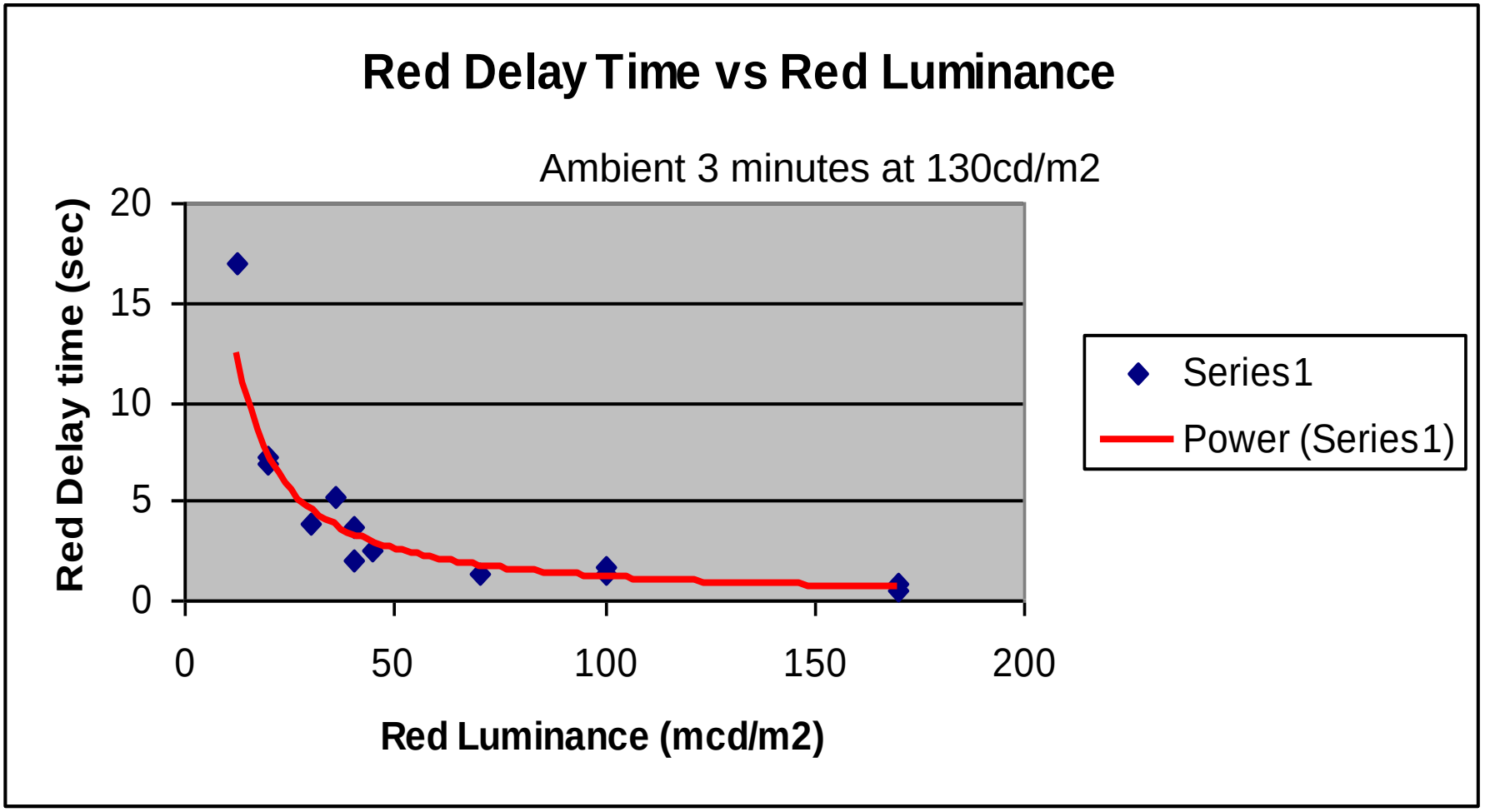
Data Table 1

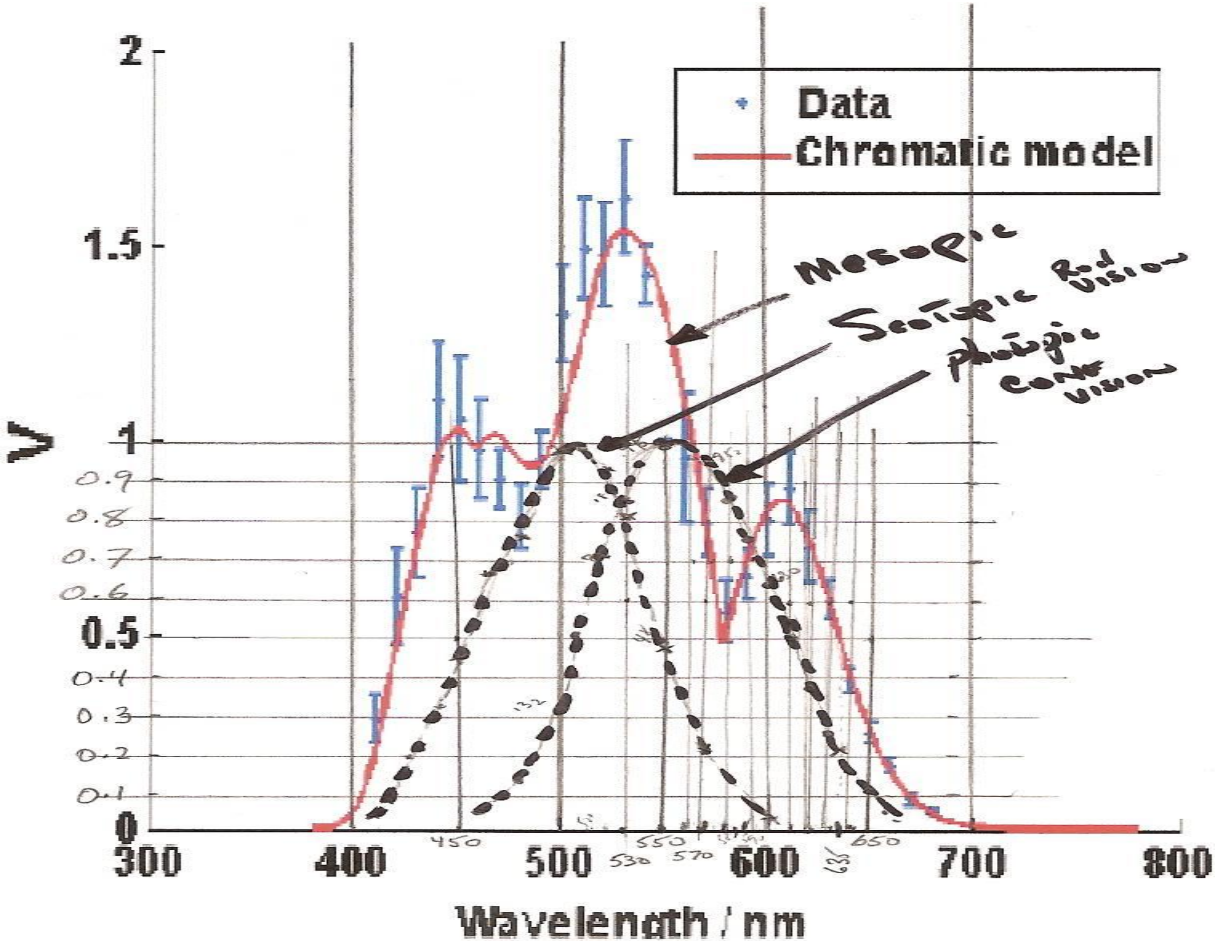
test #	Lg (mcd/m2)	Lr (mcd/m2)	tg(sec)	tr(sec)	R	G	Lr/Lg	glare time(min)	dark time
1a	60	30	2.2			*	0.5	3.0	
2a	60	45	2.27	2.27	*		0.75	3.0	
2b	60	45	2.6	2.5	*		0.75	1.0	
3a	25	30		3.89	*		1.2	3.0	
3b	25	30		2.73	*		1.2	1.0	
4a	20	20	7.3	7.3	*		1	3.0	
4b	20	20	4.5	4.5	*		1	0.5	

Data Table 2

test #	Lg (mcd/m2)	Lr (mcd/m2)	Tg (sec)	Tr (sec)	R	G	Lr/Lg	glare time(min)	dark time
5a	50	50	2.1			*	1	3.0	0.5
6a	50	40	2.45	1.89	*		0.8	3.0	0.5
6b	50	40		1.98	*		0.8	0.5	0.5
7a	12.5	12.5	6.33	17		*	1	3.0	0.5
7b	12.5	12.5	4.6	5.1		*	1	0.5	0.5


Green Delay Time vs Green Luminance
(3 minutes of Ambient Light of 130 cd/m2)
Green Delay time (sec)
12
10
8
6
4
2
0
0
50
100
150
200
Green Luminance (mcd/m2)
Series1
Power (Series1)


Red Delay Time vs Red Luminance
Ambient 3 minutes at 130cd/m2
Red Delay time (sec)
20
15
10
5
0
0
50
100
150
200
Red Luminance (mcd/m2)
Series1
Power (Series1)


Data
Chromatic model
Mesopic
Scotopic Rod vision
Photopic cone vision
V
2
1.5
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
300
400
500
600
700
800
450
530
550
570
650
Wavelength / nm

Factors that Effect Delay Time in seeing Light from Luminaire

1. **Color of Luminaire**
2. **Spectral Sensitivity of eye for Scotopic/Mesopic/Photopic Adaptations**
3. **Luminance of light source**
4. **Intensity of Ambient Light (Higher intensity –longer Delay)**
5. **Adaptation time for "On State" of Ambient Light (longer time longer Delay)**
6. **Head Position when viewing Luminaires**
7. **Other possible factors**
    1. **Age of observers – older (over 30 yrs old) have slower response and it increases with age.**
    2. **Color Blindness can suppress one color**
    3. **Liver disease effects response time**
    4. **Contrast issues for Diabetics, Insulin Resistant and Obesity**
    5. **etc**

Conclusions;

Night Driving involves Mesopic Adaptation

The observed brightness ratio of LEDs (which one is brighter) at Mesopic light levels does not agree with Photopic Luminance Measurements. (Brightness – Luminance Discrepancies Exist)

This work indicates that color harmonization (or monochromatic lighting) will help to reduce the distracting effect of the automotive instrument cluster brightness changes due to large ambient light intensity changes

In general “The Longer the Glare “On time”, the longer it takes to see the Luminaire”.

Brightness-Luminance Discrepancies exist

As pointed out by L. Ronchi - The brightness of the Luminaires change in time