Glare

Disability Glare

- Reduction in visual performance as a result of intra-ocular scatter of stray light from peripheral sources
- Off-axis scatter (stray light) <u>reduces the effective retinal contrast</u> of target stimuli making them more difficult to discriminate

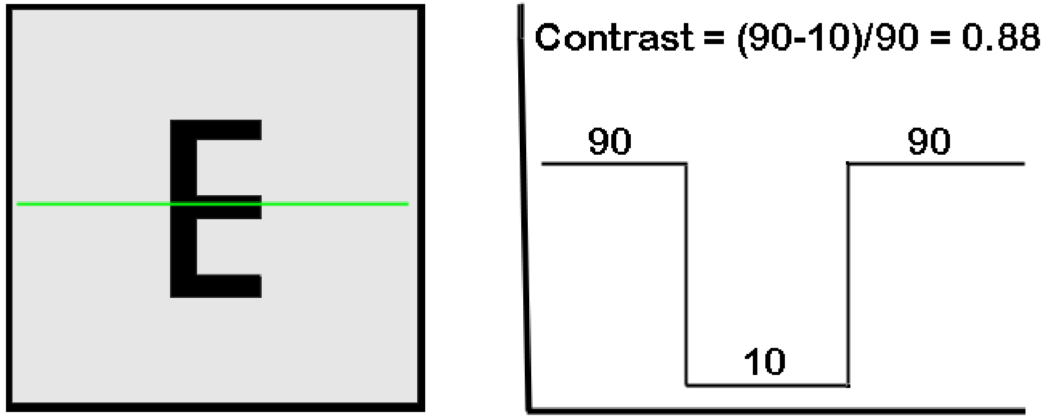
Glare as Veiling Luminance

Disability Glare

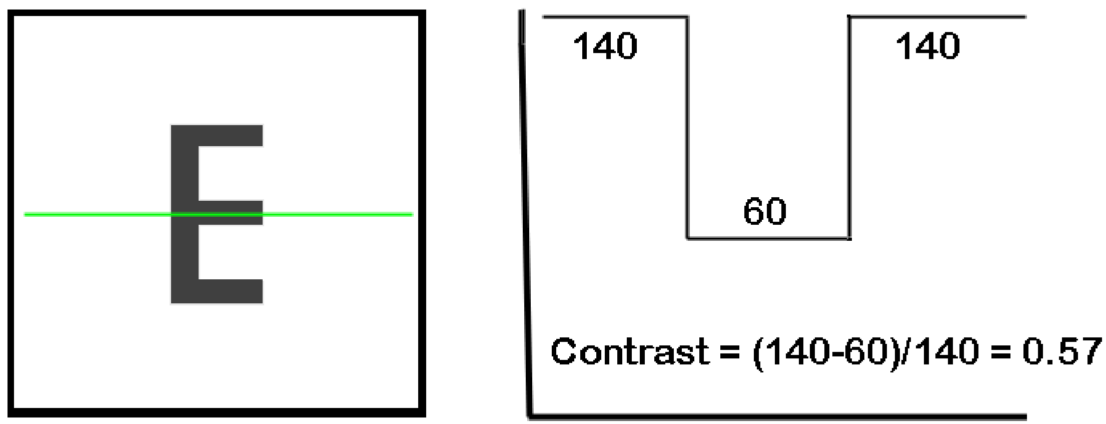
- The effects of off-axis scatter (stray light) on visibility can be modeled by estimating the **veiling luminance** it introduces to the retinal image

Effects of Veiling Luminance

Suprathreshold Stimulus



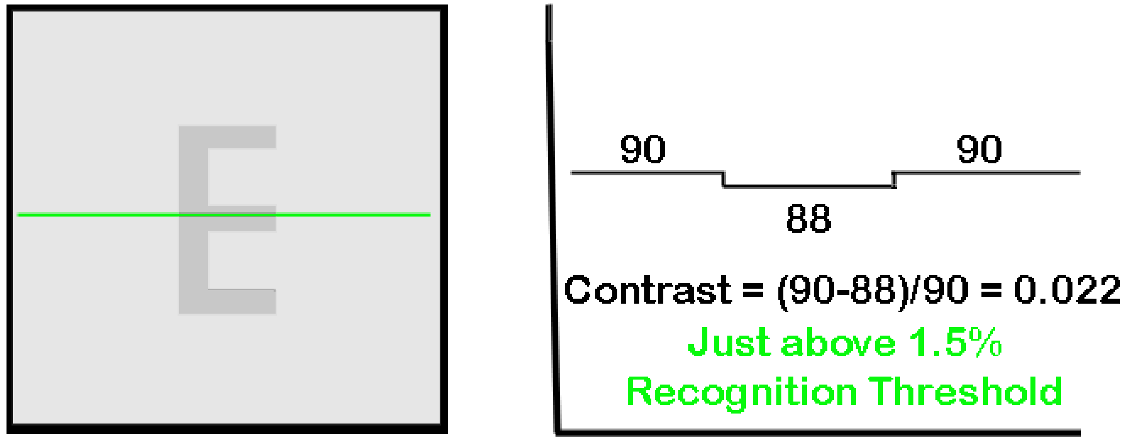
Retinal Image
w/o Veiling Luminance



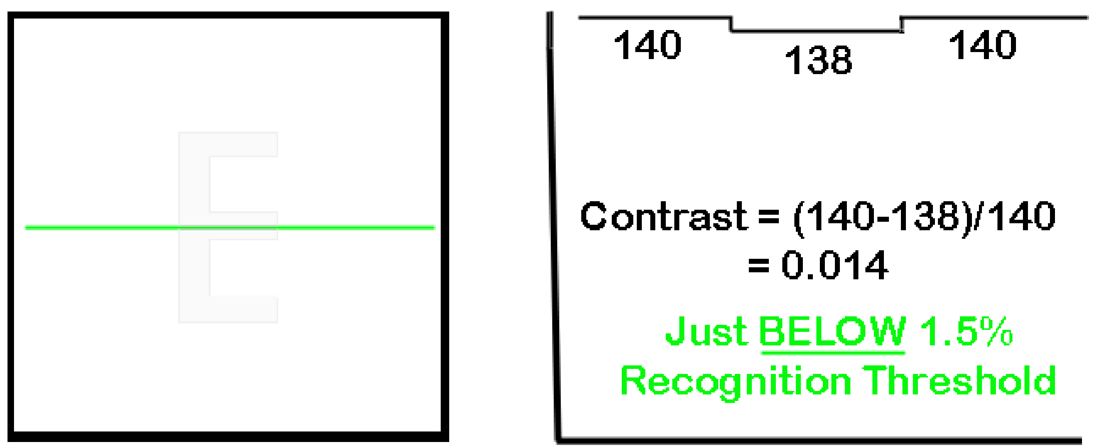
Retinal Image
with Veiling Luminance = 50

Effects of Veiling Luminance

Near Threshold Stimulus



Retinal Image
w/o Veiling Luminance



Retinal Image
with Veiling Luminance = 50

Veiling Glare Model

$$L_{equivalent} = k \cdot \frac{E_{glare}}{\theta^2} \qquad \textbf{(Equation 1)}$$

where:

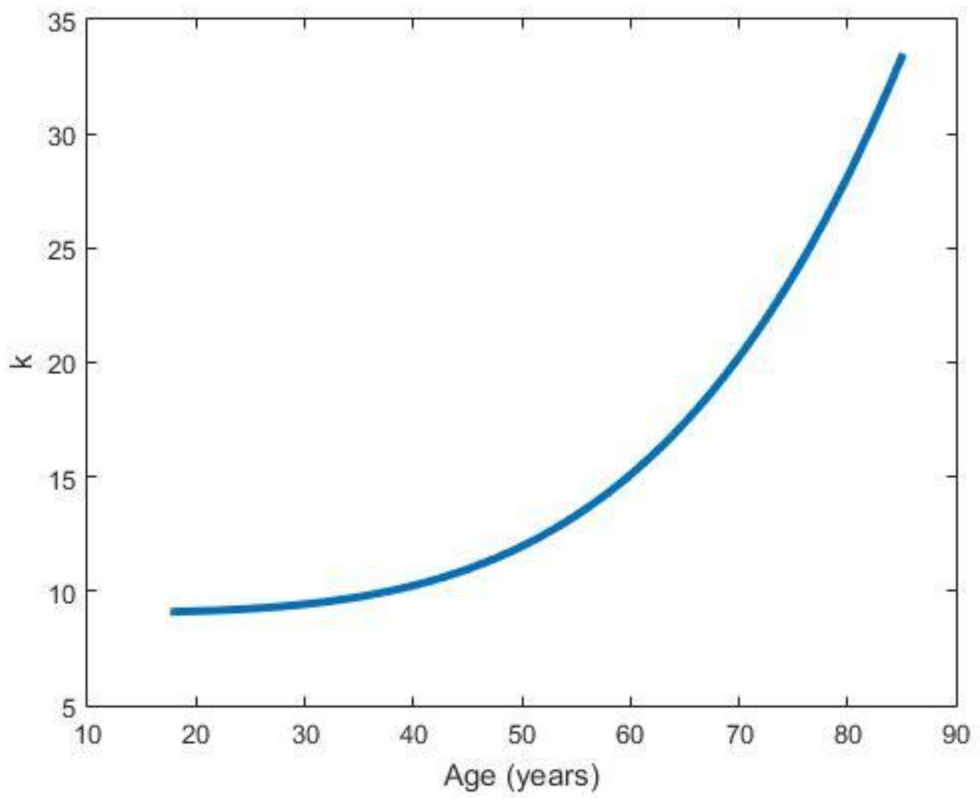
E_{glare} is the illumination of the glare source at the eye of the observer (lux)

$$k = 9.05 \left(1 + \left(\frac{\text{Age (in years)}}{66.4}\right)^4\right)$$

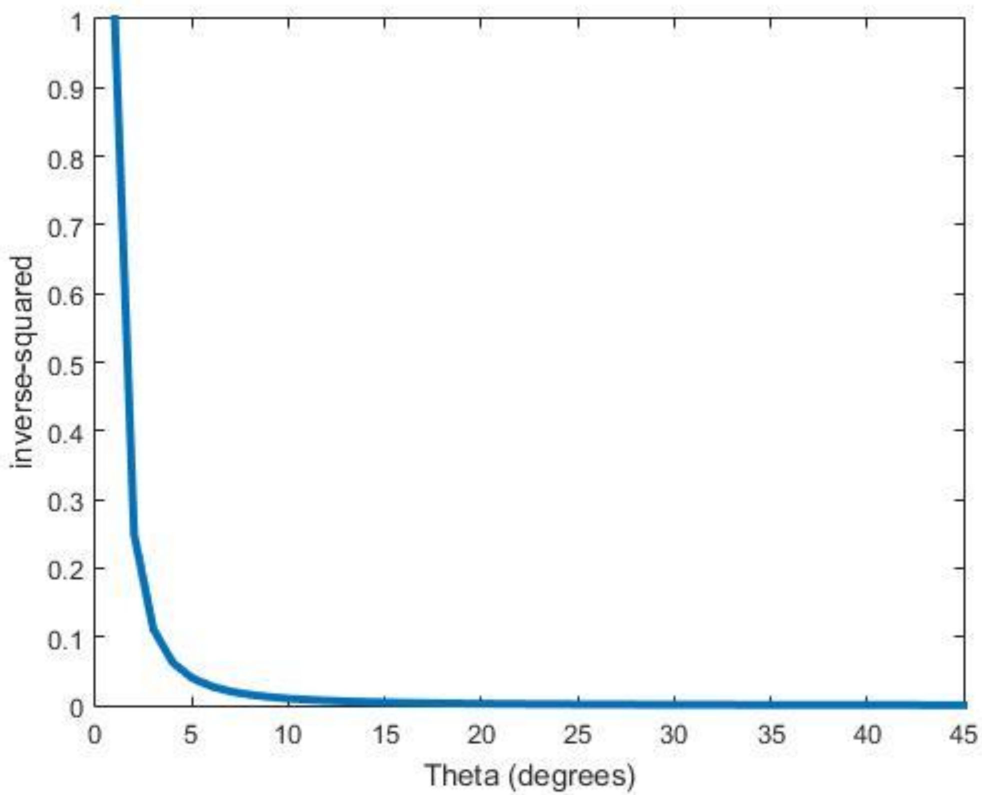
θ is the angle between the glare source and the observer's line-of-sight (degrees)

Adrian, W. & Bhanji, A. (1991). Fundamentals of disability glare: A formula to describe stray light in the eye as a function of glare angle and age. In W. Adrian (Ed.), *Proceedings of the First International Symposium on Glare* (pp. 185-193). New York: Lighting Research Institute.

Effect of Observer's Age on Veiling Luminance (Glare)



Effect of <u>Angular Separation</u> on Veiling Luminance (Glare)



$L_{equivalent}$ Estimation

Scenario: Approaching High-Beam Headlamps at <100 ft.

(Young versus Old Drivers)

Observer's Age

Glare Illuminance = 78 lux

Glare Offset = 5 degrees

k (20 yr-olds) = $9.05(1 + (20/66.4)^4) = 9.1$

k (70 yr-olds) = $9.05(1 + (70/66.4)^4) = 20.2$

L_{eq} (20-yr-olds) = $k * E_{glare}/\text{Offset}^2 = 9.1 * (78/25) =$ **28.4 cd/m²**

L_{eq} (70-yr-olds) = $20.2 * (78/25) =$ **63.0 cd/m²**

Predicting Age-Differences in Disability Glare Decrements

$$\text{Threshold}_{\text{elevation}} = \frac{\Delta L / L_{\text{background}}}{\Delta L / (L_{\text{background}} + \underline{L_{\text{equivalent}}})}$$

Given an average recognition contrast threshold of 1.5% and a background luminance of 22 cd/m²:

$$\text{Young}_{\text{elevation}} = \frac{0.33 / 22\ \text{cd/m}^2}{0.33 / 22 + \underline{28.4\ \text{cd/m}^2}} = 2.3$$

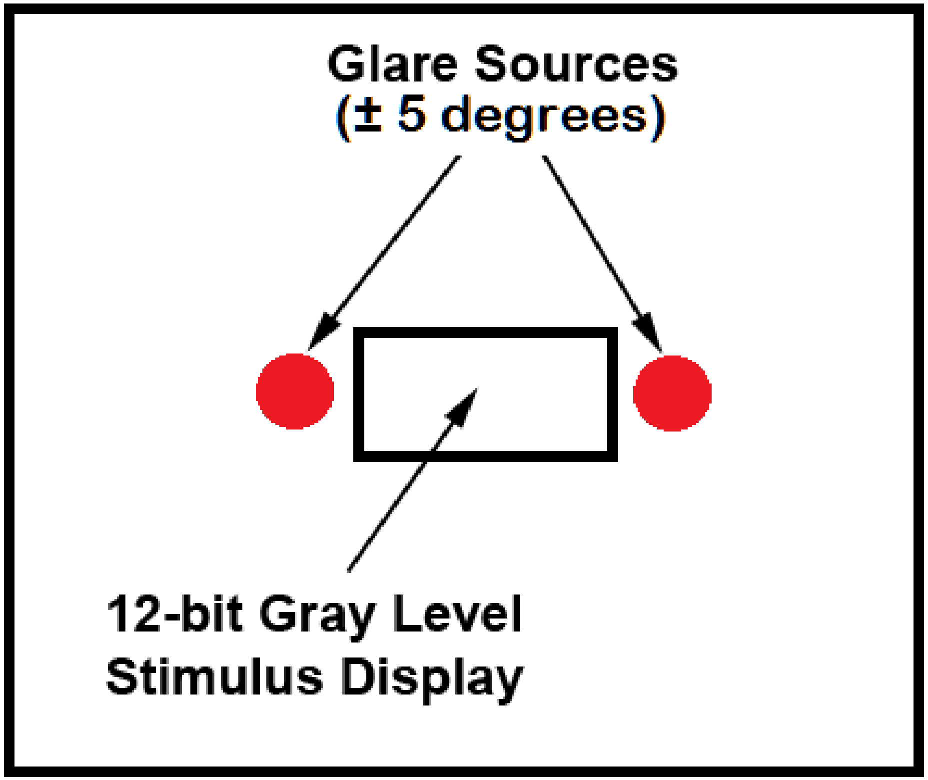
Glare Threshold Prediction:
2.3 x 1.5% = **3.45%**

$$\text{Old}_{\text{elevation}} = \frac{0.33 / 22\ \text{cd/m}^2}{0.33 / 22 + \underline{63.0\ \text{cd/m}^2}} = 3.86$$

Glare Threshold Prediction:
3.86 x 1.5% = **5.8%**

Glare Recovery Time

Glare Recovery Time Apparatus



- 22 cd/m^2 background
- 2^o tall letters (24x 20/20)
- 6m viewing distance
- Dual 50W glare lamps (78 lux at eyes)

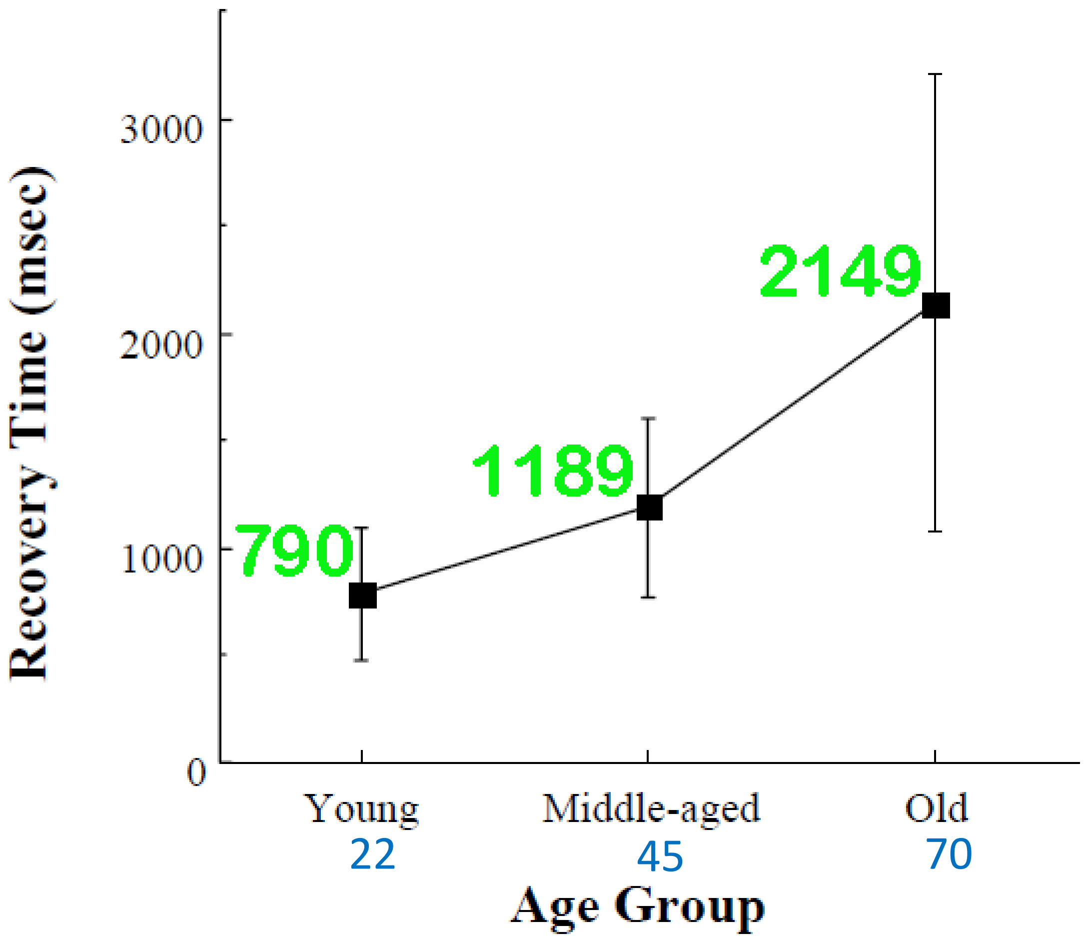
Glare Recovery Time Protocol

- Split glare sources activated for 10 sec
- High-contrast "fixation" letter reading task while glare is active
- Glare source inactivated
- Low contrast target letters (1.25x Threshold)
- Press button and read targets aloud ASAP
- Target letters disappear
- Average three recovery time estimates (Repeat trial if recognition error)

Recovery Time Predictions

- Some data available from clinical populations
- Anecdotal reports of age-related problems with glare recovery
- No quantitative models currently exist

Glare Recovery Time Results



All paired-comparisons significant at the 0.01 alpha level.

An exponential model fits the data very well:

RT (msec) = 487 * exp(0.021)

Disability Glare Conclusions

- Static (baseline) contrast <u>recognition thresholds</u> consistent with Adrian & Bhanji (1991) model

- Large age-related increases in <u>recovery time</u>:

  Old required nearly 3x longer to recover (2+ sec)

  Glare recovery time <u>increases exponentially</u> between ages 20-75

Disability Glare Conclusions (continued)

- Longer recovery times cannot be accounted-for by "general slowing" mechanism (which would predict 100 msec slowing; see Kaussler, 1991)

- The aging driving population can greatly benefit from **improved roadway delineation** maintenance schedules and/or emerging **smart LED headlamp technology**

Discomfort Glare Study

- DeBoer Scale
- Schmidt-Claussen & Bindels (1974) Model

Discomfort Glare

- Bright peripheral light sources can cause distraction, fatigue and a generally unpleasant sensation

- When such subjectively “unpleasant” sensations occur in the absence of measurable decrements in performance one is experiencing DISCOMFORT GLARE

- The physiological basis of discomfort glare is currently unknown
(intrinsically photosensitive RGC’s ???)

Discomfort Glare
from Daytime Running Lights

deBoer Discomfort Glare Scale

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

deBoer, J.B. (1967). *Public Lighting*. Eindhoven, The Netherlands: Philips Technical Library.

Schmidt-Claussen & Bindels (1974) Discomfort Glare Model

$$\text{deBoer Discomfort Glare Rating} = 5.0 - 2\log \frac{E_{glare}}{0.003\left(1+\sqrt{\frac{L_{background}}{0.04}}\right)\theta^{0.46}}$$

where:

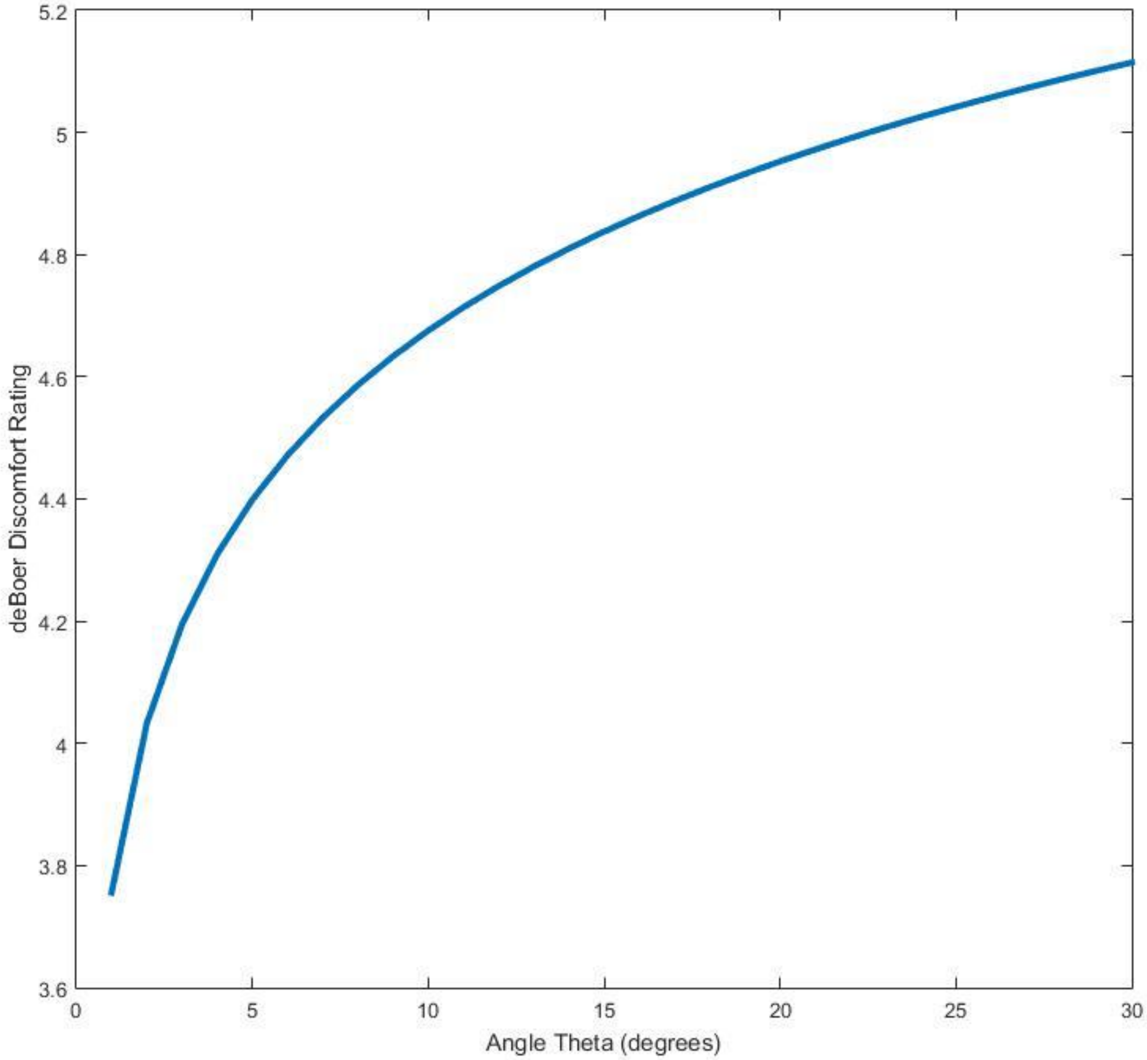
E_{glare} is the illumination of the glare source at the eye of the observer (lux)

$L_{background}$ is the background adaptation state of the observer (cd/m^2)

θ is the angle between the glare source and the observer's line-of-sight (minarc)

Schmidt-Claussen, H.J. & Bindels, J.T.H. (1974). Assessment of discomfort glare in motor vehicle lighting. *Lighting Research & Technology*, 6, 79-88. [Darmstadt]

Discomfort Glare Decreases as Angle of Separation Increases



Luminance Adaptation States
(Driving Environment)

Lighting Condition	Driver Adaptation State (cd/m^2)	Typical Roadway Illumination (lux)
road at night	1	100
late twilight/early dawn	50	
mid-twilight/mid-dawn	100	5000-7000
early twilight/late dawn	500	
overcast daytime sky	1000	
clear bright sky	5000-6000	70,000-85,000