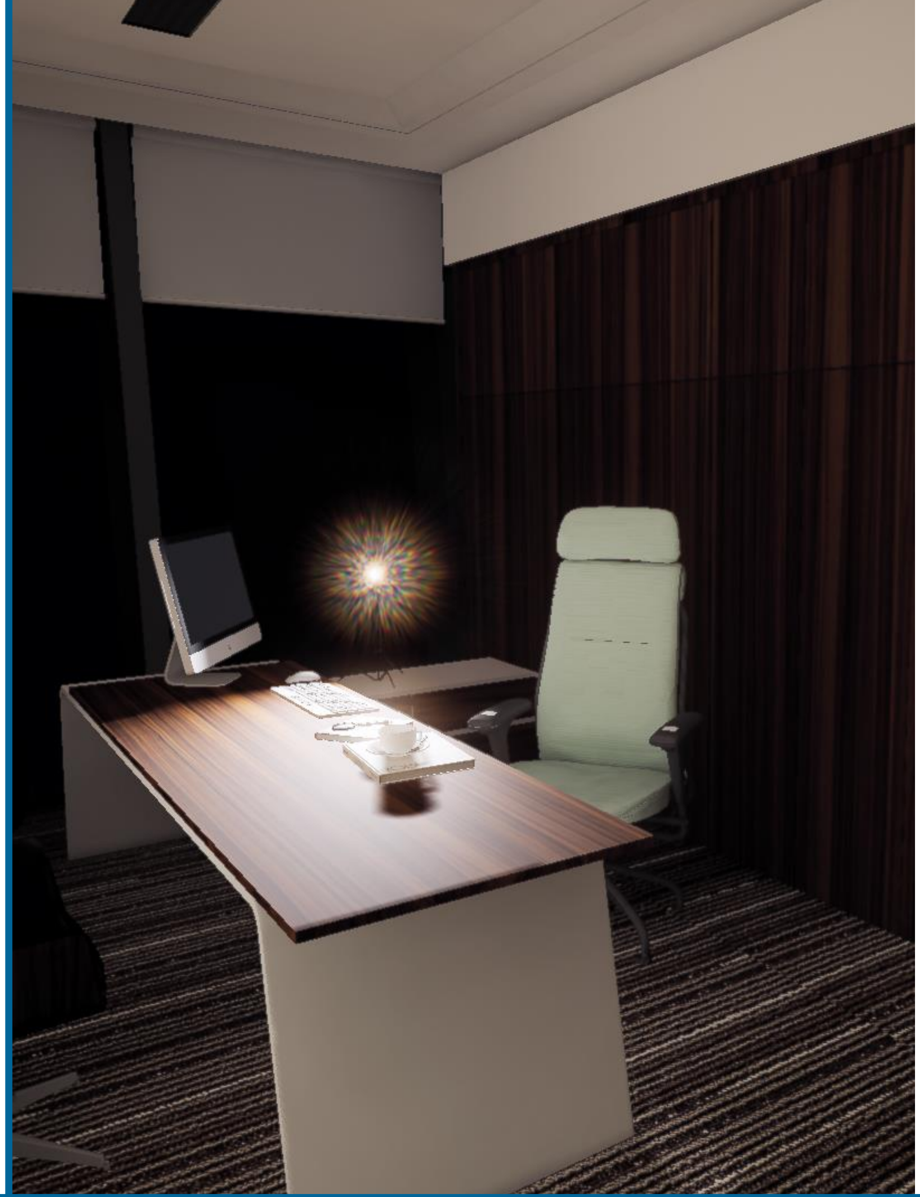

Gaze-Dependent Simulation of Light Perception in Virtual Reality

ISMAR 2020

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Research Division of Computer Graphics

Institute of Visual Computing & Human-Centered Technology

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Introduction

brightness range

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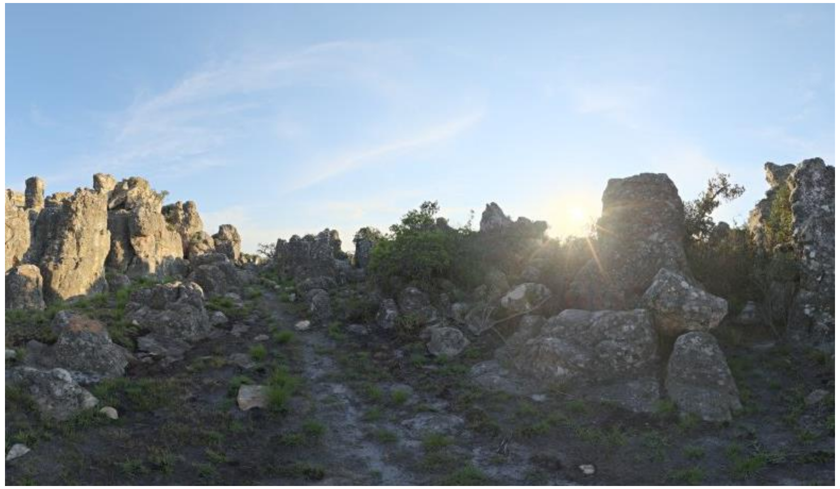
tone mapping



Introduction

Introduction

- → Perceptual algorithms necessary!
  - Medically based
  - Account for viewing direction, pupil size

Contribution

- Post-processing workflow
  - Accurate simulation of light perception in VR/AR
- Medically-based, perceptual effects
  - In real-time VR/AR
  - Following optometrist advice
- Eye tracking for measuring light incidence
- Pilot user study, comparison of
  - Real-world low-light situation
  - And VR simulation

Temporal Eye Adaptation

Visual adjustment to bright and dark

Adaptation of rods and cones over time

Perceptual Glare

Colorful patterns when viewing bright light sources

Scattering of light in the eye

Visual Acuity Reduction

Blurred details in low light scenes

Rods not present in fovea (point of sharpest vision)

Scotopic Color Vision

Color shift towards blue in low light scenes

Rods more sensitive to longer wavelength light than cones

Based on Krawczyk et al., 2005 and Ritschel et al., 2009

Temporal Eye Adaptation	Perceptual Glare	Visual Acuity Reduction	Scotopic Color Vision
Visual adjustment to bright and dark	Colorful patterns when viewing bright light sources	Blurred details in low light scenes	Color shift towards blue in low light scenes
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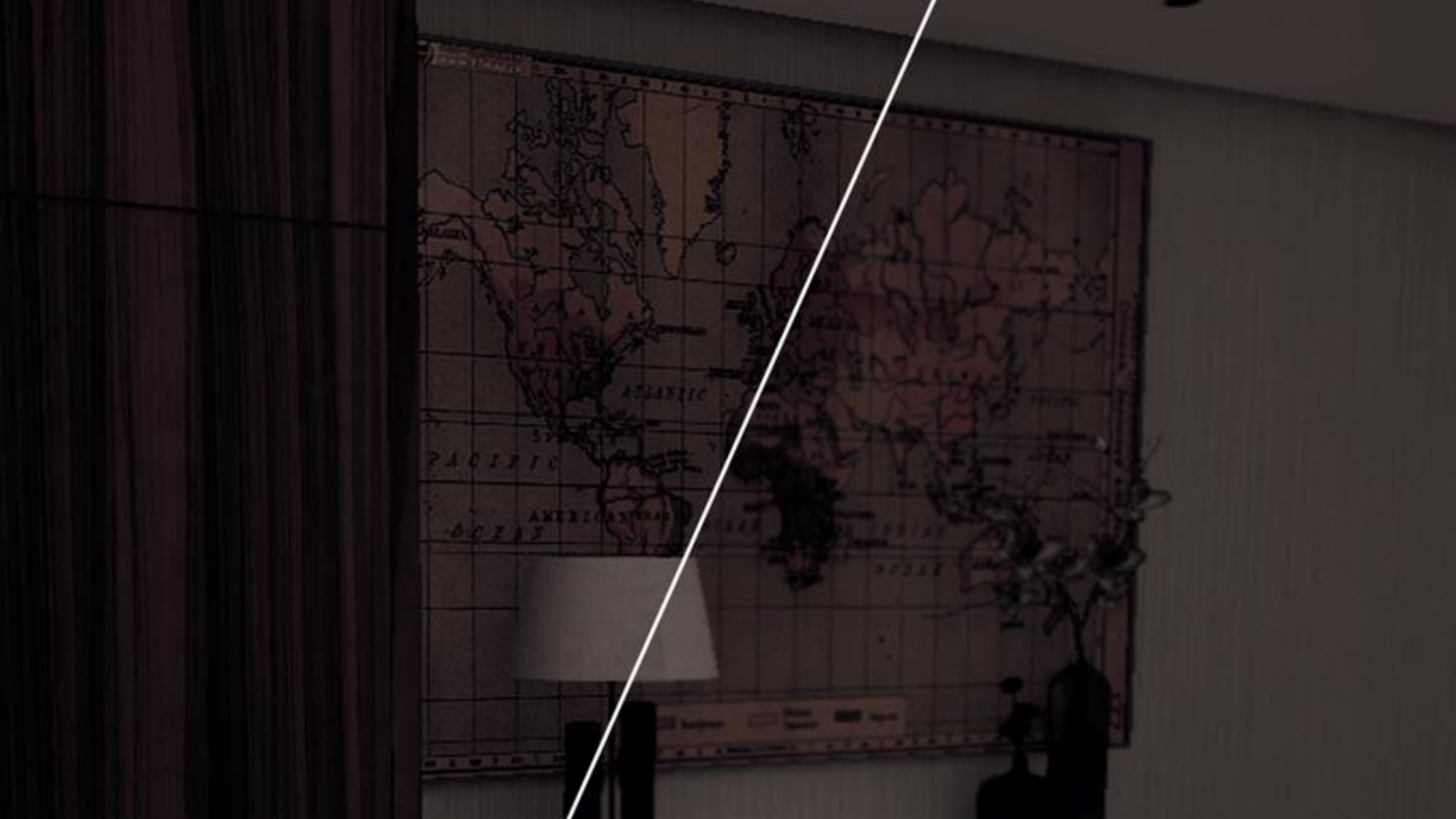
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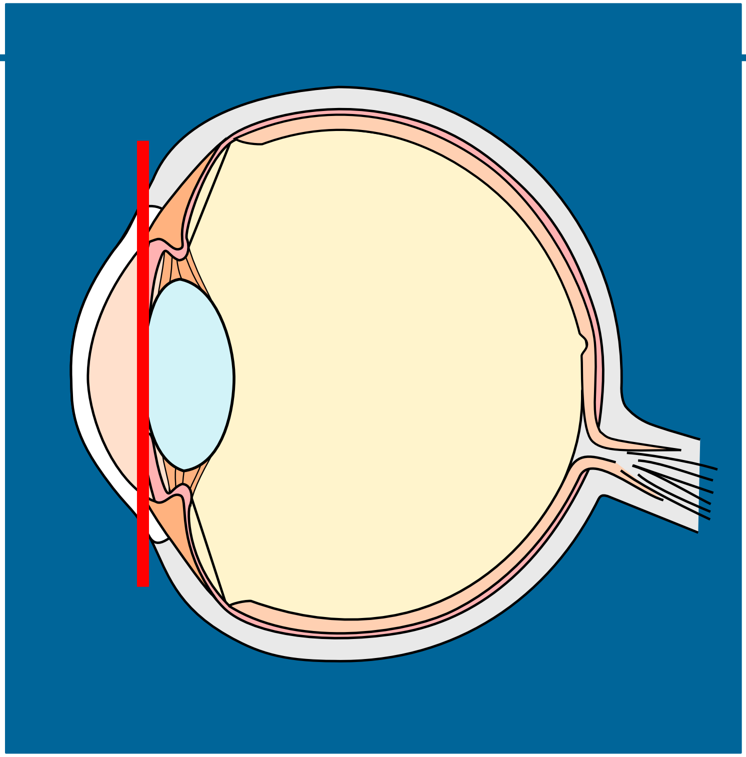
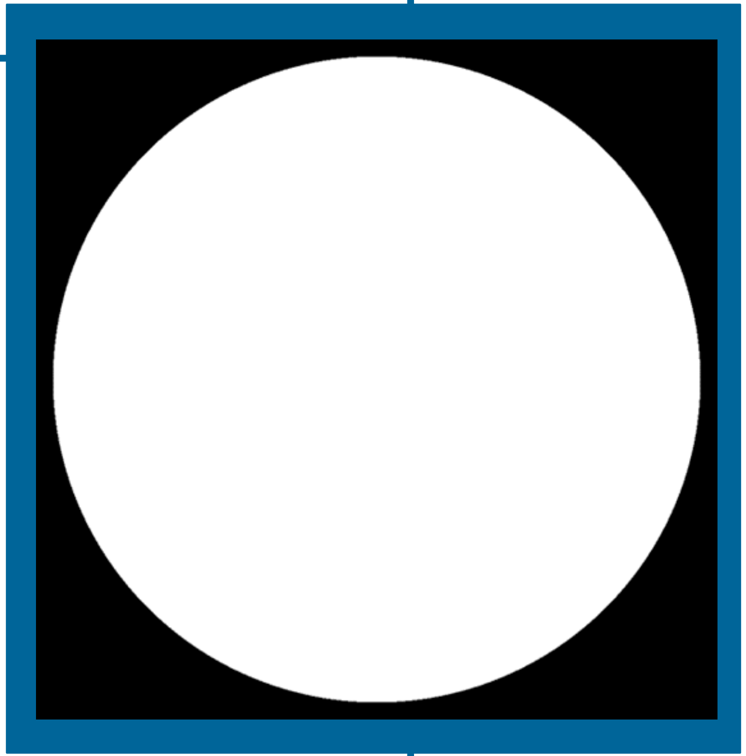
Temporal Eye Adaptation

- $L_i = L_{i-1} + (Y - L_{i-1}) \cdot \left(1 - e^{-ft/\tau(Y)}\right)$
  - Target luminance Y
  - Temporally filtered luminance L_i of frame i
  - Photoreceptor adaptation times τ

Perceptual Glare

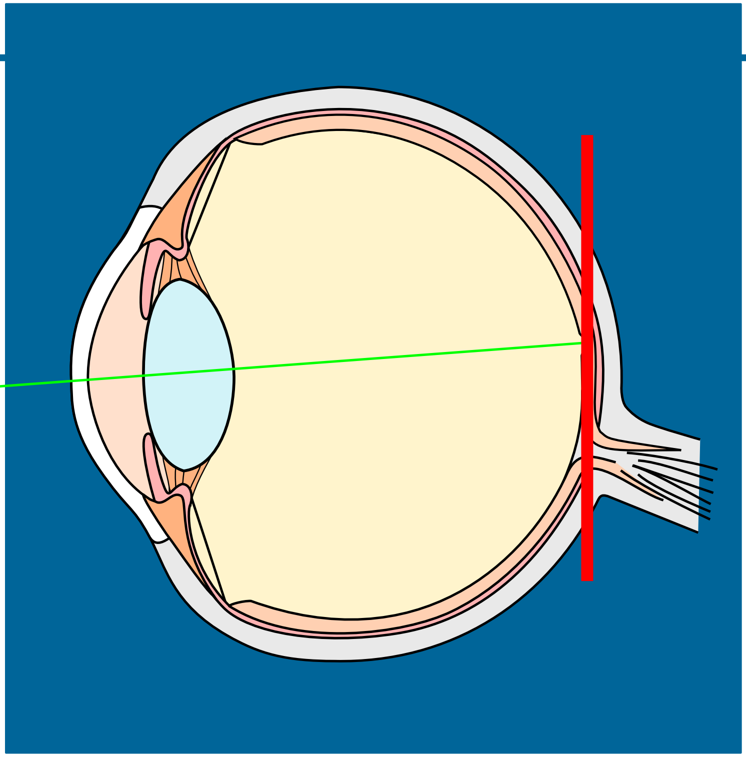


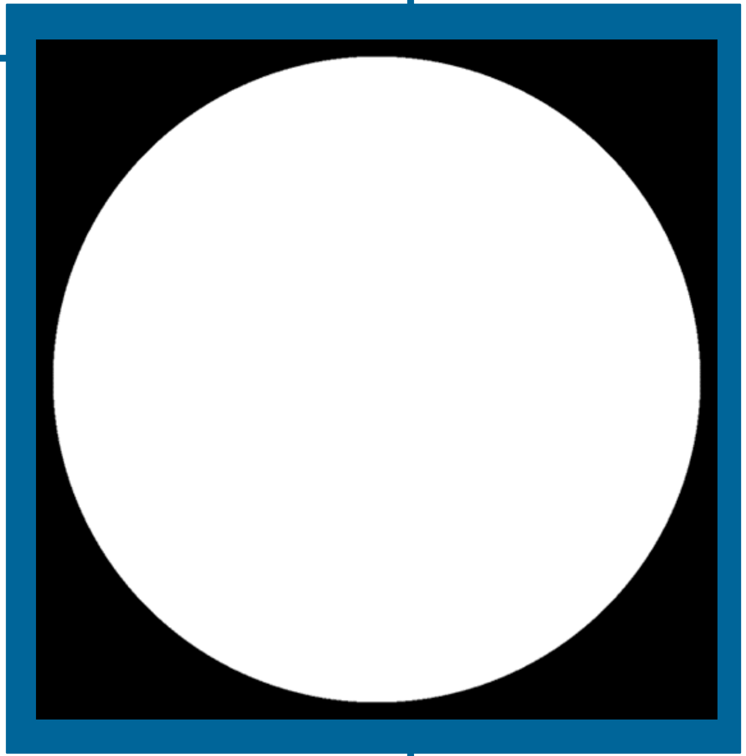


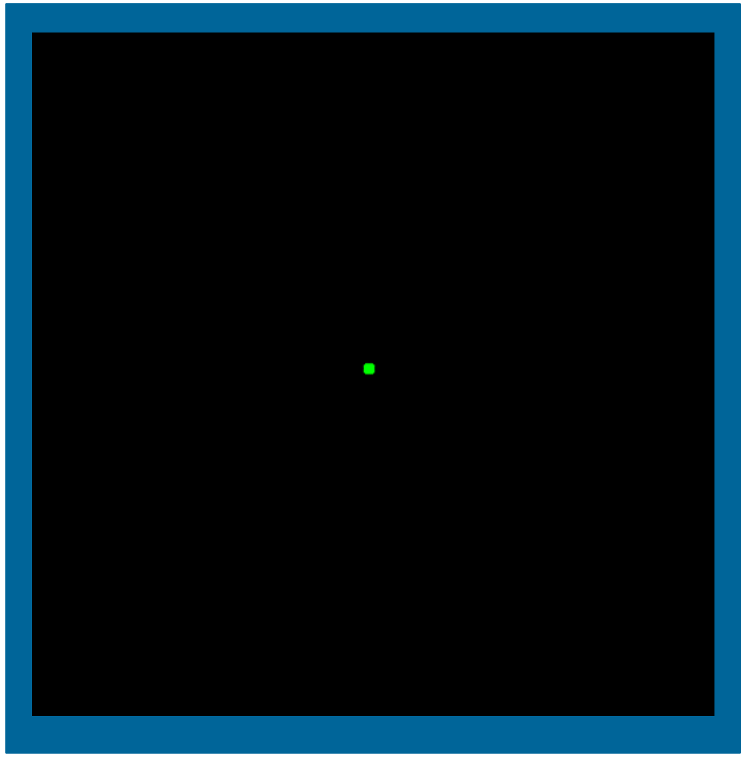
Motivation ▫
Overview ▫
Methodology ▾
Adaptation ▫
Glare ▪
VA reduction ▫
Color shift ▫
Evaluation ▫
Conclusion ▫

Image adapted from
commons.wikimedia.org/wiki/File:Eyesection.svg

Perceptual Glare







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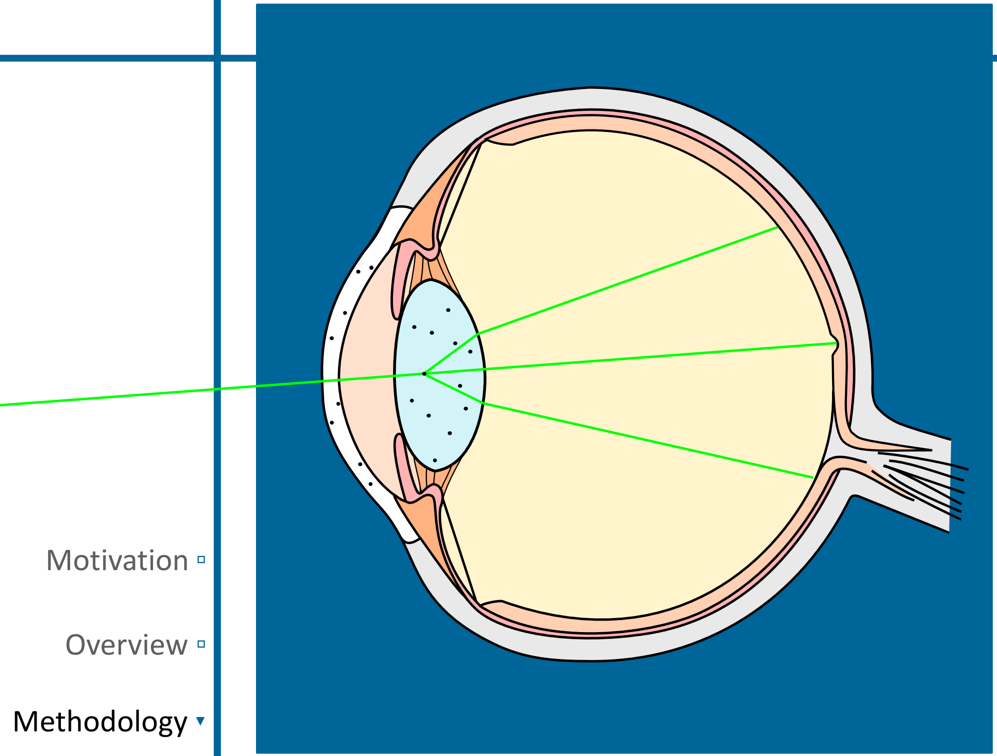
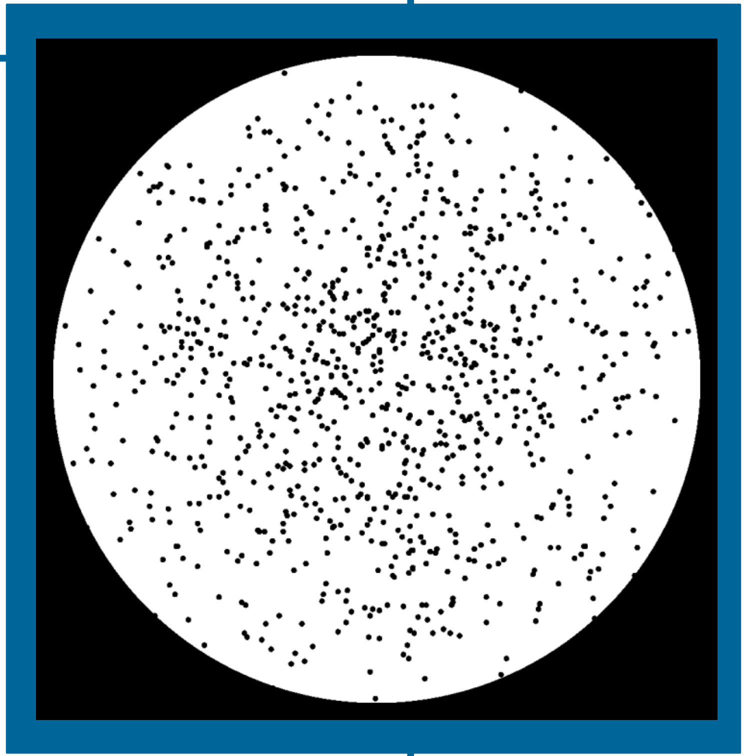
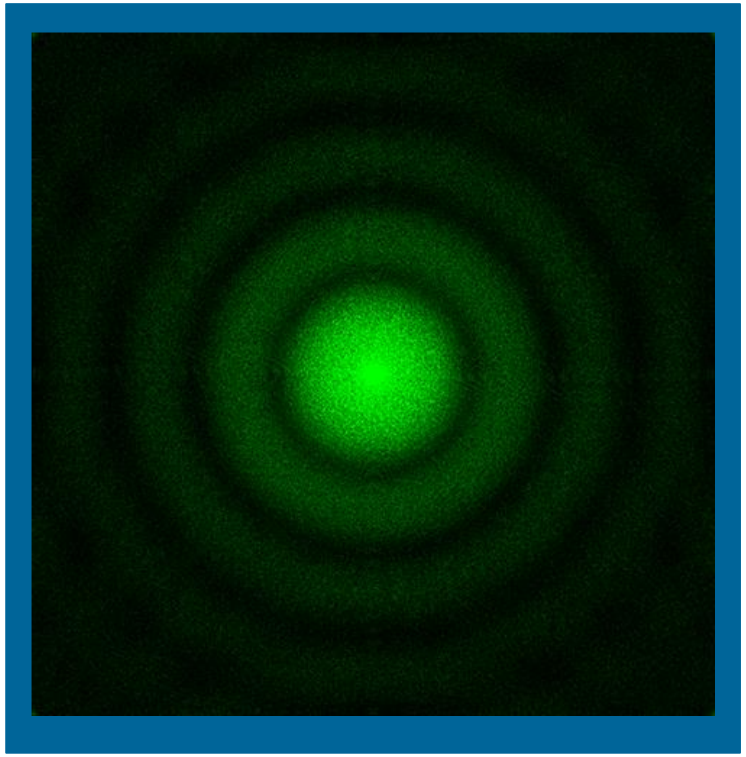
Perceptual Glare





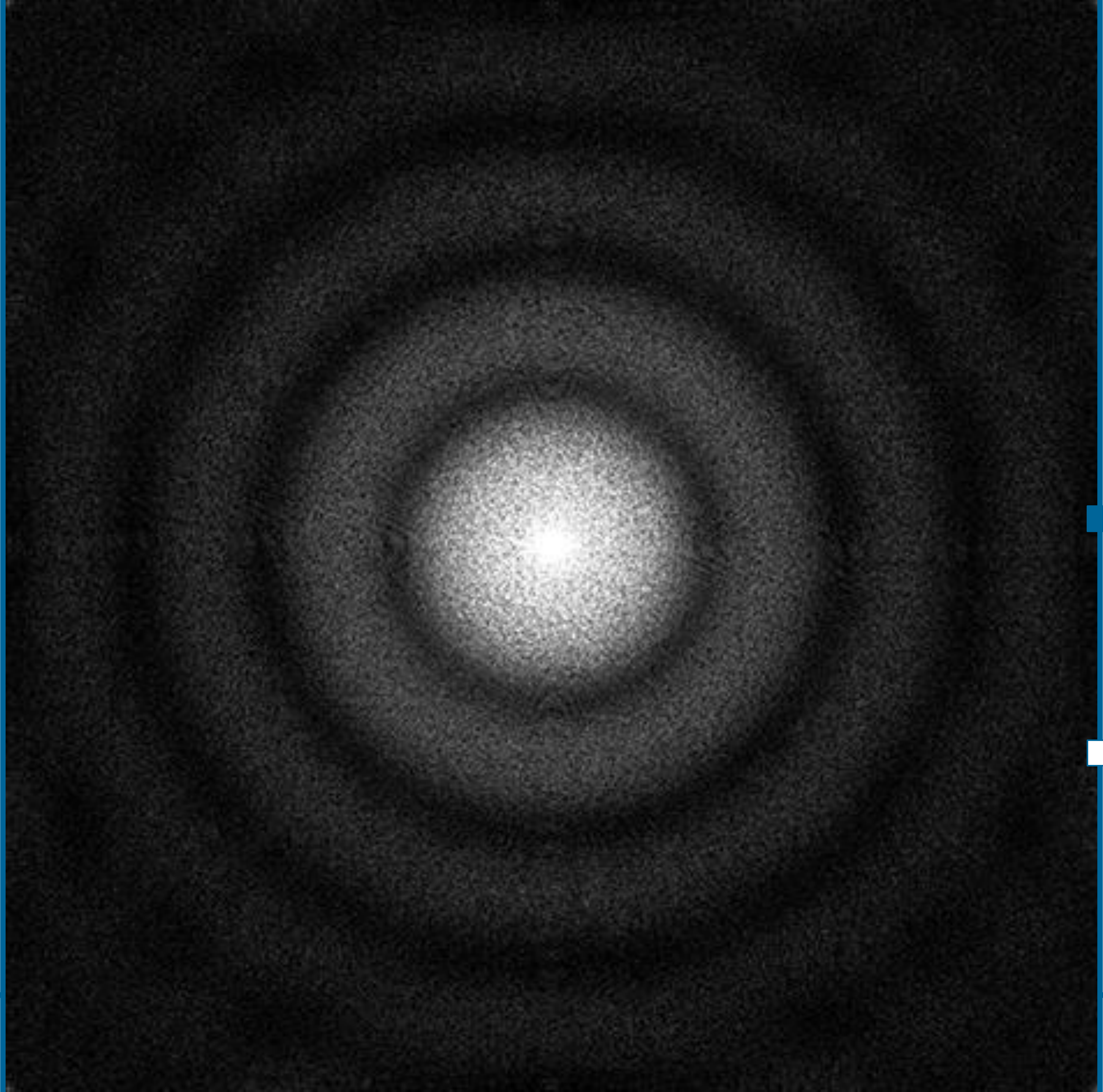


$$M(x,y) = \frac{1}{(\lambda d)^2} \left| \frac{1}{N} \cdot \mathcal{F}\left[P(x,y) \cdot e^{\mathrm{i}\frac{\pi}{\lambda d}(x^2+y^2)} \right] \right|^2$$

After Ritschel et al., 2009

Image adapted from commons.wikimedia.org/wiki/File:Eyesection.svg

Perceptual Glare

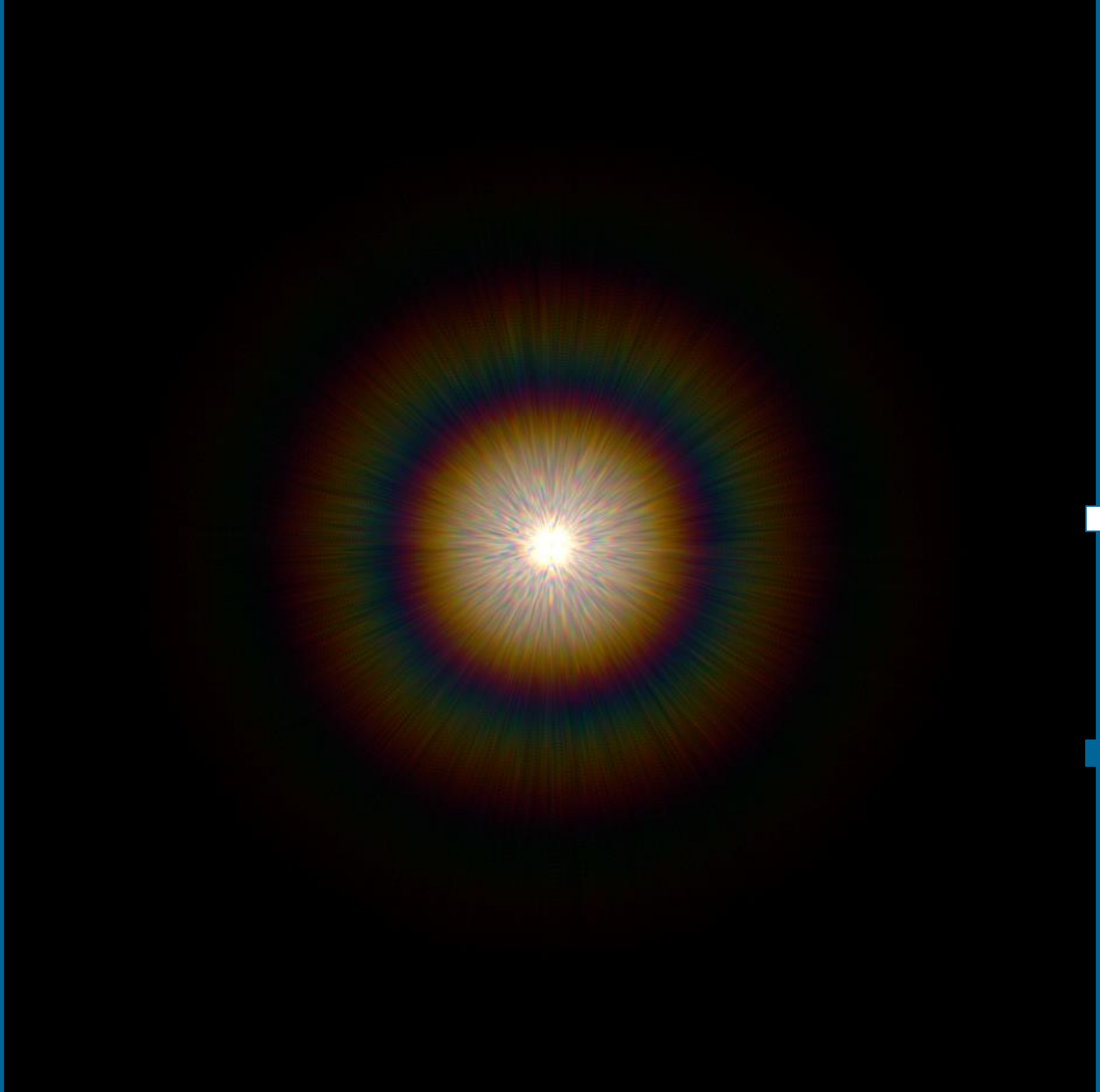


Monochromatic PSF

Diffraction on the retina of a single wavelength light source

Spectral PSF

Combination of multiple wavelengths to simulate spectral light



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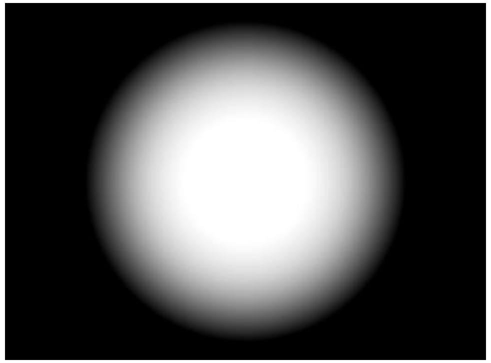
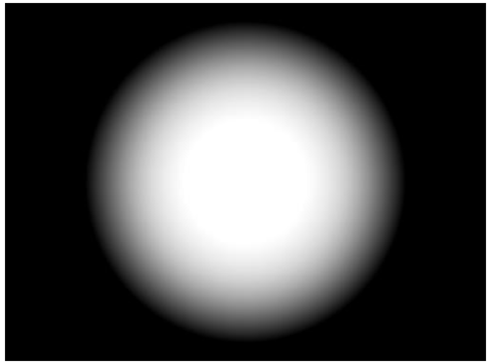
 · (1 - ) +  · 

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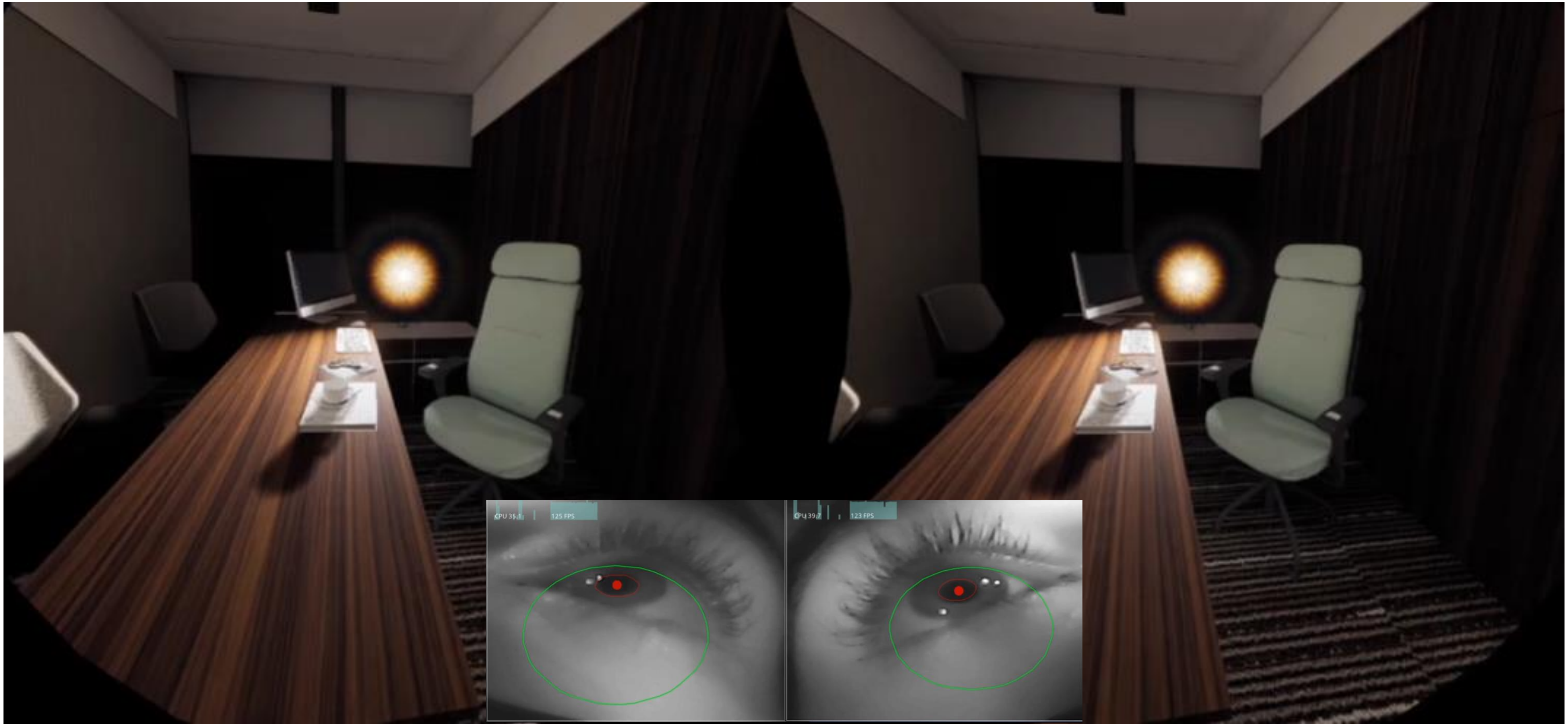
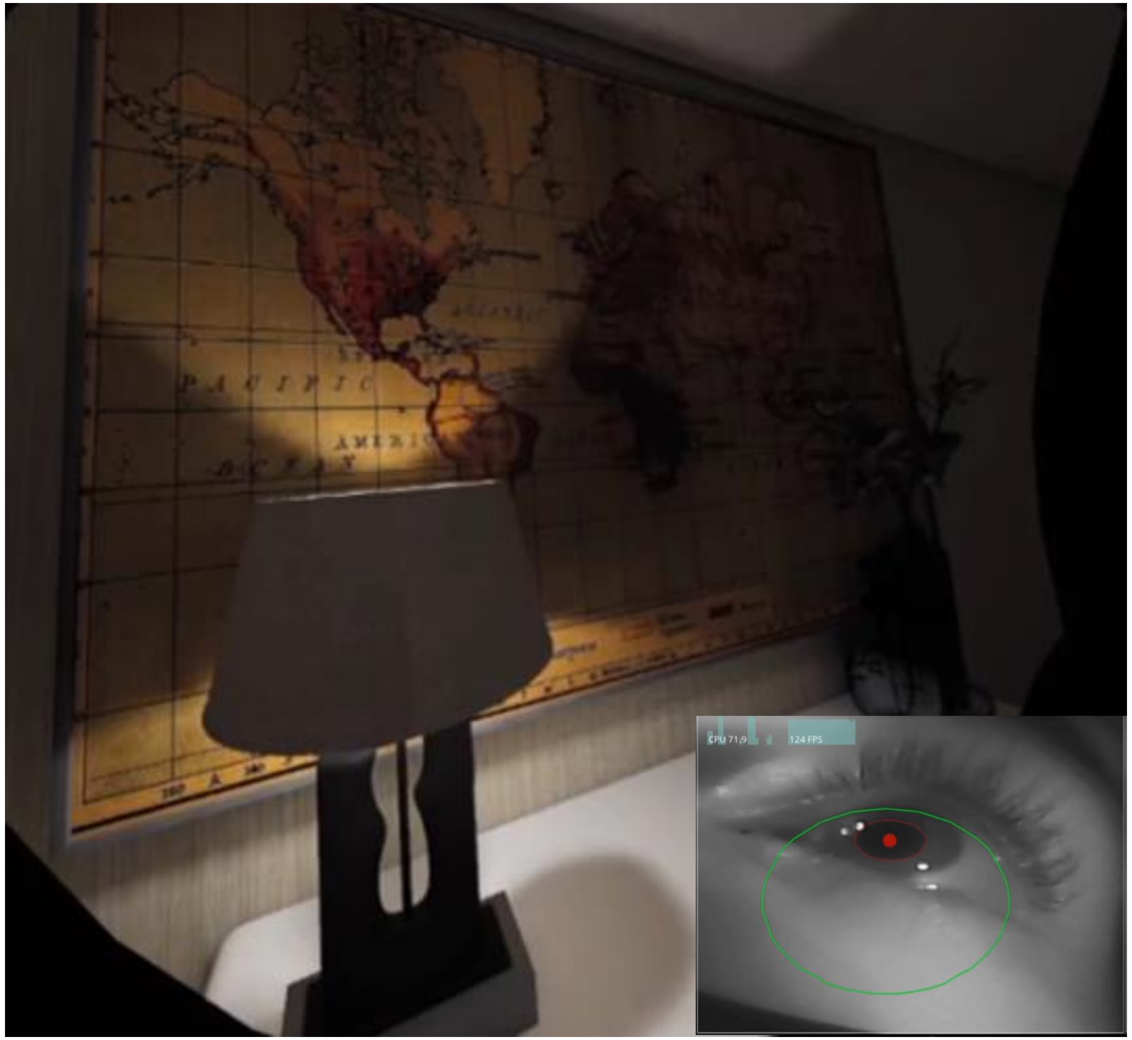
Perceptual Glare

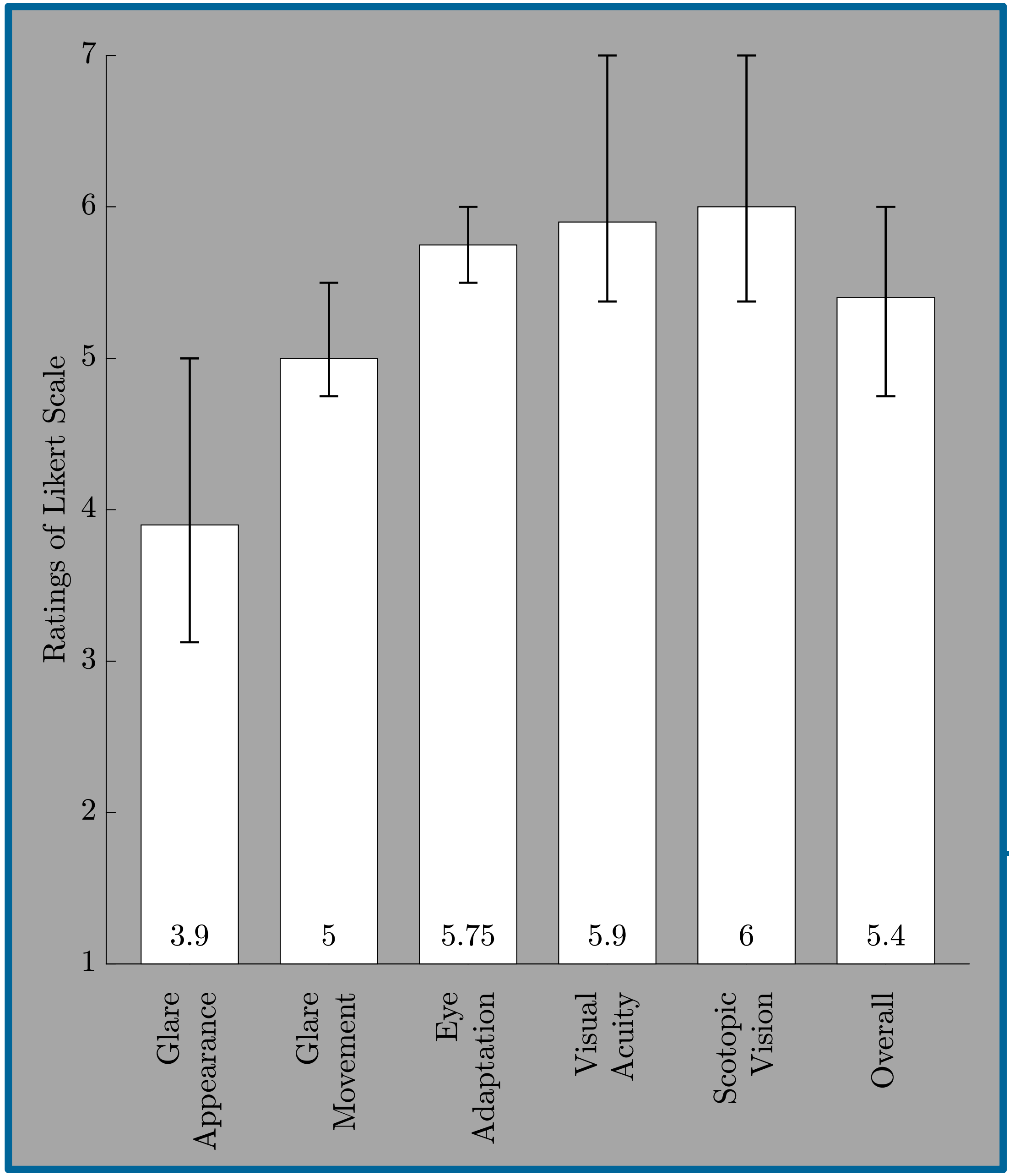


Visual Acuity Reduction



- $\sigma(L) = \max(1 - L, 0)$
  - Gaussian variance σ
  - Pixel's lightness L

Scotopic Color Vision



Evaluation

Qualitative user study with 5 participants

Conclusion

Real-time VR/AR post-processing workflow

Using eye tracking

Based on medical research

Pilot user study

- temporal eye adaptation
- perceptual glare
- visual acuity reduction
- scotopic color vision

Thank you for your attention!

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