Towards Automated Visibility Metrics

Designing Visually Accessible Spaces
NIH Grant 1 R01 EY017835-01

Rob Shakespeare
Indiana University PI

Other research team members from:
University of Minnesota, Low Vision Lab & Computational Vision
University of Utah, Computer Science & Visual Perception & Spatial Cognition

Industry is speaking…

IESNA is slowly moving from illumination based to luminance (vision) based metrics.

ANSI/IESNA RP-28-07 targets the elderly and low vision community.

American Disability Act is now working with IESNA, National Institute of Building Sciences and others, exploring building code to address the needs of low vision.

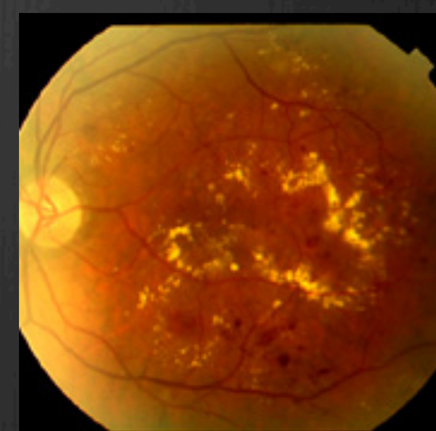
In response, a leading Illumination Engineer, software developer, and industry partner states " the DEVA project is absolutely critical to visibility building code standards development"

Industry is speaking…

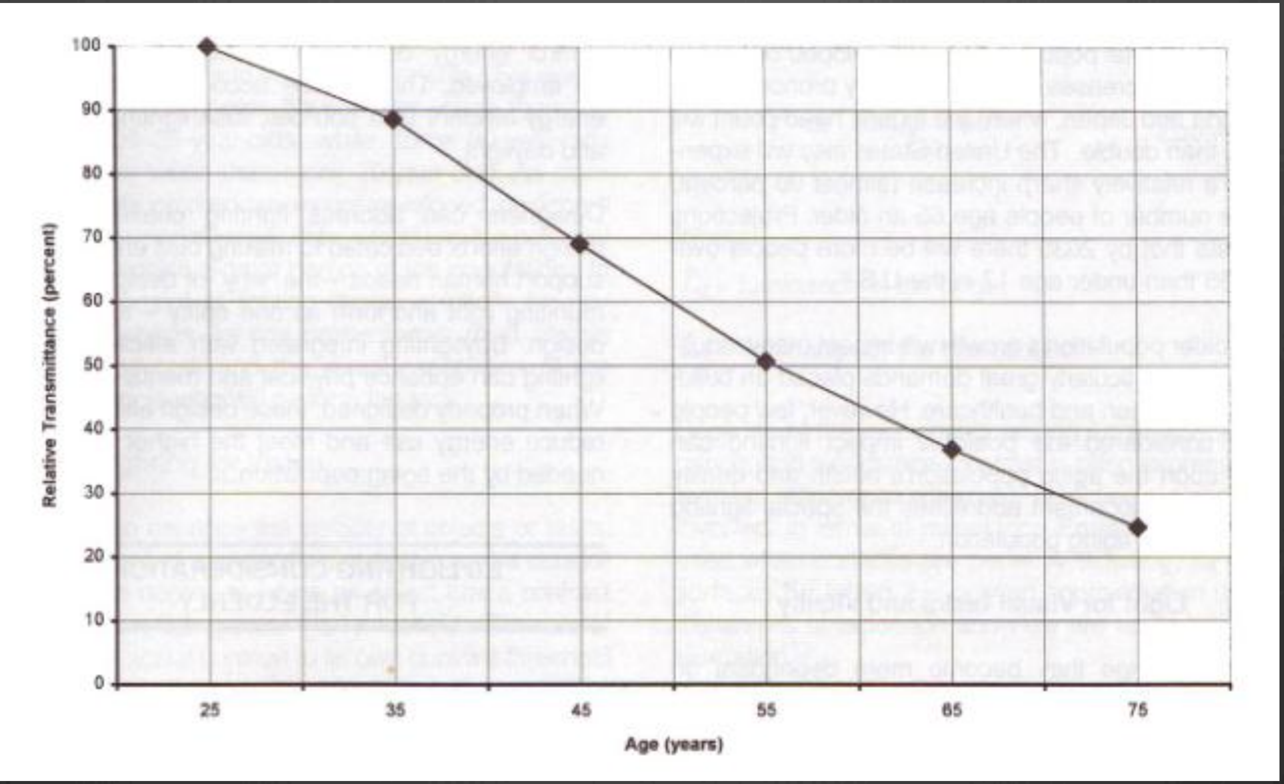
The potential impact of this work is summarized by a prominent architectural firm and industry partner : ”While architecture as a profession stands at the forefront of handeling issues of universal access, we have not encountered a means of early detection in the design development stage that can adequately address the requirements of the visually impaired. The DEVA modelling platform is of great value, allowing an iterative process that incorporates visibility analysis into an evolving design”

Normal eyesight= healthy retinas, lenses, irises, optic nerves…

Low vision= partially functioning retinas, lenses, irises…



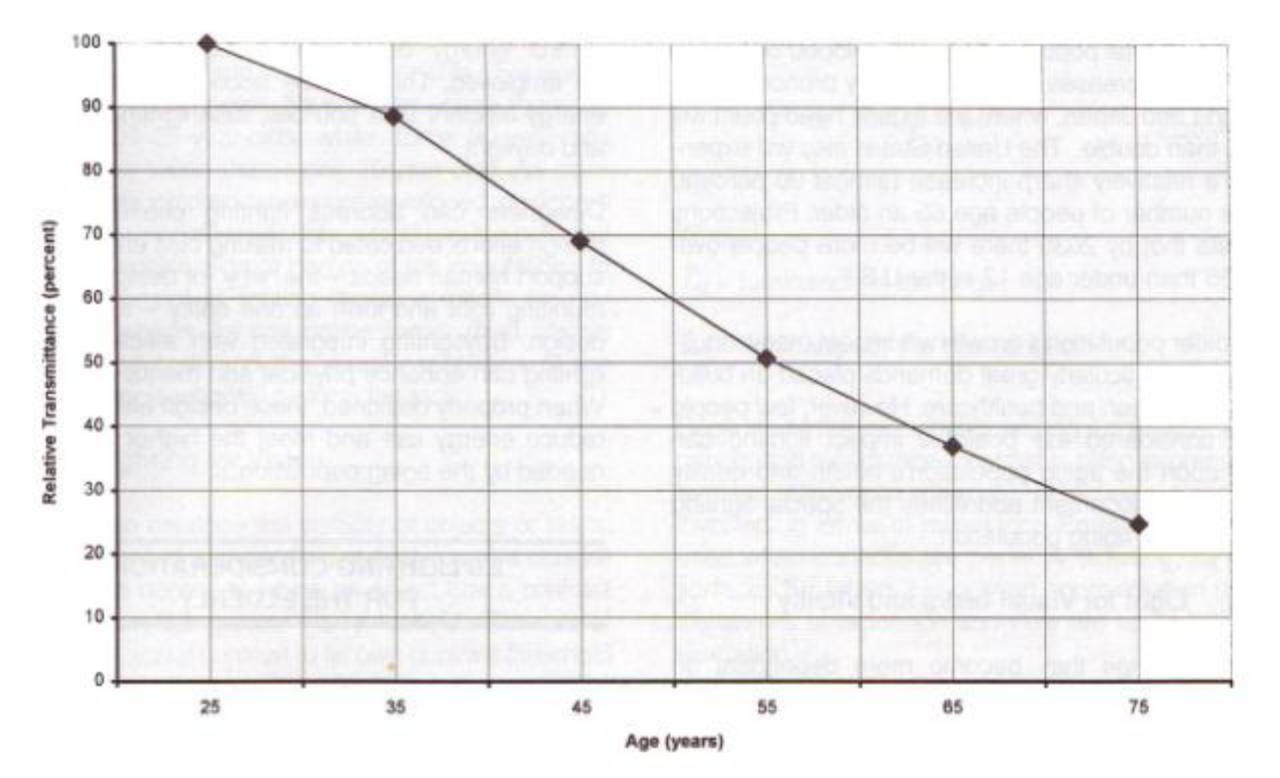
Ageing alone moves each of us towards decreased visual function



(Image from ANSI/IES RP-28-07)

- As people age, total light transmittance decreases (the pupil gets smaller and reduces the amount of light entering the eye)
- Scattering and attendant glare sensitivity also increases

Ageing alone moves each of us towards decreased visual function



(Image from ANSI/IES RP-28-07)

– As people age, total light transmittance decreases (the pupil gets smaller and reduces the amount of light entering the eye)
– Scattering and attendant glare sensitivity also increases

We live longer. There are more "elders". NO-ONE ESCAPES

Vision Basics: A brief review

Please open your envelopes …

Snellen Vision Acuity Chart

Unfold the 14” long white paper

Hold chart at this distance from one eye. The other closed. (consider removing glasses)

To the right of the row which you can just read, is your acuity.

Normal vision is 20/20

Acuity is the measure of the smallest detail which you can see.

Now test the same eye using the low contrast chart. (White is now more grey and the black is less dark.)

Your acuity has likely lowered..

Instead of 20/20, perhaps now your acuity is 20/30

Acuity and contrast are tightly bound

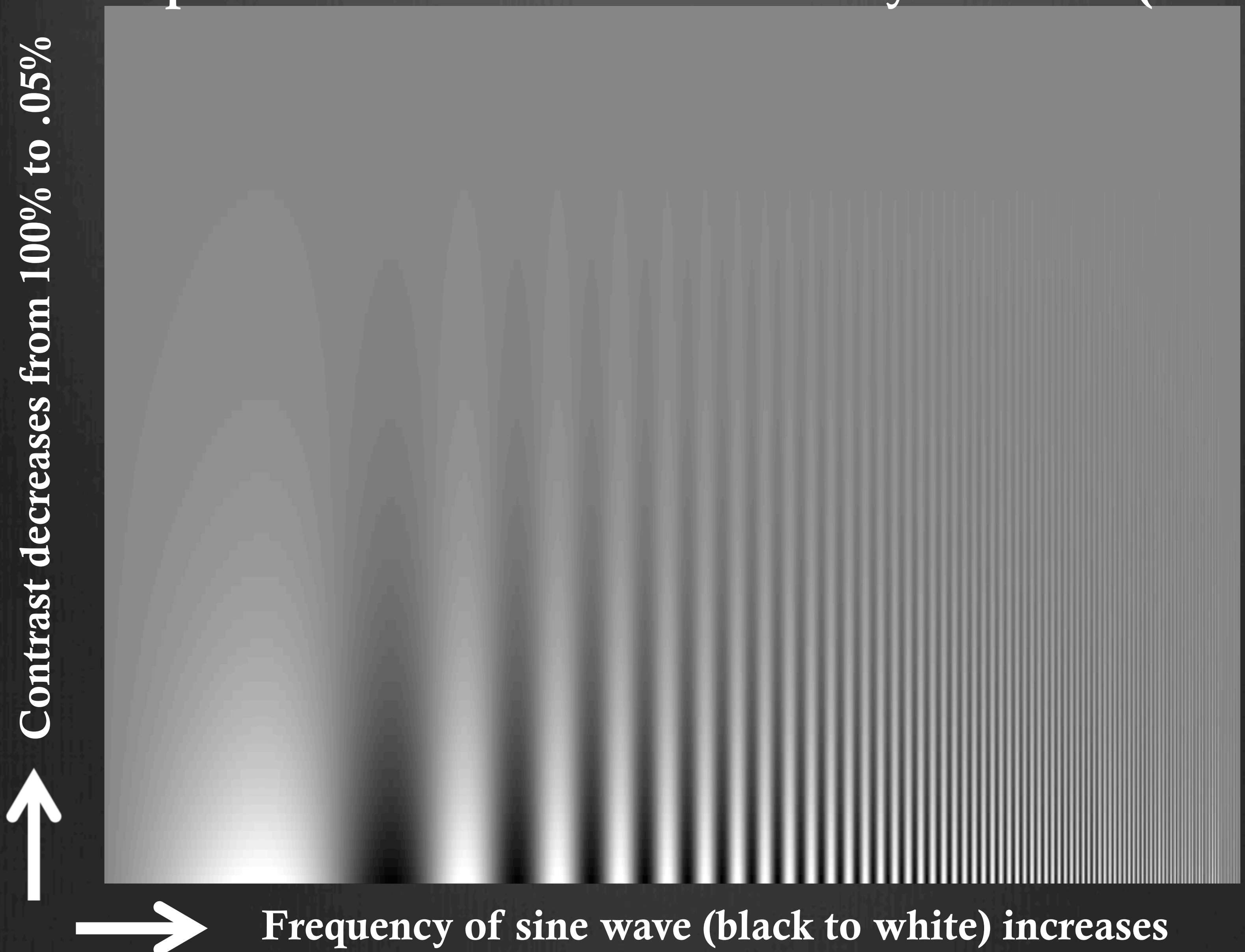
Now cover the black and white chart with the grey transparency and measure your acuity.

This example illustrates low luminance where black is black but the background is quite dim. It’s a special contrast case.

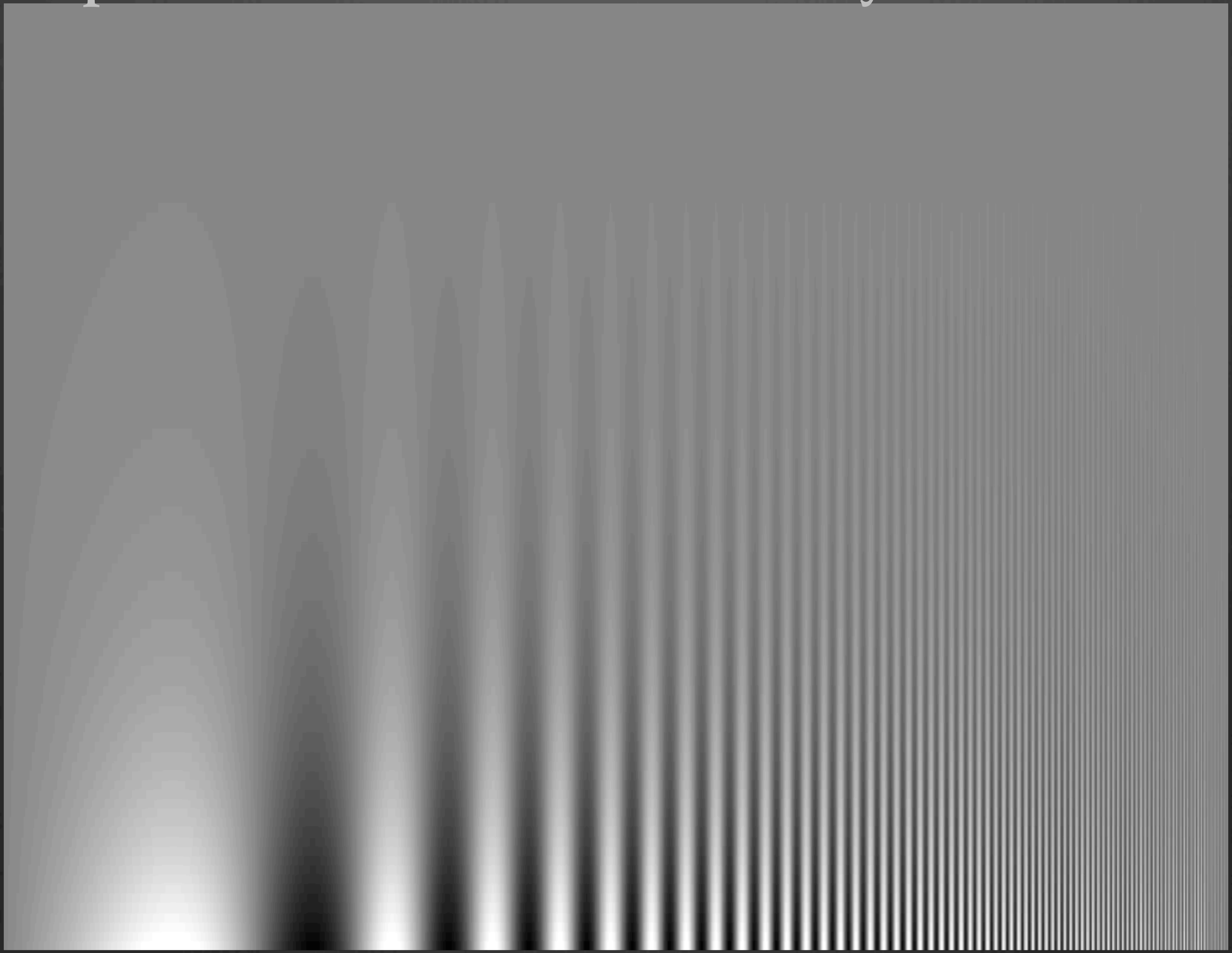
Eventually, by continuing to dim the background, you can no longer read the chart.

This is one of the visibility thresholds, the other being in a glare condition where the chart is too bright to read.

Campbell-Robson Contrast Sensitivity Function (CSF)

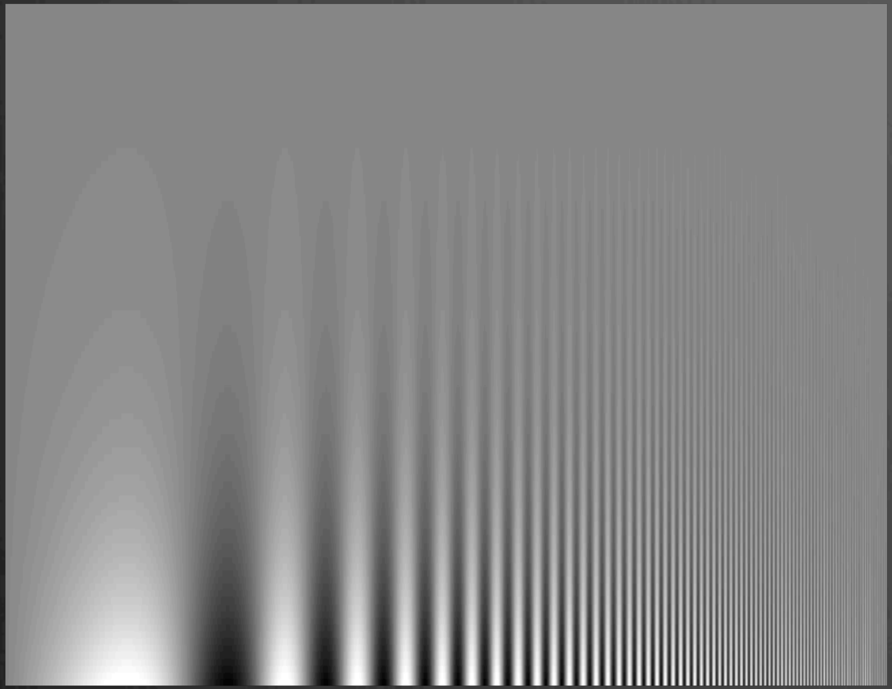


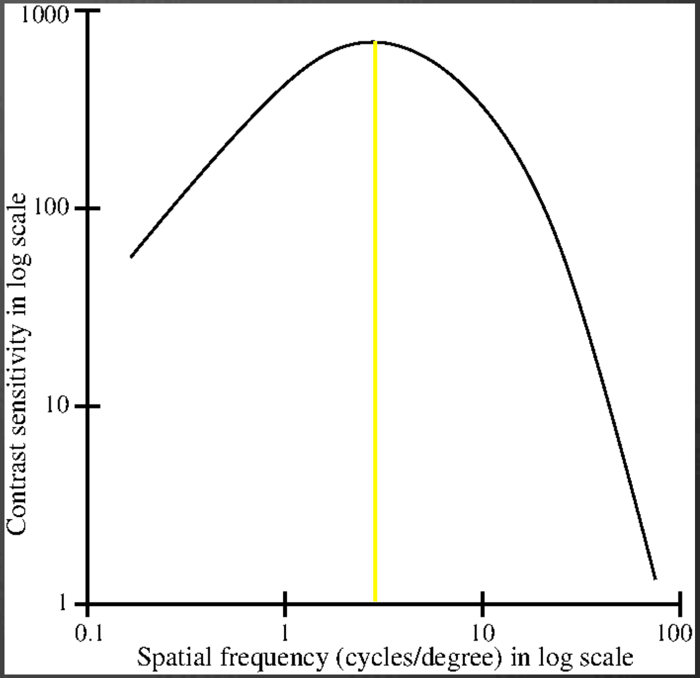
Campbell-Robson Contrast Sensitivity Function



A function of size of image features or the spatial frequency

Campbell-Robson Contrast Sensitivity Function



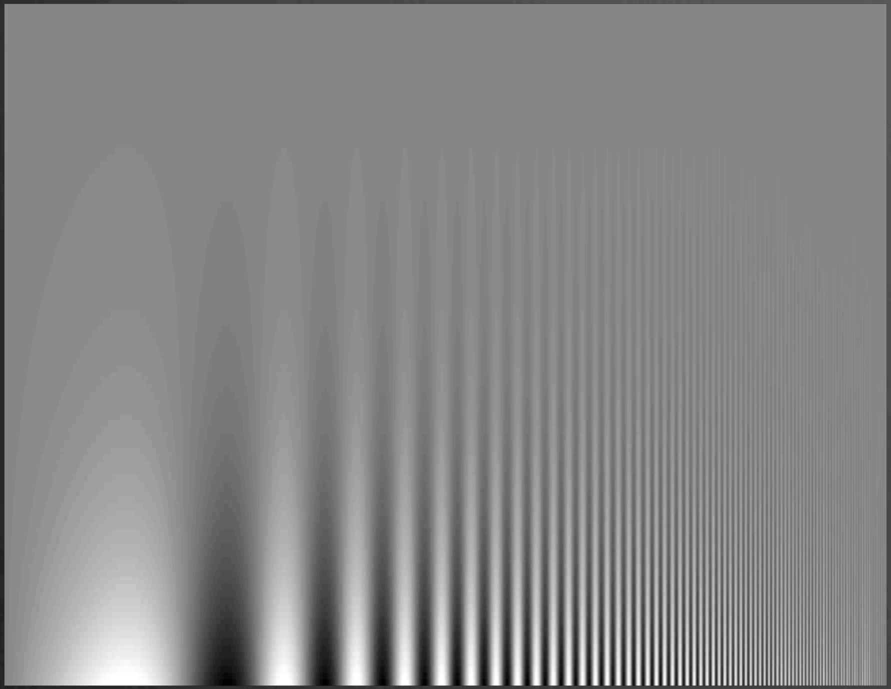


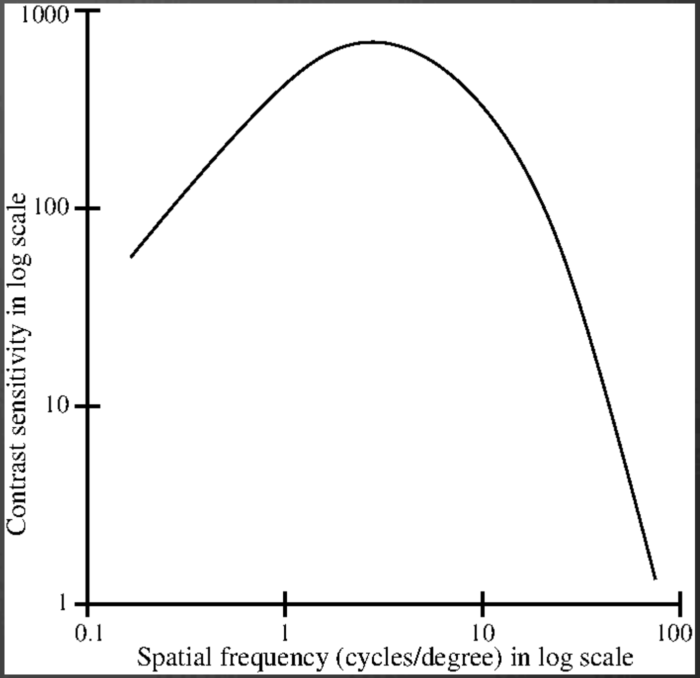
Courtesy of William Thompson

The inverted "U" shape is not in the image.. It reflects the property of your visual system .

Contrast sensitivity peaks at 2 CPD for 20/20 vision

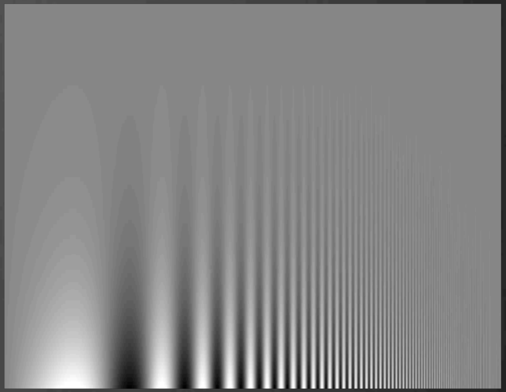
Campbell-Robson Contrast Sensitivity Function





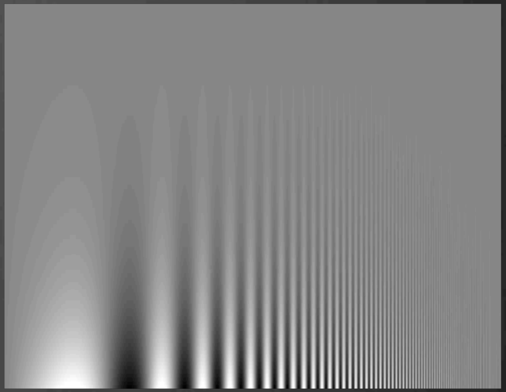
If detection of contrast is dictated solely by image contrast, the bars would appear to have equal height across the image.

Cycles per degree…



Look at the paper with stripes at arms length : 3 cycles/degree
(normal vision can detect 30 cycles/degree)

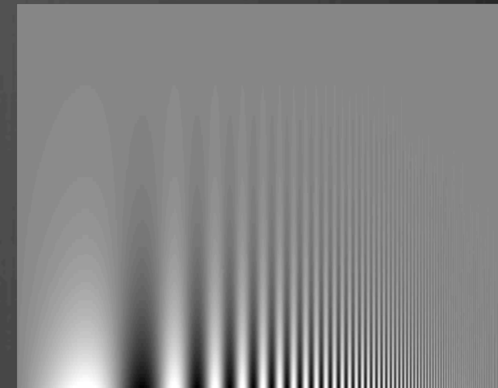
Cycles per degree…



Look at the paper with stripes at arms length : 3 cycles/degree (normal vision can detect 30 cycles/degree)

View the stripes through the diffusion medium.
The lines essentially disappear.

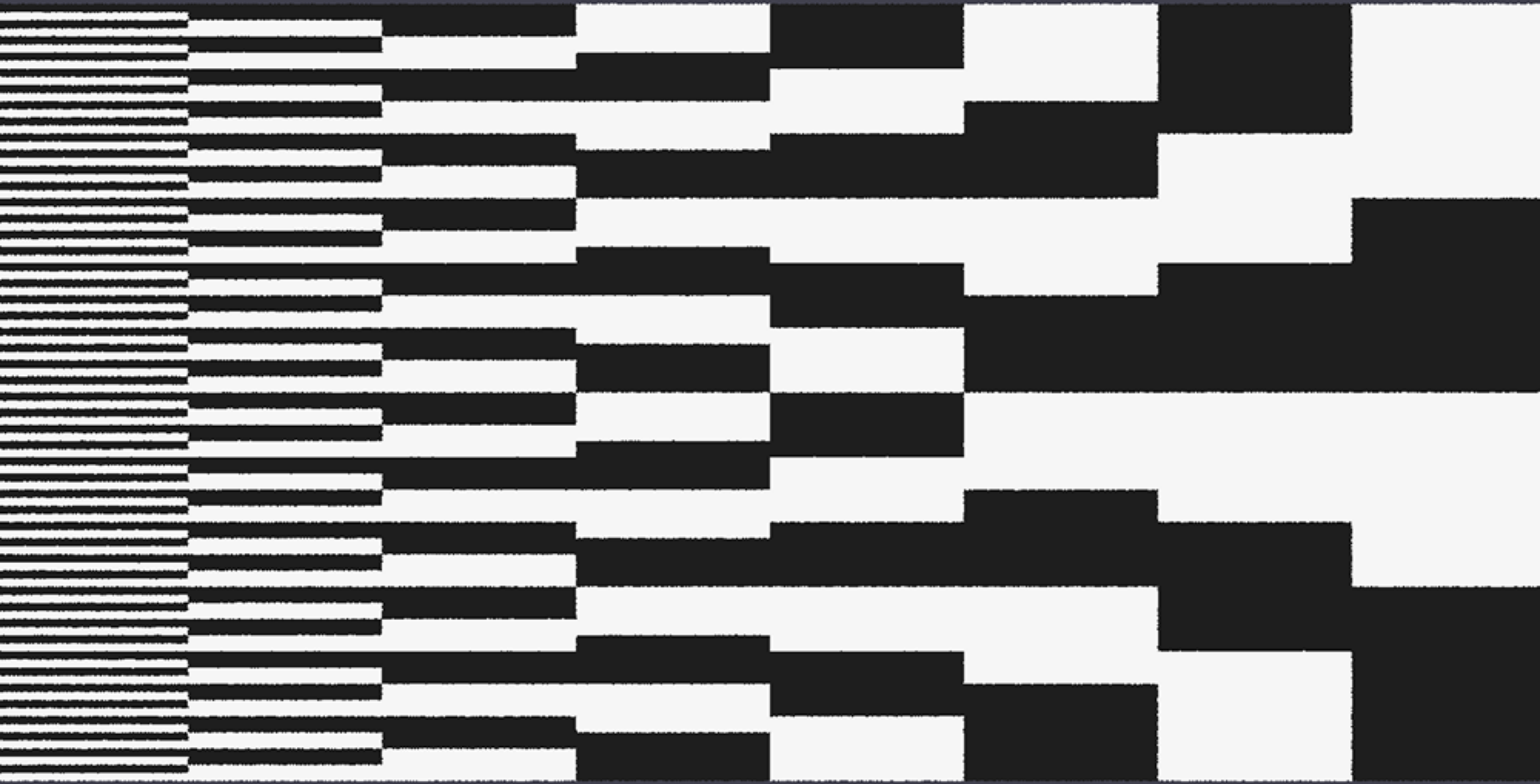
Cycles per degree…



Look at the paper with stripes at arms length : 3 cycles/degree (normal vision can detect 30 cycles/degree)

This diffusion media approximates 20/200 vision

LEGAL BLINDNESS in the USA



20/20

30 cpd

20/40

15 cpd

20/80

7.5 cpd

20/120

5 cpd

20/160

3.75 cpd

20/240

2.5 cpd

20/320

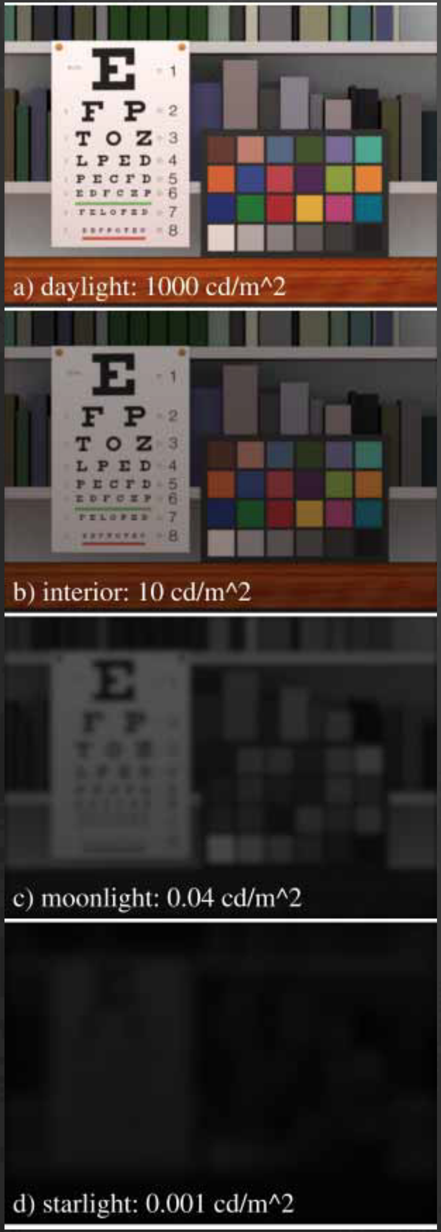
1.8 cpd

20/480

1.25 cpd

YIKES!!

Mid 1990's



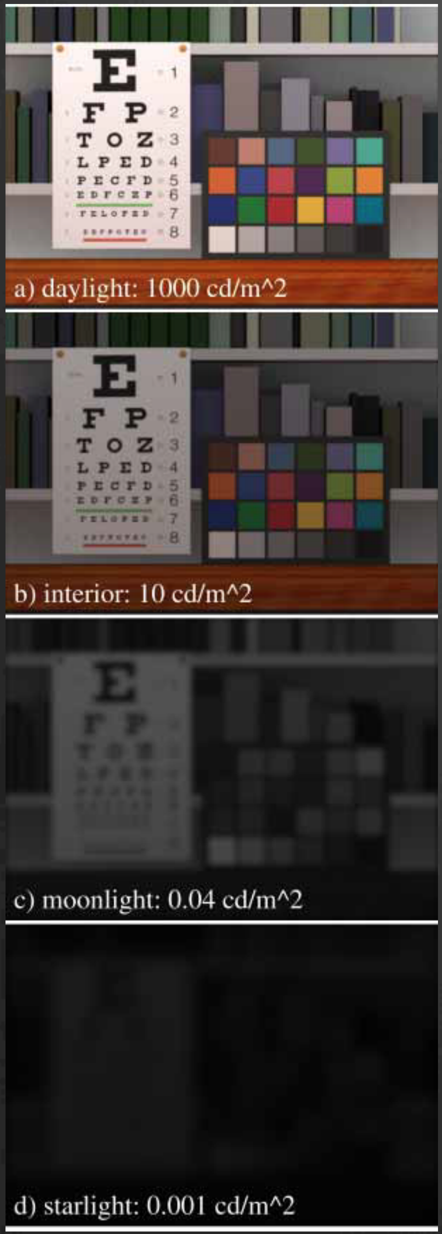
Jim Ferwerda, Pete Shirley, Greg Ward and others, developed exciting new algorithms ..

Image manipulation, tone mapping and representative artifacts, striving to indicate the adapted "appearance" of a scene.

Greg's contribution resulted in *pcond*

A Model of Visual Adaptation for Realistic Image Synthesis – Ferwerda et al. Siggraph-96

Mid 1990's

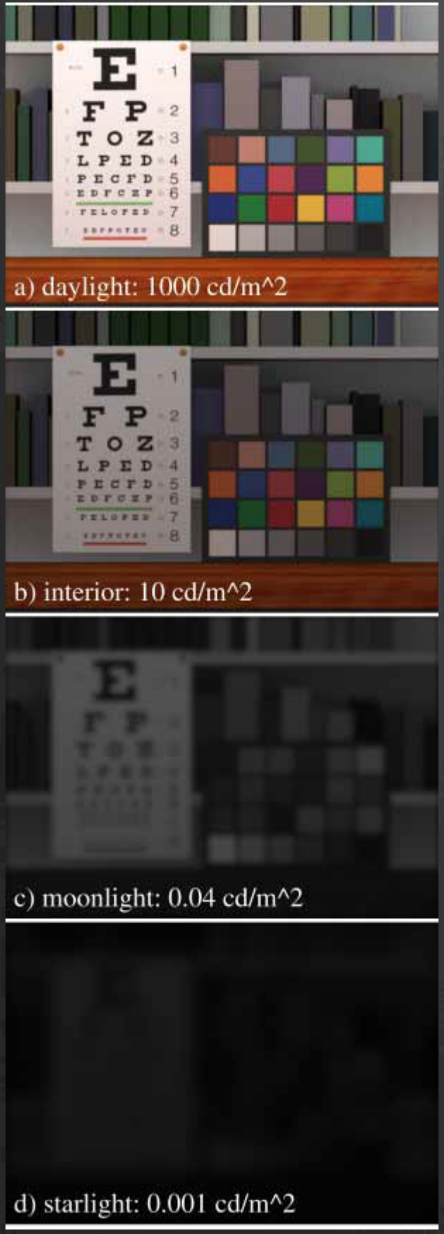


These images are not data sets of how someone would actually see the scene. They are interpretations.

Our DEVA research is not striving to produce images that "appear" to represent various visual acuities.

Our goal is to process the HDR image using proven vision functions, then analyze the simulated luminance and geometry, and determine the visibility of features and visual hazards, such as steps and ramps.

Mid 1990's



These images are not data sets of how someone would actually see the scene. They are interpretations.

Our DEVA research is not striving to produce images that "appear" to represent various visual acuities.

Our goal is to process the HDR image using proven vision functions, then analyze the simulated luminance and geometry, and determine the visibility of features and visual hazards, such as steps and ramps.

This "evaluation" of the visibility of a scene is a necessary tool to achieve Universal Visual Accessibility

This is a challenging task requiring a multidisciplinary team of scientists, engineers, design practitioners, and industry partners.

-clinical trials

-algorithm development

-user interface

.

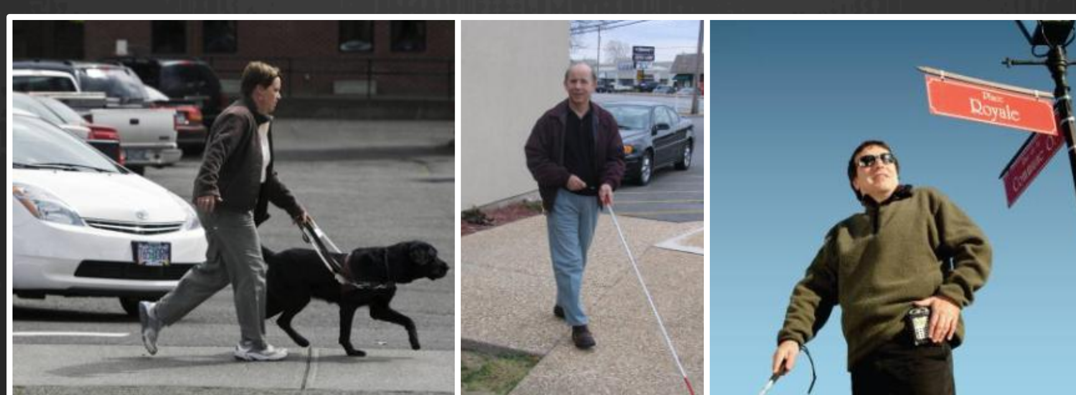
.

DEVA's tools aim to assist:

- Fully sighted acuity: 20/20
- Low vision (US definition) 20/40
- **Legal Blindness Threshold (US): 20/200**
- **Visual access for persons up to 20/600**

Low Vision persons have visual ability

BUT we do not meaningfully include their visual needs in our environments.



Back to vision and visibility

An art museum atrium: 20/400 acuity visitor (mockup)

Let’s take a walk.. (a step through)

OUCH!!!!

ARGHhhhhhh

ARGHhhhhhh

What happened.. Ohhhh no!

ARGHhhhhhh

What happened.. Ohhhh no!

call an AMBULANCE!

What happened?…

Why didn't the designers anticipate this accident and fix the problem?

What happened?…

Why didn't the designers anticipate this accident and fix the problem?

There are only recommended practices..
Illumination does not predict illuminance

There are no tools available to the design process which accurately predict visibility

Take a closer look… at 20/200

No obviously visible hazard… it's noon

View a few hours later…

Hmmm.. something is emerging

View a few hours later… at 20/20 acuity

Is this a lighting problem? NO

This view could have been avoided by..

20/20 acuity

by adding a darker stain!

Case study….

(Sorry, 10th workshop attendees)

What’s in front of you?

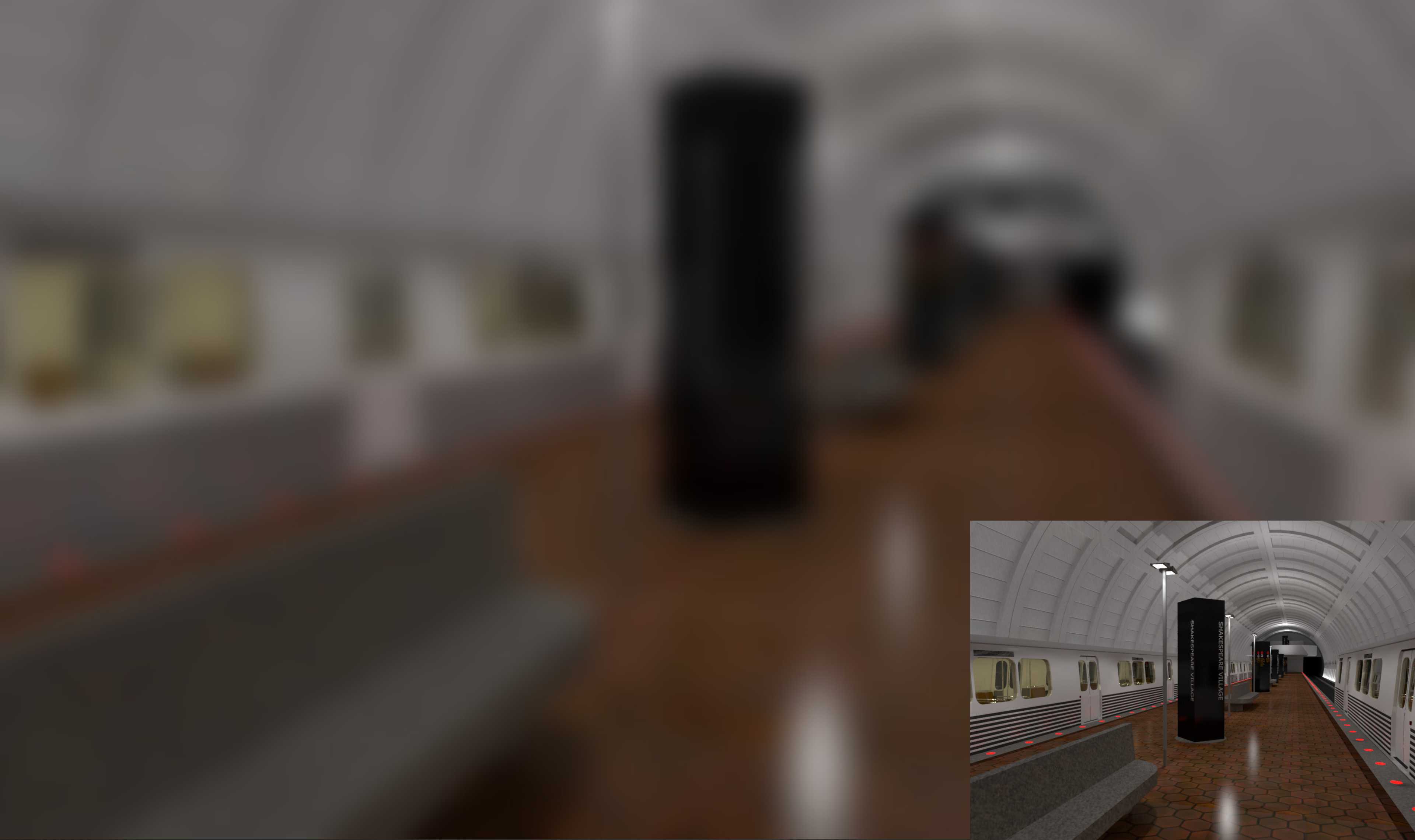

SHAKESPEARE VILLAGE
SHAKESPEARE VILLAGE


SHAKESPEARE VILLAGE
SHAKESPEARE VILLAGE

The floor region and granite bench particularly, score
very high risk at 20/600 acuity, and modest risk at 20/20 acuity.

Designer fix #1. Add area light, reduce indirect. N/C in total E

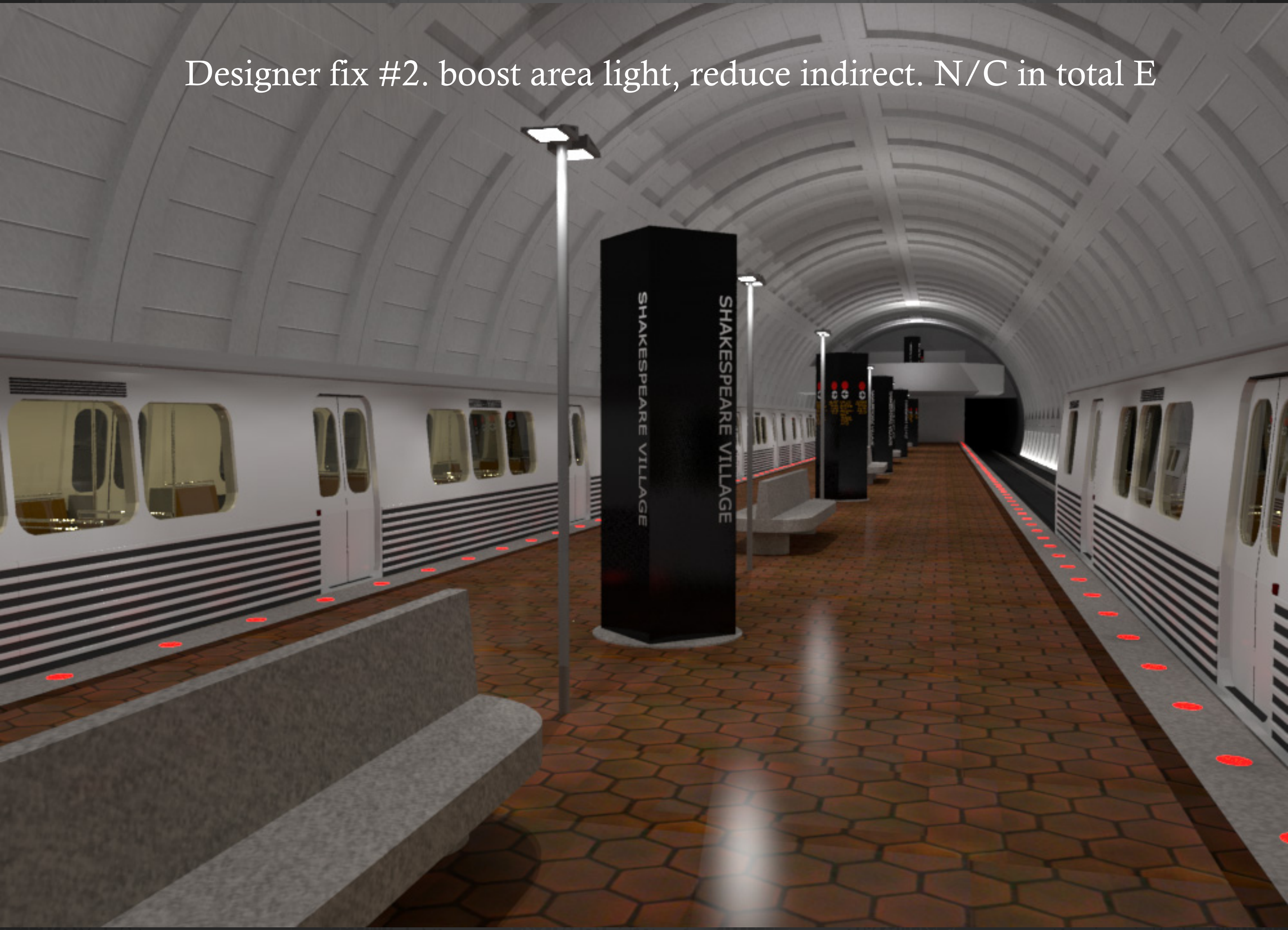
At 20/600 improved granite bench/floor contrast = modest risk.
Modest > low risk at 20/20 acuity.

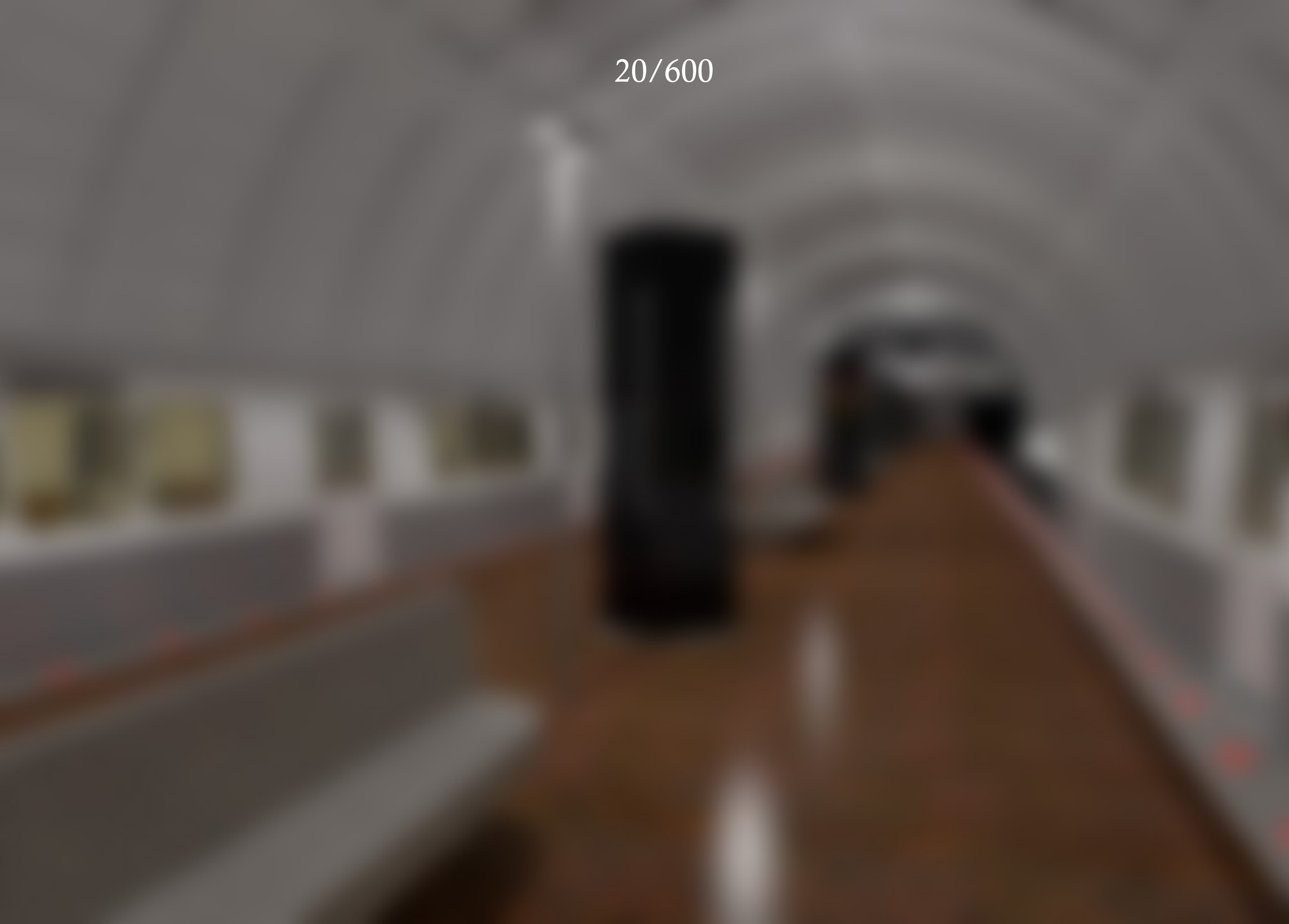


Designer fix #1. At 20/900 still high risk

Modest > Low at 20/20

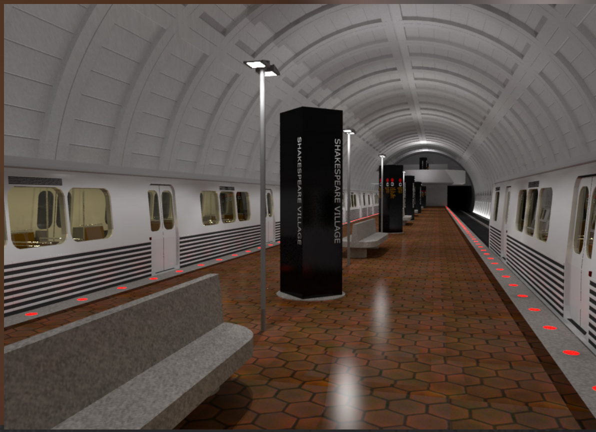
Designer fix #2. boost area light, reduce indirect. N/C in total E




20/600

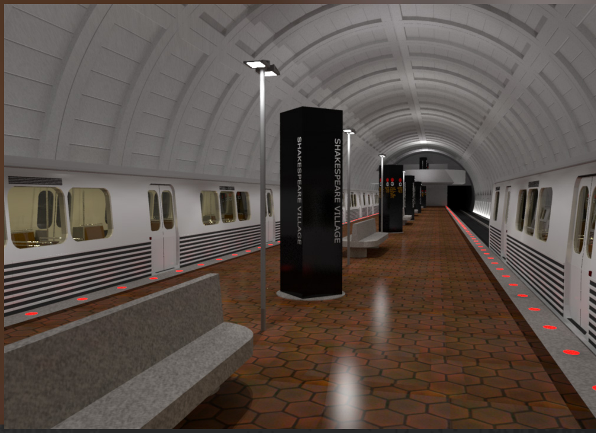
Designer fix #2. Modest > Low risk at 20/600

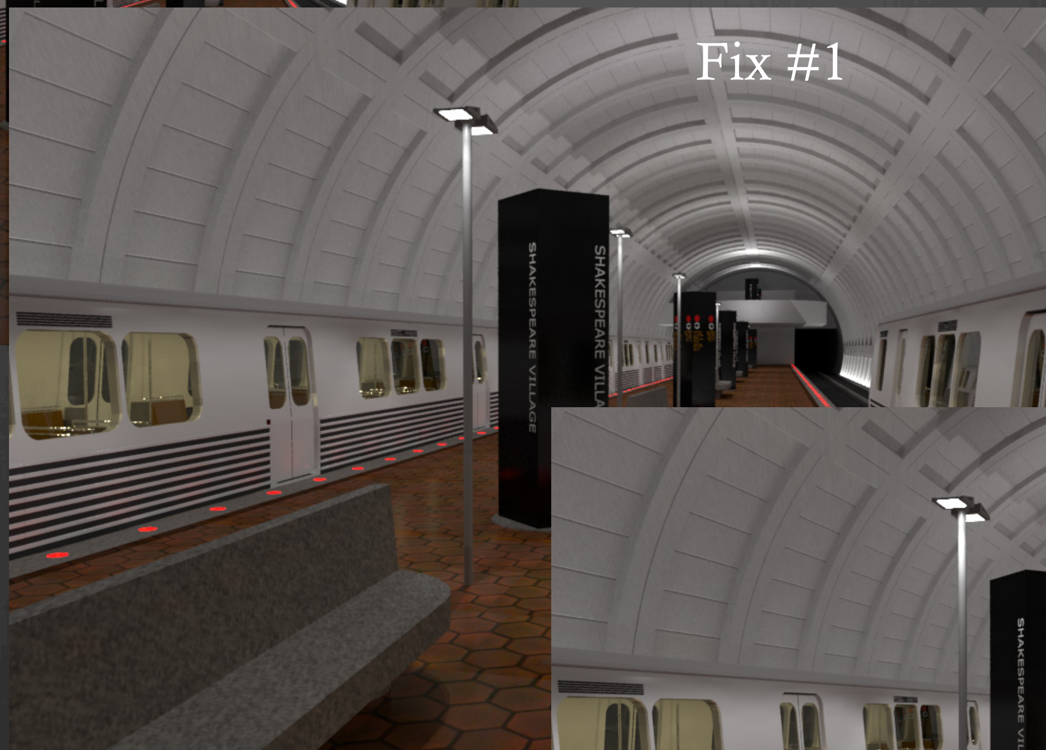
Low risk at 20/20

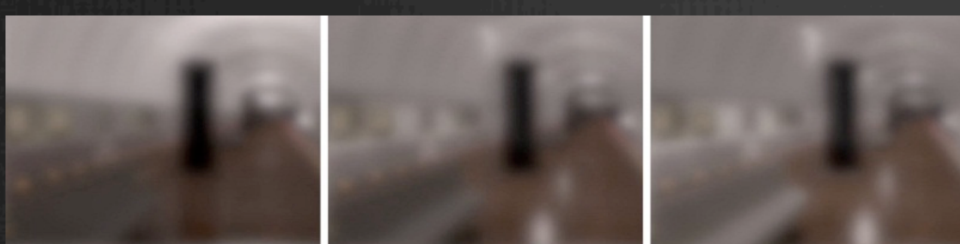


Designer fix #2. Modest risk at 20/900

Low risk at 20/20







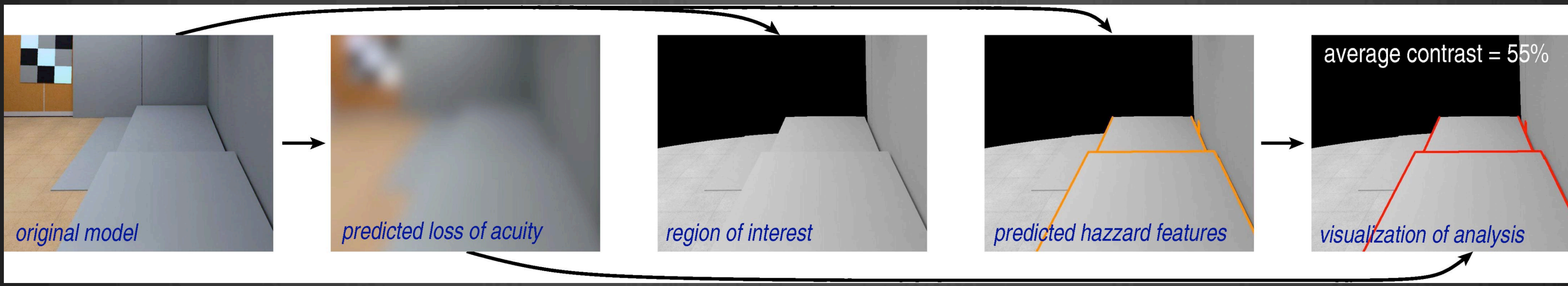
DEVA acuity filter images

Research and progressive refinement of pipeline

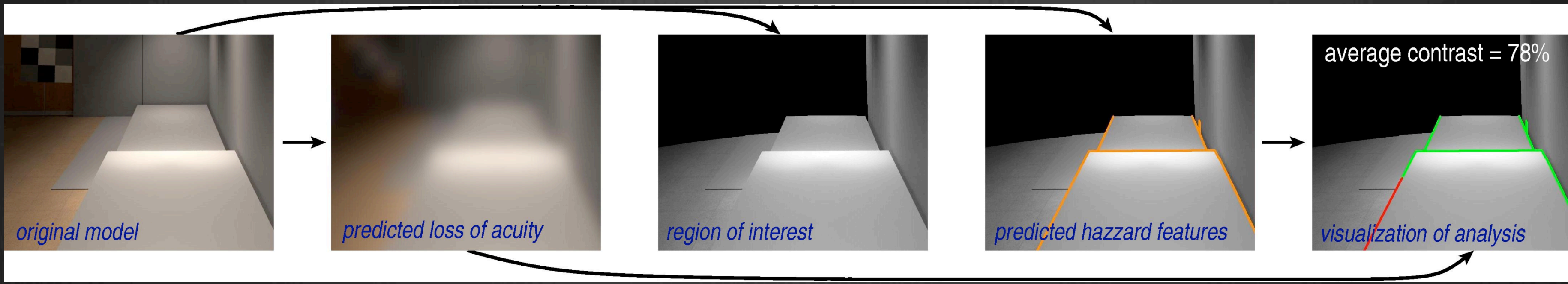
- HUMAN STUDIES
- Start with simulated low vision – subject views test scene through blur foils
- Extend to actual low vision – direct viewing of test scenes
- In certain circumstances both view Radiance scene images on ~calibrated display
- Update/calibrate pipeline based on study results

"blur" goggle

DEVA acuity pipeline – version 2012

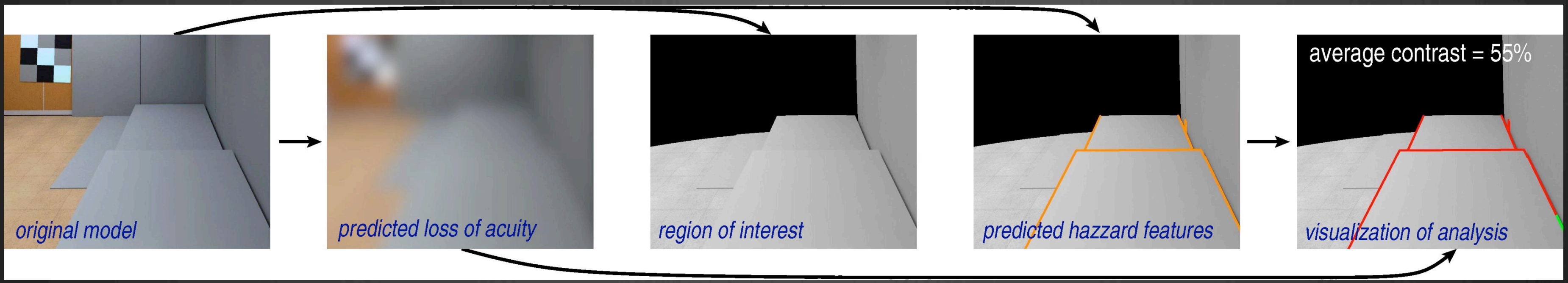


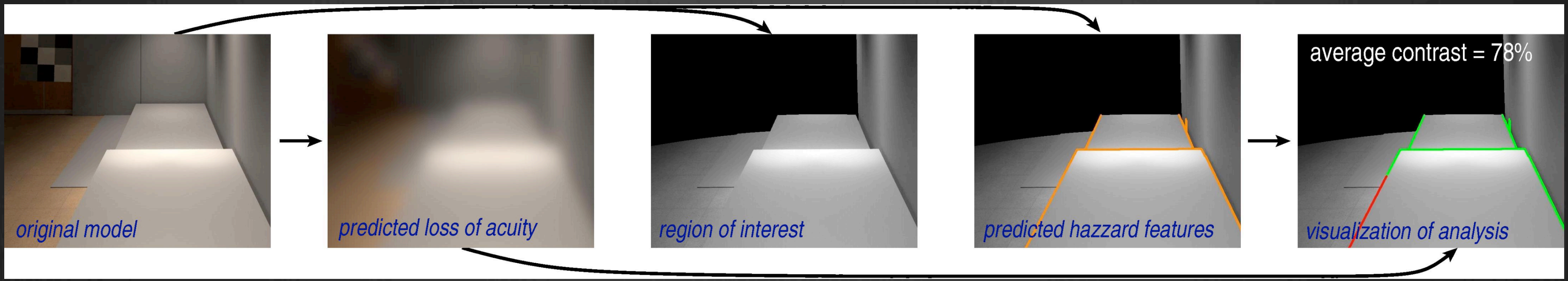
Not Visible



Visible

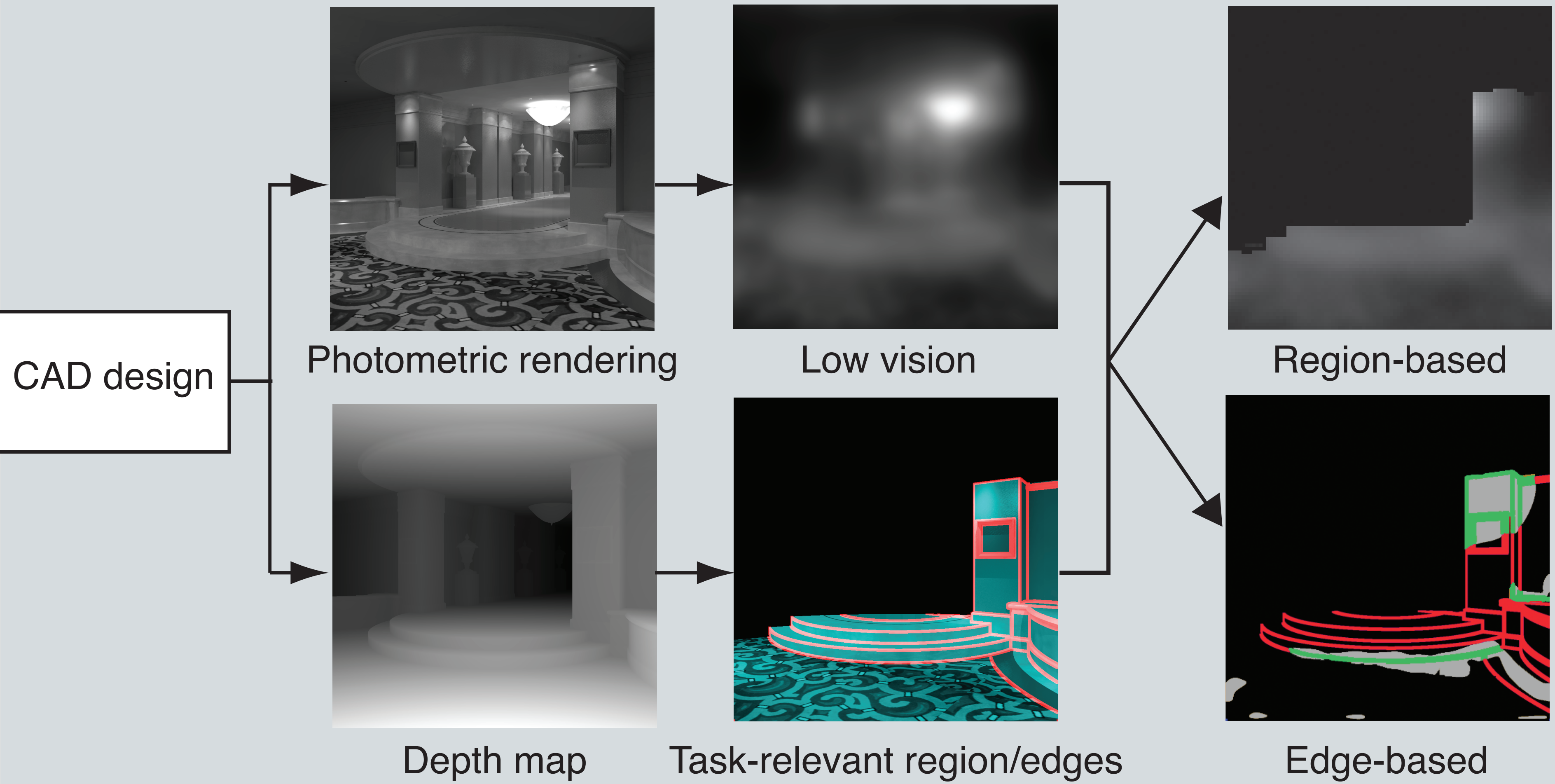
DEVA acuity pipeline – version 2012

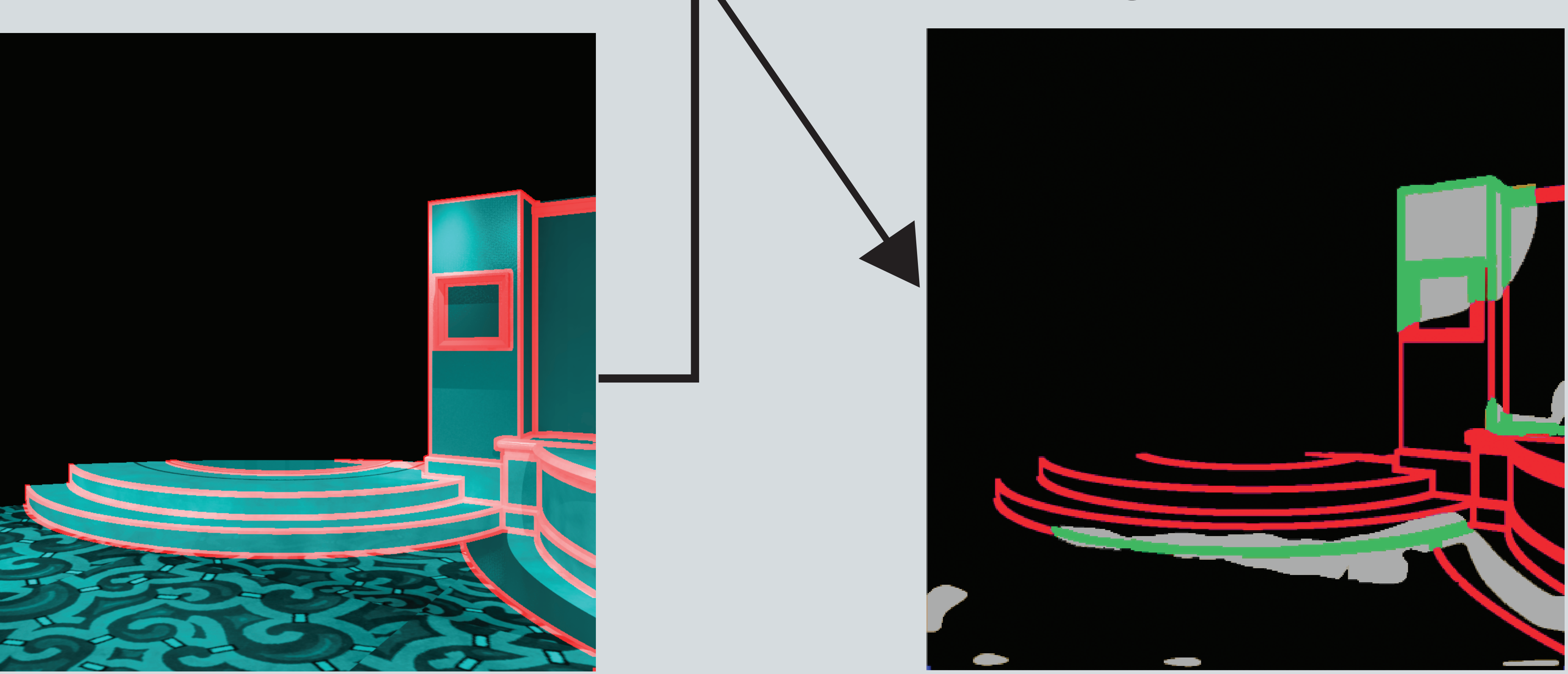




NOTE: Our filtered images are for computational analysis.
NO artifacts have been added to "mimic" appearance
Significantly differs from the work in the 1990's

DEVA acuity pipeline details





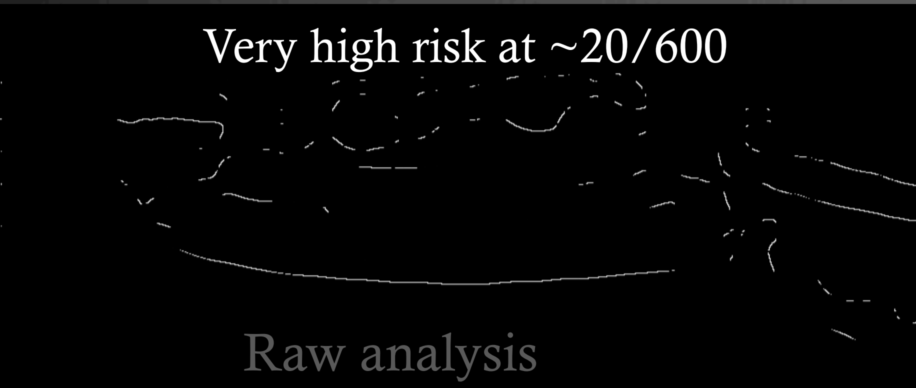
-relevant region/edges

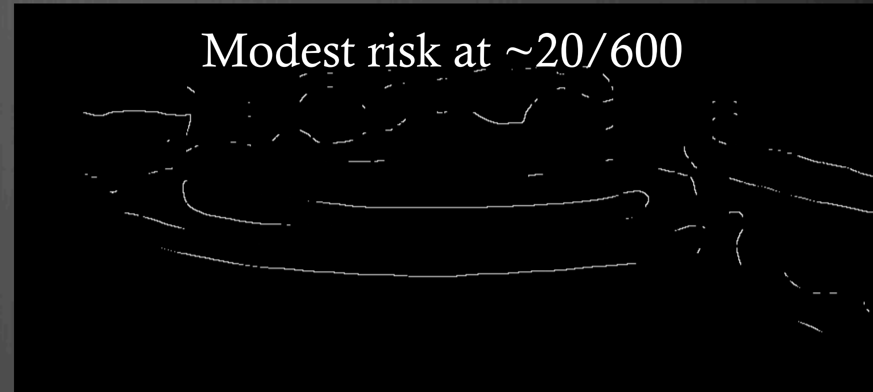
Edge-based

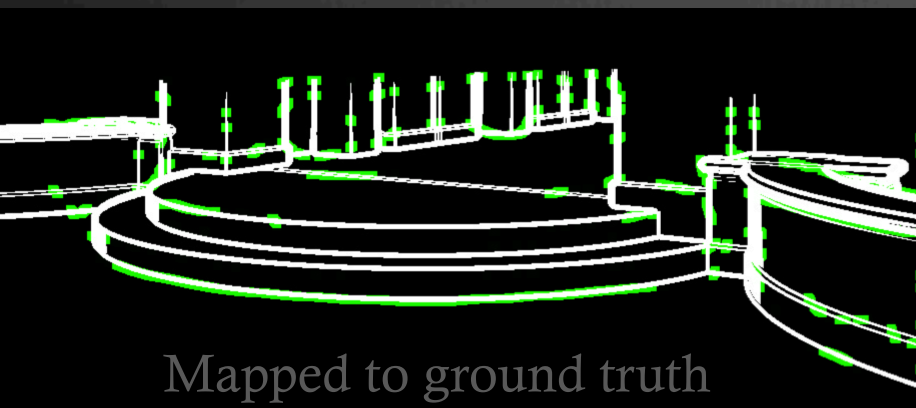
RED = geometric change
GREEN= Luminance pattern

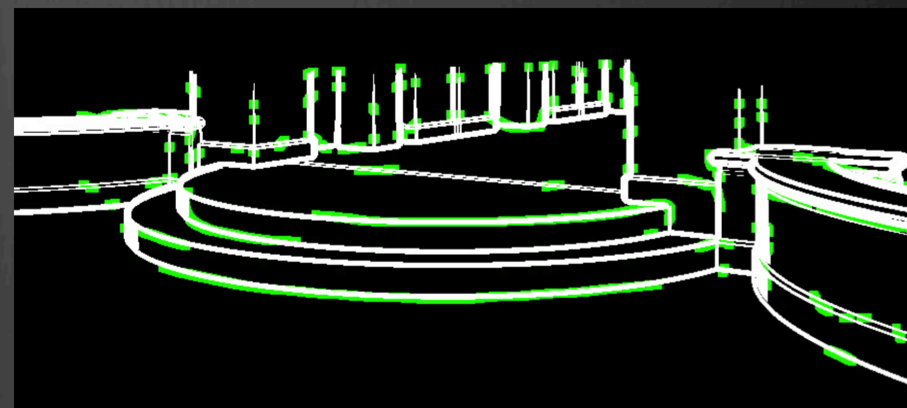
RED = misses. Not visible geometric change
GREEN= True positive where contrast predicts geometric change. Visible.
GREY = False positive. Contrast predicts a geometric change where there is not one.

Edge detection… earlier iteration







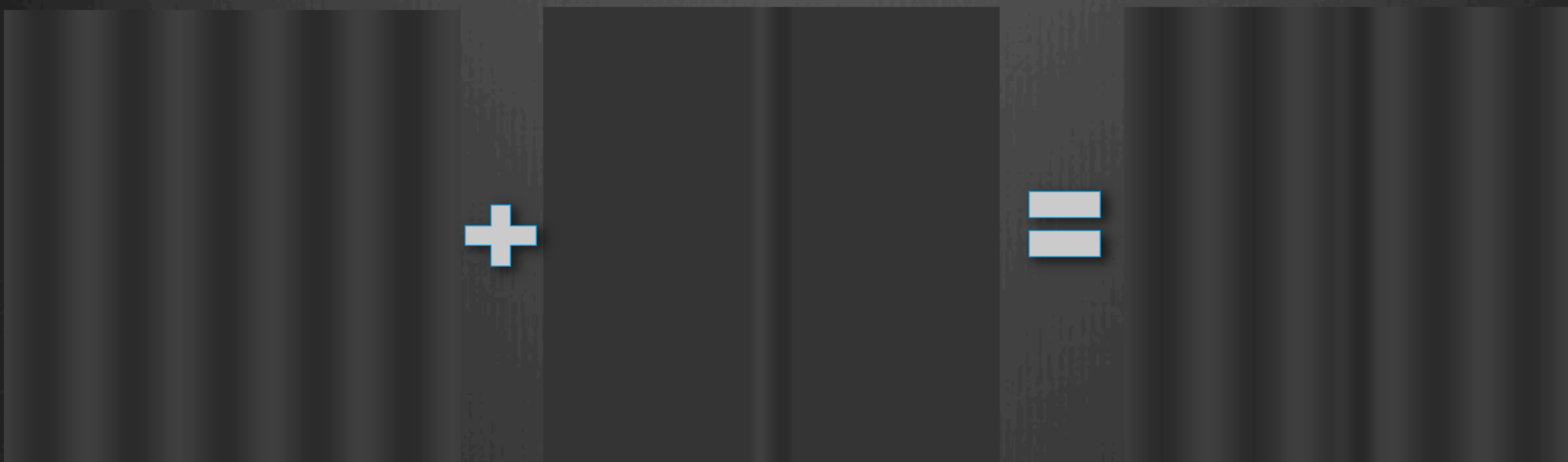


Edge pixel count: 2056

Edge pixel count: 2471

Edge pixel : Maximum change in Low Vision Response Function

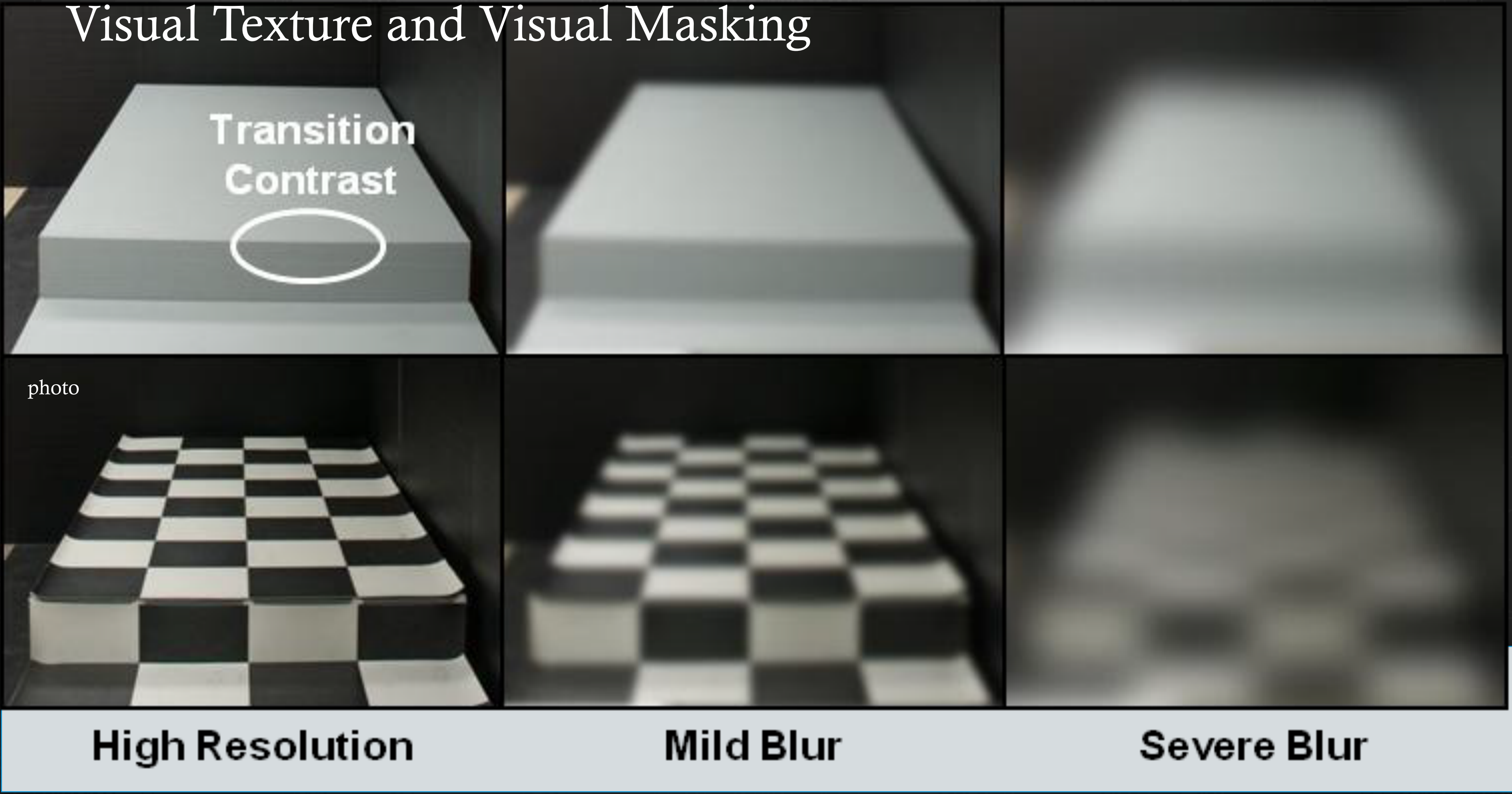
Visual Texture and Visual Masking



Visual Texture and Visual Masking

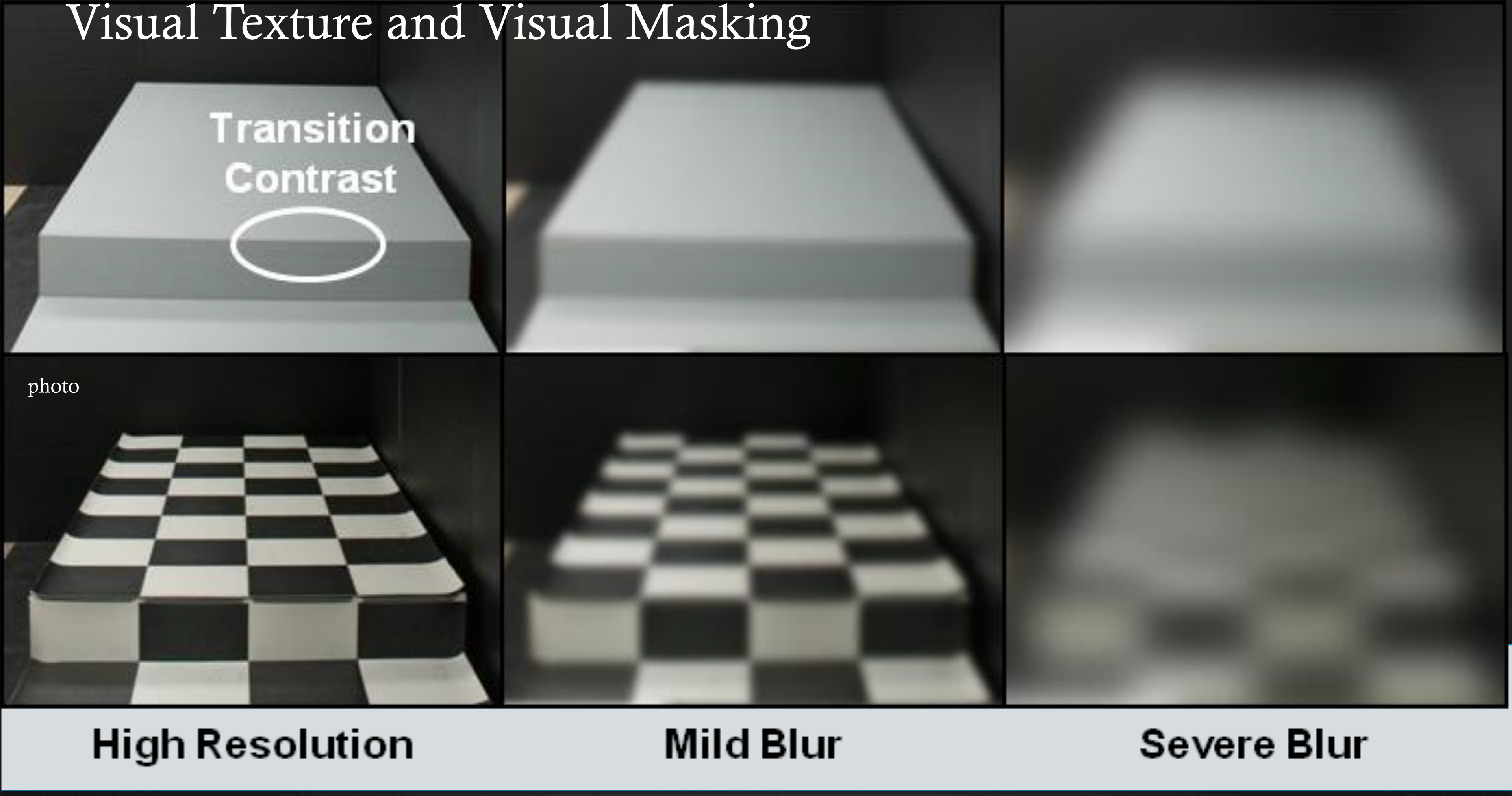
Impact of Texture and Locomotion – Bochsler et al 2012

Visual Texture and Visual Masking



Static viewing of texture masked the hazard: Motion increased detection

Visual Texture and Visual Masking

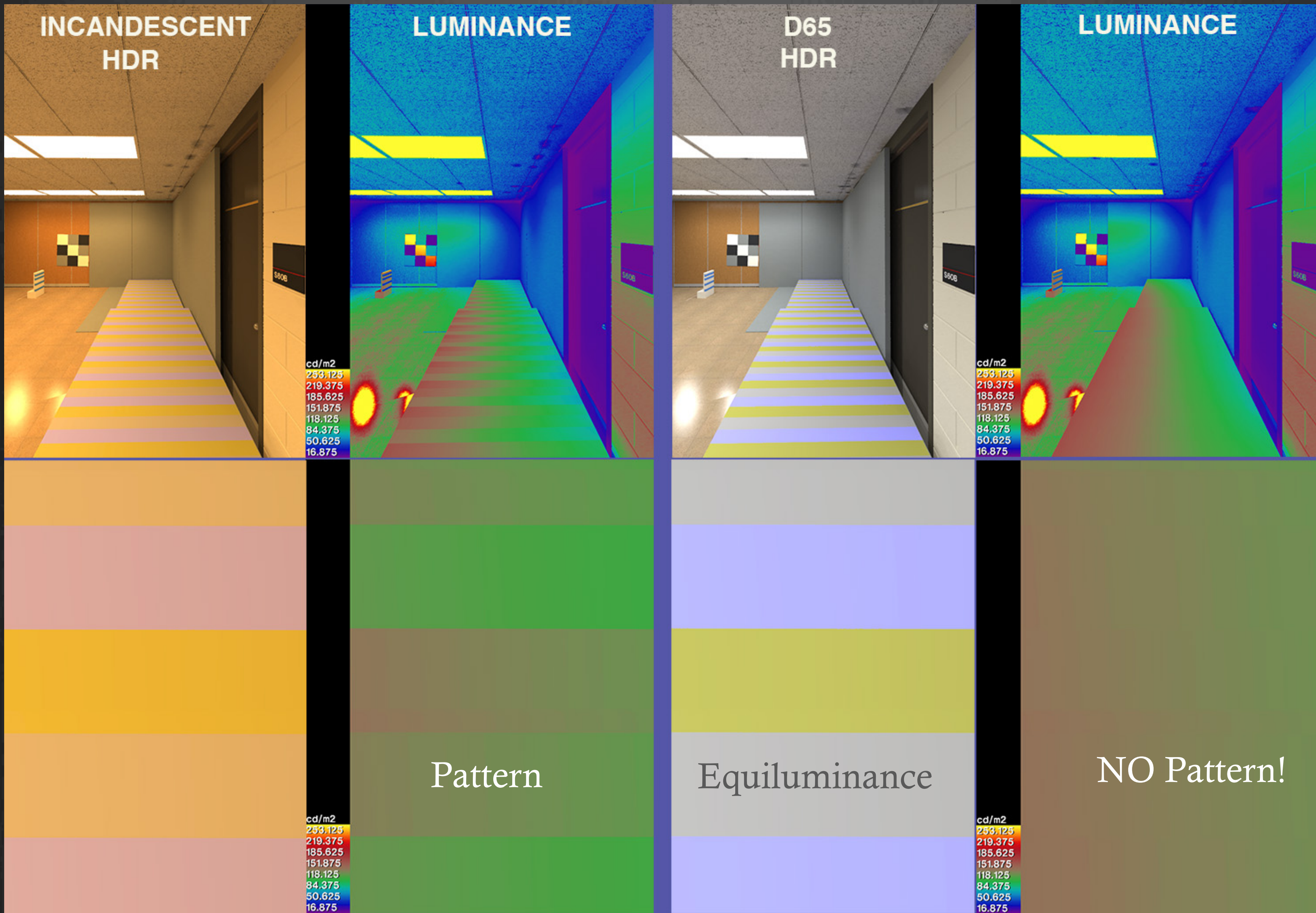


Static viewing of texture masked the hazard: Motion increased detection

Future work: Explore visibility using stereo images and off-axis images

Luminance and Patterns

Same materials and colors



Equiluminance Patterns

Equal luminance pattern

At 20/300, pattern uniform at transition. Advantage or not?

Equiluminance Patterns

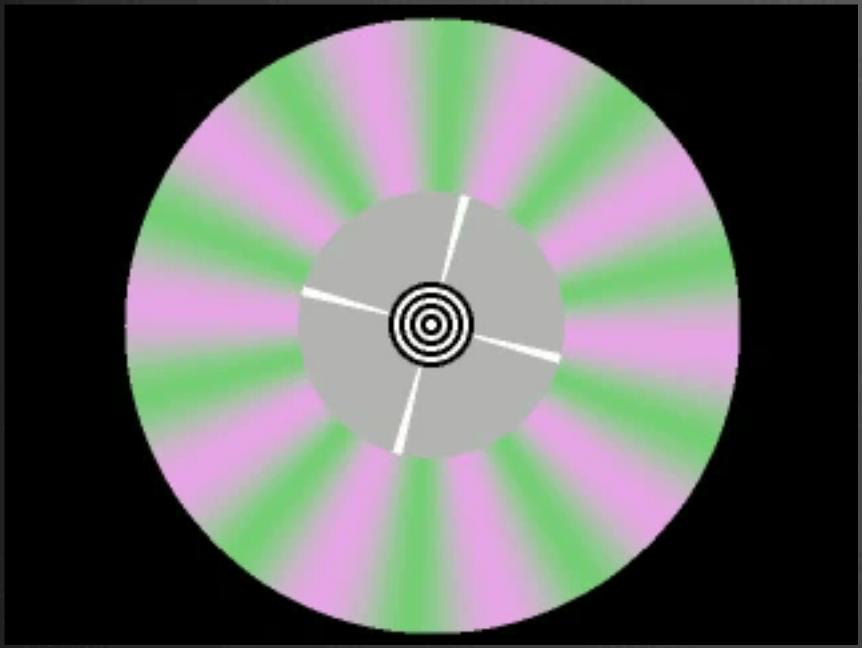
DEVA tools based on luminance.
Luminance is independent of color.

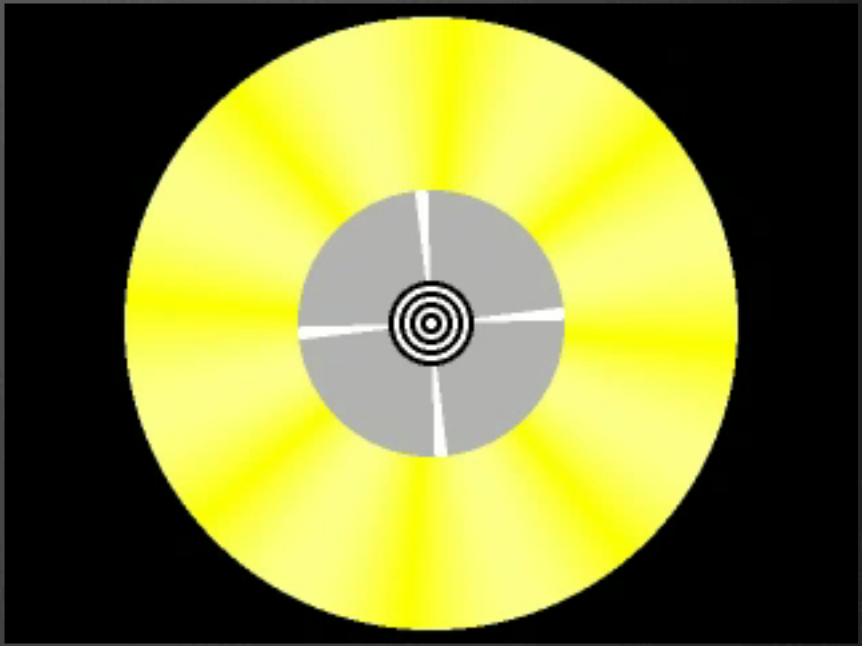
No human data to analyze same luminance color patterns.

Color may not be relevant > 20/600

Future work: explore color contrast masking/enhancing effects

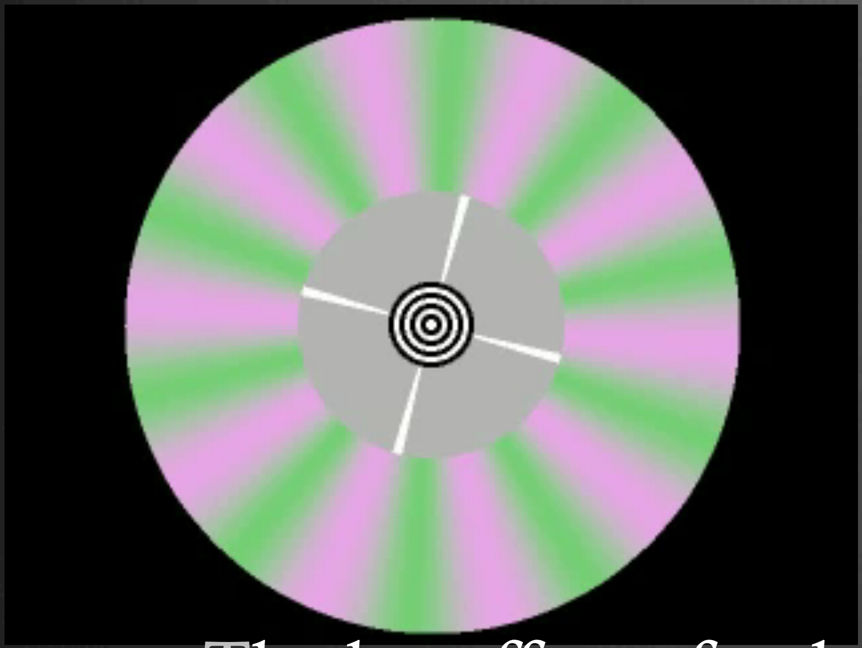
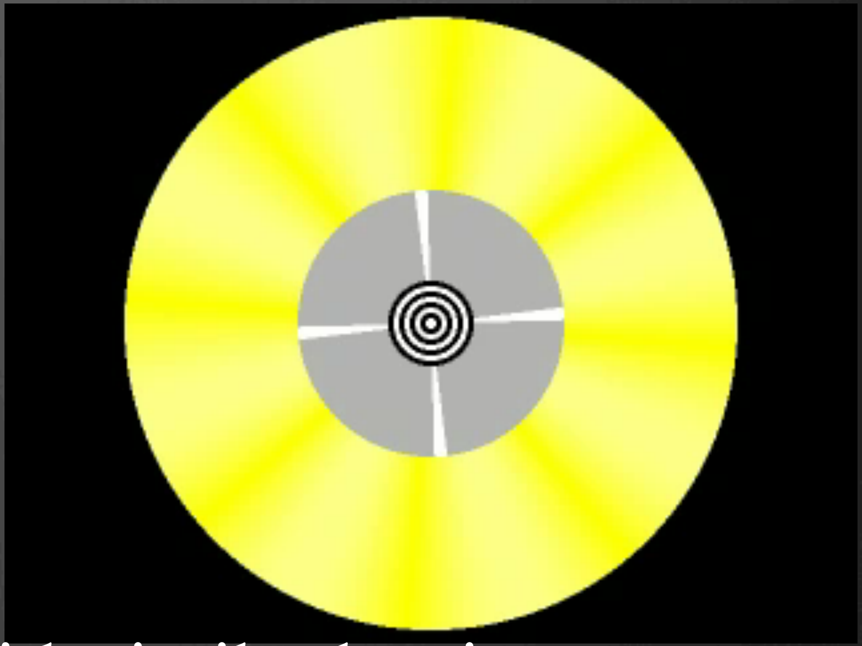
At 20/300, pattern uniform at transition. Advantage or not?





(Harvard Vision Lab)

Fixate on the center of the wheel

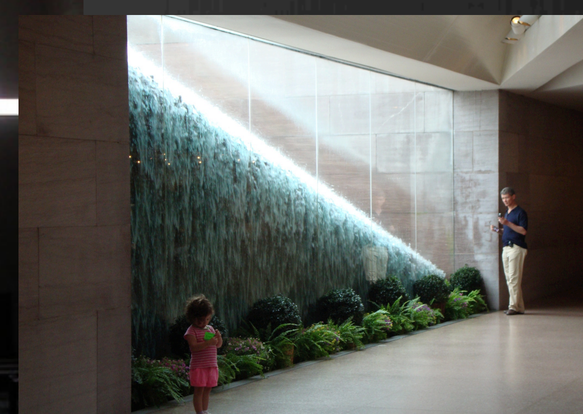
 

The lag effect of colors with similar luminance may cause momentary disorientation.

Imagine transitioning onto a mosaic floor which appears to move more slowly than your stride.

Might be worthy of a study

The Daylighting Community has a lot of expertise in GLARE



The effects of glare on normal vision are understood

The effects of glare on normal vision are understood

Detailed effects of glare on low vision are unknown

Small glare points, disruptive to normal vision may have only minimal effect on low vision

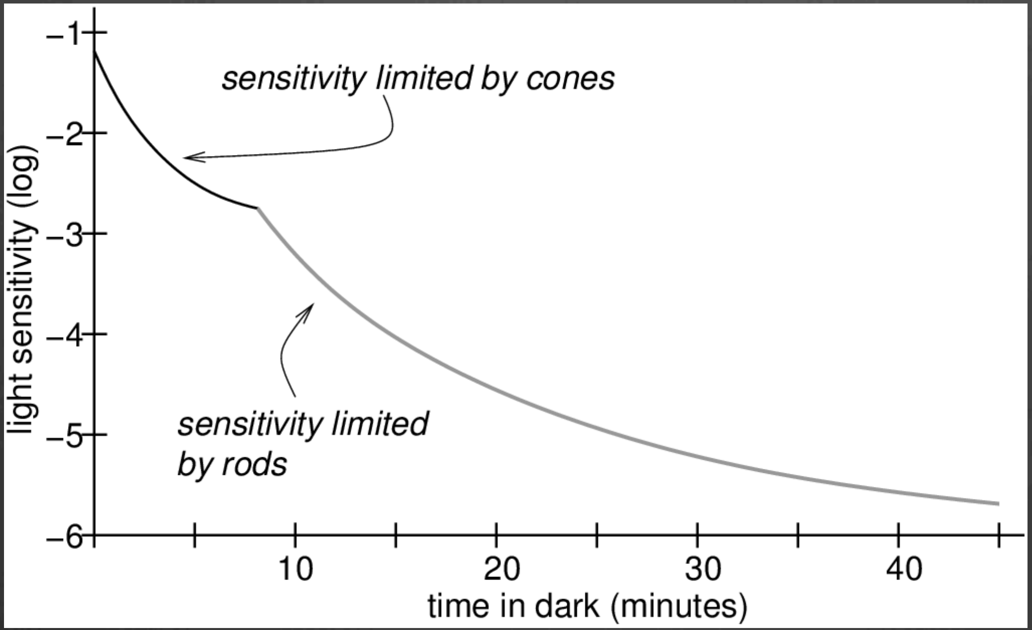
The effects of glare on normal vision are understood

Detailed effects of glare on low vision are unknown

Large luminous areas acceptable to normal vision may impede low vision

FUTURE WORK: Low Vision Glare Studies

FUTURE WORK: Adaptation variables



Predicting the adaptation state, upon entering a new space, will assist in accurately predicting visibility.

Universal Access and Visibility Analysis Requires:

vision models ranging from 20/20 – 20/600
architectural models with materials
lighting simulation (RADIANCE)
computational tools
designer intuitive graphical interfaces
optimized data analysis
building code standards

Integrated into a tool accepted and inserted into the architectural design profession's process.

Universal Access and Visibility Analysis Requires:

vision models ranging from 20/20 – 20/600
architectural models with materials
lighting simulation (RADIANCE)
computational tools
designer intuitive graphical interfaces
optimized data analysis
building code standards

Integrated into a tool accepted and inserted into the architectural design profession's process.

THE WORK CONTINUES

Designing Visually Accesible Spaces

In press

Bochsler, T.M., Legg, G.E., Kallie, C.S. & Gage, R. (in press). Seeing steps and ramps with simulated low acuity: Impact of texture and locomotion. Optometry & Vision Science.

Rand, K., Tarampi, M.R., Creem-Regehr, S.H, & Thompson, W.B. (in press). The influence of ground contact and visible horizon on perception of distance and size under severely degraded vision. *Seeing and Perceiving*. [PubMed abstract]

2012

Bochsler, T.M., Legge, G.E., Gage, R., & Kallie, C.S. (2012). Does locomotion enhance the visibility of steps and ramps for people with low vision? Poster Presented at the 2012 annual meeting of The Association for Research in Vision and Opthalmology. Fort Lauderdale, FL.

Rand, K., Bakdash, J., Stefanucci, J. , Creem-Regehr, S., & Gustafson, W. (2012). Perceptual dependence of size and distance? A within subjects variability approach. Poster presented at the Vision Sciences Society annual conference, Naples FL.

2011

Beckmann, P., Legge, G., Kallie, C., & Thompson, W. (2011). Validation of Image Filters for Studies of Visual Accessibility. Poster presented at the Fall Vision Meeting of the Optical Society of America, Seattle, WA.

Benson, C., & Kersten, D. (2011). Reward attribution and choice behavior after losing visual information due to blur. Poster presented at the 11th Annual Meeting of the Vision Sciences Society, Naples, FL.

Bochsler, T.M., Kallie, C.s., Legge, G.E., Gage, R., & Chen, M. (2011). Does Locomotion Enhance the Visual Accessibility of Ramps and Steps? Poster presented at the 11th Annual Meeting of the Vision Sciences Society, Naples, FL.

Lessard, D. A., Tarampi, M., Geuss, M. N., Creem-Regehr, S. H., Stefanucci, J. K., & Thompson, W. B. (2011). Overestimating action capabilities for passing through vertical and horizontal gaps under severely degraded vision. Poster presented at the 11th Annual Meeting of the Vision Sciences Society, Naples, FL. [abstract]

Rand, K., Tarampi, M.R., Creem-Regehr, S.H, & Thompson, W.B. (2011). The Importance of a visual horizon for distance judgments under severely degraded vision. *Perception*, 40(2) 143-154. [PubMed]

Rand, K. M., Tarampi, M. R., Thompson, W. B., & Creem-Regehr, S. H. (2011). The influence of object-ground contact on perception of distance and size under severely degraded vision. Poster presented at the 11th Annual Meeting of the Vision Sciences Society, Naples, FL. [abstract]

Shakespeare, R.A. (2011). DEVA-Automated Visual Hazard Detection. Presented at the 10th Annual International Radiance Workshop, Lawrence Berkeley National Labs, U.C. Berkeley.

Tarampi, M., Creem-Regehr, S. H., Bakdash, J., & Thompson, W. B. (2011). Translational spatial updating of multiple targets under normal and severely degraded vision. Poster presented at the 52nd Annual Meeting of the Psychonomic Society, Seattle, WA.

2010

Bochsler, T.M., Kallie, C.S., Legge, G.E., & Gage, R. (2010). Does Visual Texture Enhance The Recognition Of Ramps And Steps? Poster presented at the 10th Annual Meeting of the Vision Sciences Society, Naples, FL. [abstract]

Kalia, A.A., Legge, G.E., & Kallie, C.S. (2010). Effective Acuity for Low-Pass Filtering of Real World Images. Poster presented at the 10th Annual Meeting of the Vision Sciences Society, Naples, FL. [abstract]

Kalia, A.A., Legge, G.E., Roy, R. & Ogale, A. (2010). Assessment of Indoor Route-finding Technology for Visually-Impaired People. *Journal of Visual Impairment & Blindness*, 24(4), 1-15. [PubMed]

Legge, G.E., Yu, D., Kallie, C.S., Bochsler, T.M., & Gage, R. (2010). Analyzing the Cues for Recognizing Ramps and Steps. Talk presented at the 10th Annual Meeting of the Vision Sciences Society, Naples, FL. [abstract]

Legge, G.E., Yu, D., Kallie, C.S., Bochsler, T.M., & Gage, R. (2010). Visual Accessibility of Ramps and Steps, *Journal of Vision* 10(11):8, 1-19. [PubMed]

Shakespeare, R.A. (2010). Designing Visually Accessible Spaces (2010). Presented at the 9th Annual International Radiance Workshop, Fraunhofer Institute, Freiburg Germany.

Shakespeare, R.A., Tarampi, M.R., & Creem-Regehr, S.H. (2010). Designing Visually Accessible Spaces. Presented at the American Institute of Architects National Conference, Miami, FL.

Shakespeare, R.A., Tarampi, M.R., & Thompson, W.B. (2010). Designing Visually Accessible Spaces. Lightfair International Conference, Las Vegas, NV.

Tarampi, M.R., Creem-Regehr, S.H., & Thompson, W.B. (2010). Intact Spatial Updating with Severely Degraded Vision. *Attention, Perception, & Psychophysics*, 72(1), 23-27.

Thompson, W.B., Rand, K., Tarampi, M., & Creem-Regehr, S.H. (2010). The importance of a visual horizon for diatance judgments under severely degraded vision. Presented at the European Conference on Visual Perception. [abstract]

2009

Kalia A. (2009) Navigating Through Buildings with Impaired Vision: Challenges and Solutions.
Ph.D. Thesis, University Of Minnesota.

Yu, D., Gage, R., Kallie, C.S., & Legge, G.E. (2009). Visual Accessibility of Ramps and Steps. Poster presented at the 2009 Annual Meeting of the Association for Research in Vision and Ophthalmology, Ft. Lauderdale, Florida.

2008

Hegdé, J., Bart E. & Kersten, D. (2008). Fragment-based learning of visual object categories. *Current Biology*, *18*, 597-601. [PubMed]
Kalia, A.A., Legge, G.E. & Giudice, N.A. (2008). Learning building layouts with non-geometric visual information: The effects of visual impairment and age. *Perception*, 37, 1677-1699. [PubMed]
Kallie, C.S., Legge, G.E., Cheong, A.M.Y., & Park, H. (2008). Curved Objects May Enhance Visual Accessibility. Poster presented at the 2008 Annual Meeting of the

Kalia, A.A., Legge, G.E. & Giudice, N.A. (2008). Learning building layouts with non-geometric visual information: The effects of visual impairment and age. *Perception*, 37, 1677-1699. [PubMed]

Kallie, C.S., Legge, G.E., Cheong, A.M.Y., & Park, H. (2008). Curved Objects May Enhance Visual Accessibility. Poster presented at the 2008 Annual Meeting of the Association for Research in Vision and Ophthalmology, Ft. Lauderdale, Florida.