Designing Visually Accessible Spaces (DeVAS): Visibility prediction tools and introducing the Hazard Visibility Score

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Principal Research Team:
Dr. Gordon Legge, Psychology, Low Vision Lab, University of Minnesota
Dr. Dan Kersten, Psychology, Computational Vision, University of Minnesota
Dr. Bill Thompson, Computer Science, University of Utah,
Dr. Sarah Creem-Regehr, Psychology, Cognition and Neural Science, University of Utah

Rob Shakespeare, Lighting Designer, Indiana University. Shakespe@IU.edu

... tools for use in the architect’s design workflow

Daylight Symposium
VELUX Days in Paris, October 9, 2019
Why is Visibility Prediction Important?

Fully sighted acuity 20/20 6/6
Low Vision USA 20/40 6/12
Low vision (WHO) 20/60 6/18
Legal blindness threshold (US) 20/200 6/60
Blindness threshold (WHO) 20/400 6/120

<table>
<thead>
<tr>
<th>Population</th>
<th>Europe (Geographic)</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low vision</td>
<td>~26 mil</td>
<td>~164 mil</td>
</tr>
<tr>
<td>Completely blind</td>
<td>~3.2 mil</td>
<td>~55 mil</td>
</tr>
</tbody>
</table>
Why is Visibility Prediction Important?

<table>
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<tr>
<th>Condition</th>
<th>Acuity</th>
<th>WHO</th>
<th>US</th>
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<tr>
<td>Fully sighted acuity</td>
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<td>6/6</td>
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<td>20/400</td>
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Europe (Geographic)                   World

Population                           ~738 mil          ~7.7 bil
Low vision                           ~26 mil            ~164 mil
Completely blind                      ~3.2 mil           ~55 mil

**Low Vision Community has visual ability BUT we do not yet design environments enabling them to navigate spaces safely.**
What is a Visual Hazard?

Unseen edges within the path or route of a traveller can become a hazard

“the Potential to Cause Harm”

...benches,
steps,
ramps,
protruding corners,
columns,
the edge of a subway platform...
A shift in luminaire location obliterates a 60% difference in the reflectivity of these materials. Note how the edge disappears, in the right image, by moving the luminaire ~ 60cm...

**WOULD BE MISSED** using typical illumination calculations and analyses.

Design by luminance, not by illumination and material contrast specifications, **IS DESIGN BY WHAT WE SEE**
DeVAS Filter

Acuity and Contrast
DeVAS Filter

Our approach builds on the work of Eli Peli, who described a method for transforming an image to simulate the visibility associated with a particular Contrast Sensitivity Function (CSF).

Slide left for reduced Acuity – Slide down for reduced Contrast Sensitivity

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Fig. 1. The Chung & Legge [15] CSF is an asymmetric parabola when plotted in $S_1 - S_2$ space. The plotted values show two instances of the CSF, one shifted left (lower acuity) and down (lower contrast sensitivity) compared to the other.
DeVAS Filter

Removes image details predicted to be not visible, while leaving intact, details predicted to BE visible.

(Legally Blind: 20/200 or less with best possible correction)

Fig. 8.
(a) Original logMAR chart, with third line from top corresponding to logMAR 1.1 and the fourth line from the top corresponding to logMAR 0.9. For correct character size, view the chart from a distance equivalent to 3.33 times the width of the chart image. (b) Original logMAR chart, filtered to simulate an acuity of logMAR 1.0. The third line is readable, the fourth line is not.
DeVAS-Visibility: The application tool, built upon DeVAS-Filter, that predicts visibility.
DeVAS Visibility

DeVAS-Visibility: Automated Visibility Prediction Application

Radiance Rendering plus Geometry Data

New: rtpict

DeVAS-Filter: Severe Low Vision

Ground Truth Edges

Luminance Boundaries: Canny Edges
DeVAS
Visibility

Ground Truth Edges

Luminance Boundaries
Severe Low Vision

RED edges predicted **NOT** to be **visible**
Green edges predicted **visible** for Severe LV
DeVAS
Visibility

Low Vision: Severe
Orange: < 1cd/m²*m

Low Vision: Severe
Change bench material
Low Vision Mild
DeVAS
Visibility

Low Vision: Moderate
Low Vision 8 Legally Blind Threshold
DeVAS Visibility

Low Vision: Severe
DeVAS Visibility

Low Vision: Profound
DeVAS
Visibility

Change the illumination
Low Vision: Profound
DeVAS Visibility

Bench Visibility Study
Introducing Hazard Visibility Score HVS
Introducing Hazard Visibility Score **HVS**

A Region of Interest ROI is created which contains the potential visual hazard.
Introducing Hazard Visibility Score HVS

HVS 1.0 = *highly visible*
HVS 0.0 = *invisible*

<table>
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<tr>
<th>Mild</th>
<th>HVS</th>
<th>0.84</th>
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</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>HVS</td>
<td>0.74</td>
</tr>
<tr>
<td>LB</td>
<td>HVS</td>
<td>0.67</td>
</tr>
<tr>
<td>Severe</td>
<td>HVS</td>
<td>0.51</td>
</tr>
<tr>
<td>Profound</td>
<td>HVS</td>
<td>0.17</td>
</tr>
</tbody>
</table>
DeVAS
HVS

Area Light + Grey Bench

Severe HVS= 0.92

Profound HVS= 0.78

Mild     HVS = 0.99
Moderate  HVS = 0.98
LB        HVS = 0.95
Severe    HVS = 0.92
Profound  HVS = 0.78
DeVAS
HVS

Area Light + Grey Bench

Platform Edge ROI

Severe HVS = 0.98

Profound HVS = 0.84

Mild    HVS = 0.97
Moderate HVS = 0.98
LB      HVS = 0.98
Severe  HVS = 0.98
Profound HVS = 0.84
DeVAS
Steps Study
DeVAS
Steps Study
DeVAS
Steps Study

Low Vision: Mild

Mild

HVS = 0.528
DeVAS Steps Study

Moderate HVS = 0.449

Low Vision: Moderate
DeVAS
Steps Study

Severe

HVS = 0.236

Low Vision: Severe
DeVAS Steps Study

Profound HVS = 0.001

Low Vision: Profound
DeVAS
Steps Stud

Change flooring

Low Vision: Severe

Severe

HVS = 0.490
DeVAS Steps Study

Low Vision: Severe

Change baseboards

Severe HVS = 0.702
### DeVAS Steps Study

#### Hazard Visibility

<table>
<thead>
<tr>
<th>Severe Level</th>
<th>HVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>0.991</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.987</td>
</tr>
<tr>
<td>LB</td>
<td>0.970</td>
</tr>
<tr>
<td>Severe</td>
<td>0.944</td>
</tr>
<tr>
<td>Profound</td>
<td>0.373</td>
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</table>

#### Hazard Leading Edge Visibility

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<tbody>
<tr>
<td>Mild</td>
<td>0.991</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.979</td>
</tr>
<tr>
<td>LB</td>
<td>0.977</td>
</tr>
<tr>
<td>Severe</td>
<td>0.947</td>
</tr>
<tr>
<td>Profound</td>
<td>0.741</td>
</tr>
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Add white stripes
DeVAS Daylight Study

Design by luminance

48" x 96" skylight at 8' above floor

WEST

EAST

24" x 24" x 12"(H) box

r=20%  r=20%  r=20%  r=80%

VIEW
Severe HVS = 0.29
DeVAS
Daylight Study

Severe HVS = 0.33

09:00
DeVAS
Daylight Study

Severe HVS = 0.34
Severe HVS = 0.10
Severe HVS = 0.09
Severe HVS = 0.10
DeVAS Daylight Study

Severe HVS = 0.94
DeVAS Daylight Study

Severe HVS = 0.97

14:00
Severe HVS = 0.97
Possible atrium/exterior annual daylight HV studies?
DeVAS
Daylight Study

Possible annual atrium/exterior daylight HV studies?
**Determine dangerous hazard times/dates and address**
DeVAS Toolset

HDR Rendering

Filter

Mild 20/45
Moderate 20/115
LB 20/200
Severe 20/285
Profound 20/710

Ground Truth

Luminance Boundary

False Positive

Visibility
HVS: 0.872

Severe 20/285 + CSF

Visibility
HVS: 0.488

Profound 20/710 + CSF
DeVAS Validation Study Results:

Hazard Visibility Score (HVS) predicts Human Performance!
- As HVS increases, probability of identifying the step correctly increases

5 Views x 5 Platform Variations x 5 Lighting Conditions x 2
250 images x 14 subjects = 3500 samples
DeVAS Limitations

View Dependent

Requires lighting and material specifications

High luminance areas can mask nearby lower luminance details

Strident high contrast material patterns can result in incorrect visibility analysis

**NEED Visibility Recommended Practices to evaluate:** Compliant/not Compliant
DeVAS Tools are open source, fully functional prototypes compiled for Windows and OSx. DeVAS Visibility is being incorporated into LADYBUG, a RHINO/GRASSHOPER plugin. We welcome other developers.

**rt pict**: a gift from Greg that generates and associates all files necessary for DeVAS-visibility.
DeVAS tools enable the designer to analyze and improve visibility of hazards, potentially within the design palette of the project, to aid in the creation of architectural spaces that are accessible to those with vision impairment who make use of vision for mobility.

Standards could potentially be structured for luminance studies, such as DeVAS, where compliance is sought to a visibility metric standard.
Thank you!

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