Game Over UGR
An alternative physiological model for discomfort glare

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Glare

- **Disability**
  Impairs the vision of objects

- **Discomfort**
  Causes annoyance or pain
Unified Glare Rating

\[ UGR = 8 \log \left( \frac{0.25}{L_b} \sum \frac{L^2(\omega)}{p^2} \right) \]

- Light source luminance
- Solid angle
- Background luminance
- Position index
- Each luminaire one term => uniform approximation

UGR < 10 => No glare
UGR > 40 => Unbearable glare
Problem non-uniform light sources

‘Old’ lamps

‘Old’ glare metrics valid for ‘new’ lamps?

‘New’ lamps
‘Your reporter has referred to UGR as a “leaky boat”. Is it time, therefore, to develop a new system rather than to try further patch the “leaks”.’
Solutions

Option 1: UGR for non-uniform sources

Quickfix

CIE JTC7
Discomfort caused by glare from luminaires with a non-uniform source luminance

Option 2: New discomfort glare index

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Quickfix UGR

As in CIE 117-1995, appendix C3: “Luminiare size and shape data”

luminous area > 500 cd/m²

⇒ Reduce solid angle
⇒ Increase average luminance
Solutions

Option 1: UGR for non-uniform sources

Quickfix

CIE JTC7
Discomfort caused by glare from luminaires with a non-uniform source luminance

Defining the Actual Luminous Surface in the Unified Glare Rating. Leukos, 13 (4), 1-10.

Option 2: New discomfort glare index

An alternative physiological model for discomfort glare

Pupillary light reflex, receptive field mechanism and correction for retinal position for the assessment of visual discomfort. Lighting Research and Technology

A psychophysical model for visual discomfort based on receptive fields. Lighting Research and Technology
Human Visual Perception System

Hubel, 1988. Eye, Brain and Vision
Pupillary Light Reflex

Dim environments: pupil dilation
Bright environments: pupil constriction

\[ D_{\text{Barten}} = 5 - 3 \tanh \left( 0.4 \log \frac{L_s a}{40^2} \right) \]

\[ D_{\text{Stanley Davies}} = 7.75 - 5.75 \left( \frac{L_s a / 846^{0.41}}{L_s a / 846^{0.41} + 2} \right) \]

\[ E_{\text{ret}} \sim L_{\text{object}} \cdot A_{\text{pupil}} \]

Retinal position

more away from the line of sight => lower brightness perception

\[ E_{ret} \rightarrow E_{p,ret} \]
Centre-Surround Receptive Fields

- Centre:
  - direct path
  - link to bipolar cells
- Surround:
  - indirect path
  - via horizontal cell to bipolar cell
- Bipolar cell to ganglion cell
- Ganglion cell to brain
Receptive Field convolution: Edge detection

\( (C - WF \cdot S) \)

- Edge length
- Edge height
- Edge sharpness
Receptive field model

Discomfort $\text{Glare} = \ln \sum_{\text{pix}} \omega_{\text{pix}} \cdot \left| (C - WF \cdot S) \ast E_{p,\text{ret}} \right|$
Paired Comparison Experiment

Uniform  360x360  179x179  2x2  6x6  60x60  26x26

7  6  5  1  2  4  3

(7) SE

z-score for discomfort

Uniform  3:1  6:1  60:1

9  8  (3)
Functional organization of the peripheral retina: Sensitivity to periodic stimuli

Hilz & Cavonius, 1974.
Visual discomfort model Performance
Validation experiment

Office luminaires test

Diffusor luminaires test
Validation Experiment

Office luminaires test  Diffusor luminaires test
Comparison with standard UGR

Office luminaires test

Diffusor luminaires test

R² = 0.45

R² = 0.76
Comparison with Quickfix UGR

Office luminaires test

Diffusor luminaires test

![Graphs showing the comparison between PC and ME assessments for different lighting conditions. The graphs illustrate the relationship between Improved UGR and the assessments, with R² values of 0.72 and 0.91.]
Overview results

<table>
<thead>
<tr>
<th></th>
<th>Standard UGR</th>
<th>Quickfix UGR</th>
<th>Physiological Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Luminaire Test</td>
<td>0.45</td>
<td>0.72</td>
<td>0.86</td>
</tr>
<tr>
<td>Diffusor Luminaire Test</td>
<td>0.76</td>
<td>0.91</td>
<td>0.81</td>
</tr>
</tbody>
</table>
Game Over UGR?

• Short term: not really! Patches keep the UGR floating: Use the Quickfix!

• Long term: The model including the receptive field mechanism and the pupillary light reflex is able to predict the visual discomfort and is promising to replace current standard glare metrics, specifically when non-uniform luminaires are to be evaluated.
Thank you!

Questions?
Remarks?
Suggestions?