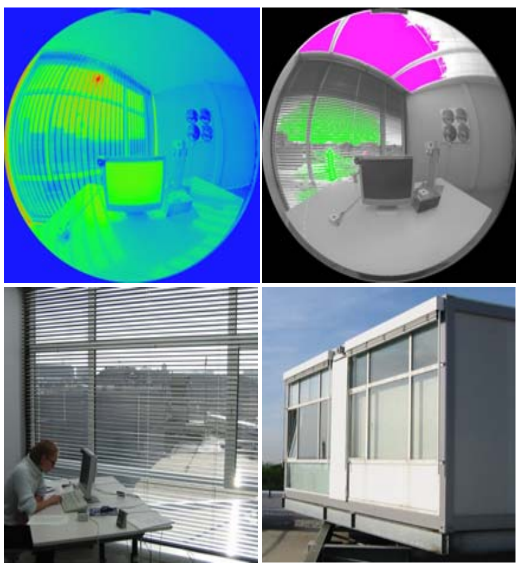
Workshop Glare analysis of HDR images

- Background information: Introduction into daylight glare evaluation
- Introduction into evalglare and exercises



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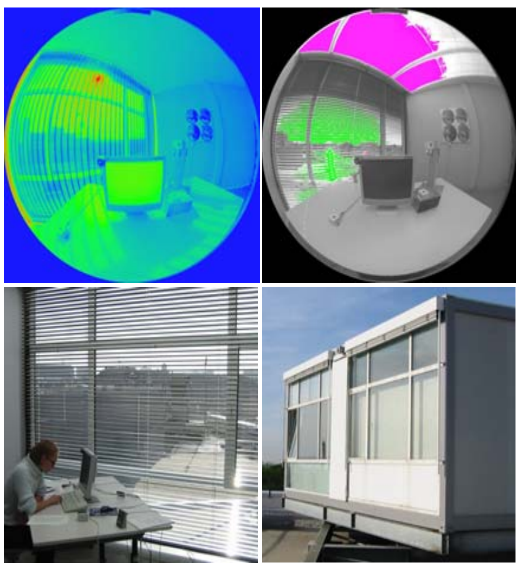
Daylight glare (in offices)

Introduction



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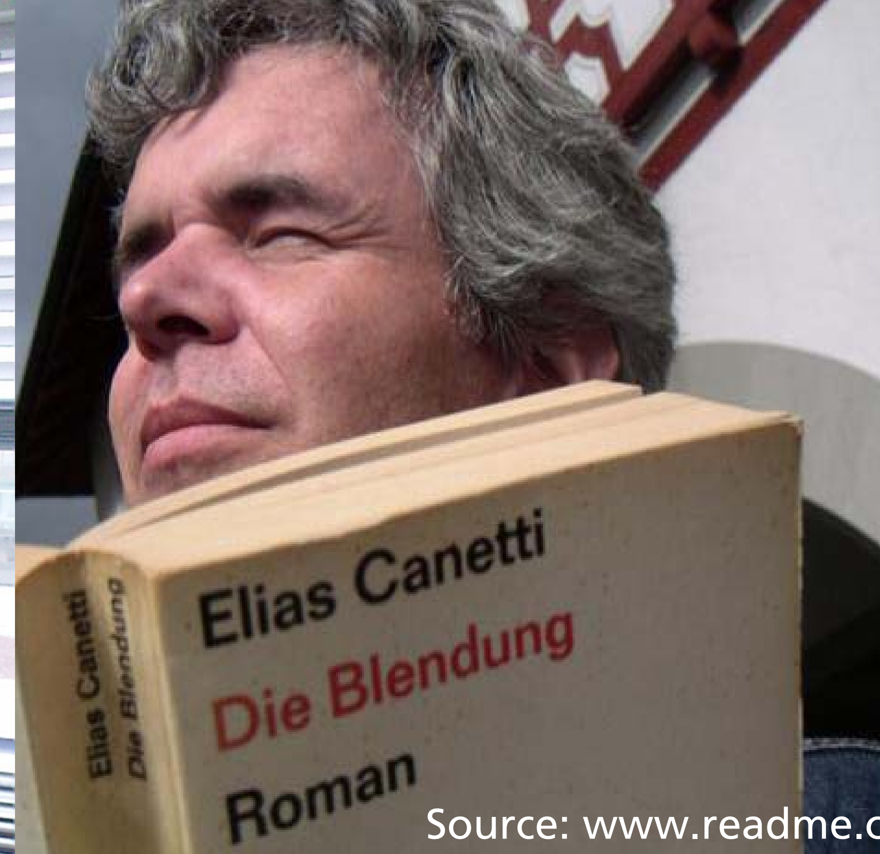
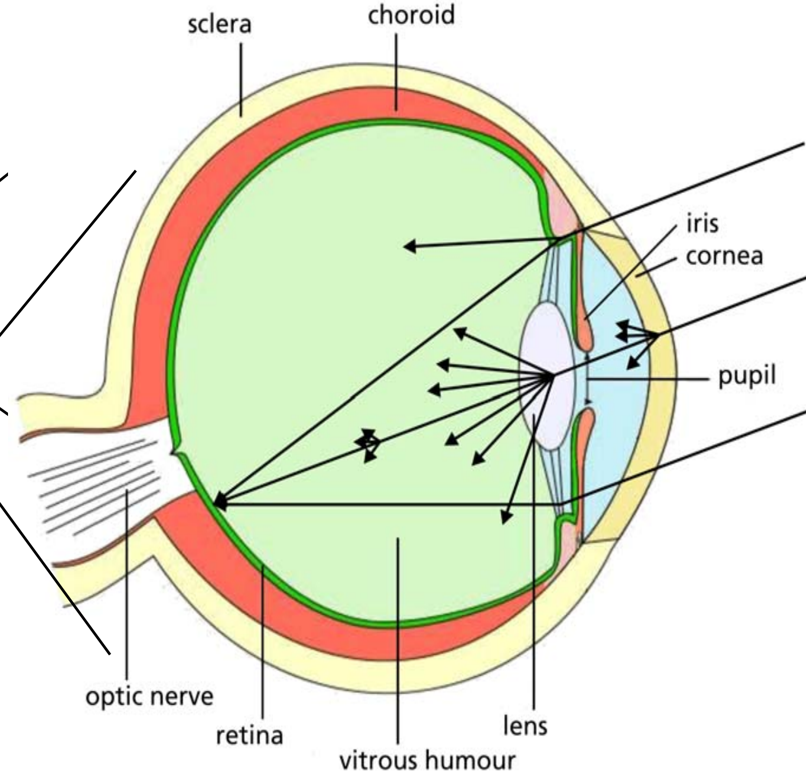


Source: www.readme.c

Glare can be divided into

- Reflex glare
- Disability glare
- Discomfort glare



Discomfort glare

- Discomfort = Subjective rating
- In most cases below disability glare
- Possible scaling:
  imperceptible
  perceptible
  disturbing
  intolerable

⇒ Indirect consequences (headaches, getting fatigue), often not direct measurable

⇒ Investigated within thesis

Motivation

or this situation ?

Daylight glare metrics – up to now

Principal structure of existing complex glare formulas:

$$G = f\left(\frac{L_s^{a_1}\,\omega_s^{a_2}}{L_b^{a_3}\cdot P^{a_4}}\right)$$

L_s: Luminance of source

ω_s: Solid angle of source

L_b: Background luminance $\Rightarrow$ adaptation

P: Position index

Developed under artificial lighting conditions

Not under daylight

How reliable are these discomfort glare formulas?

Daylight glare metrics – Daylight glare index DGI

$$G = f\left(\frac{L_s^{a_1} \cdot \omega_s^{a_2}}{L_b^{a_3} \cdot P^{a_4}}\right) \qquad DGI = 10\log_{10} 0.48 \sum_{i=1}^{n} \frac{L_s^{1.6} \cdot \Omega_s^{0.8}}{L_b + 0.07\,\omega_s^{0.5}\, L_s}$$

L_s: Luminance of source
ω_s: Solid angle of source
L_b: Background luminance $\Rightarrow$ adaptation luminance
P: Position index

Developed with less than 10 subjects

Content

- Methodology
- User assessments
- Evaluation of existing glare metrics
- Development of a new glare metric and validation: The daylight glare probability DGP

Methodology user assessment

Two identical test rooms

Test room

Instrumentation room

Questionnaire

Measurements : Luminance camera Illuminances

User analysis

Image processing

correlations

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User Assessments: 2 sites (D,DK), 3 window sizes, 3 shadings

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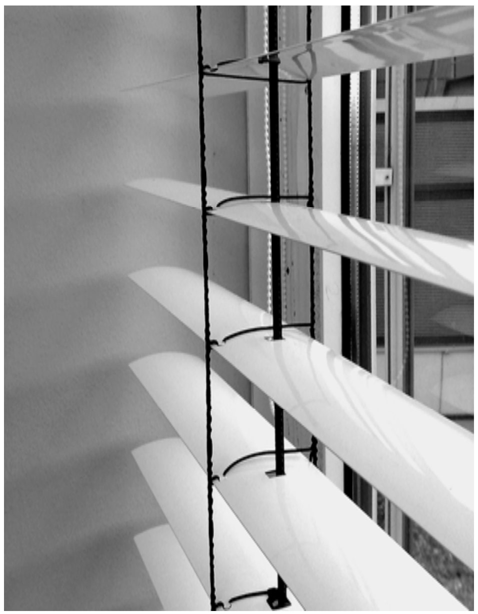
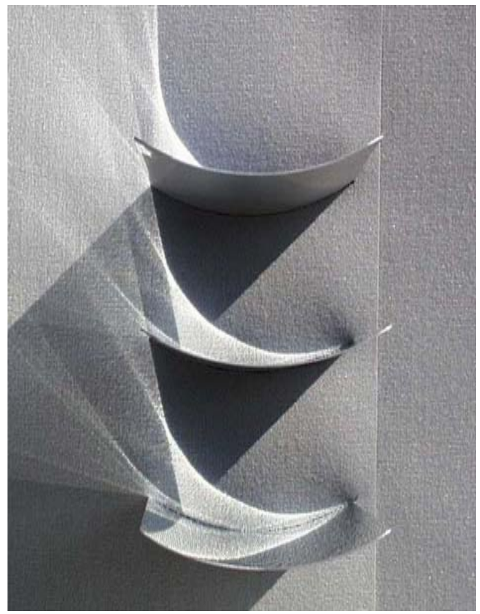
Tested three shading devices

White Venetian blinds
80mm, convex, ρ=.84
D (sunny), DK (sunny)



Specular Venetian blinds
80mm, concave, ρ=.95
D (sunny) ,DK (cloudy)



Vertical foil lamellas
τ=0.02
D (sunny)

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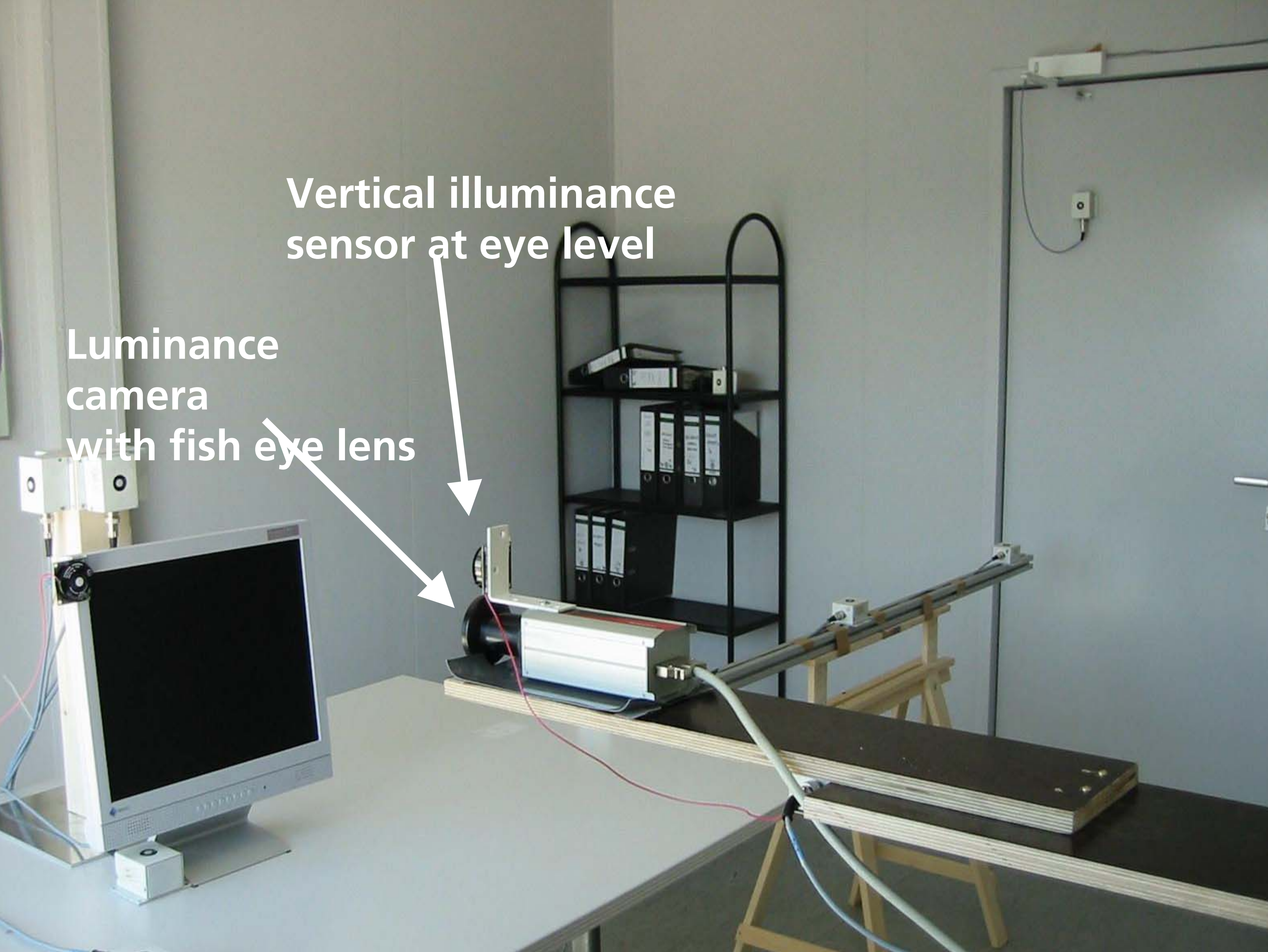

Vertical illuminance
sensor at eye level
Luminance
camera
with fish eye lens

Methodology user tests : Office like tasks

WhwNdzo zltpVY 1CCAe kDw he t3
TkW3rm8U ya BpE O2B L8Y A5 She
PQtb 90DViRCDG 1H pSM yEqZz 6F
jyA3 sATQesa ANUU VLH Ou1p2JBE
vbR l1Y5rVr SA9mr DmPETLV 2uO2
7phnFd2oyT 83ee zKo8h KyiTJgAL
vXMu 6Kugm 3ElkxsOWhCK1FTMA T6
LuGF5 ad HsicT H0jkHv ssAq U8Q
8dW rmrtfGqh HCsnGdYIMQEITS fo
o1 XVw6 2VogMFo6 PH uJD3c DXj8
yW 5LN 6Bv0 fGPhdZ Cn x9gUiaH3
fySFoauaxj UeK bKQz 2uZa MmnCN
4t HT3OFuMUSo piq1uUh8tdRbK1Tn
Ez 33Q 6w fvVR 7B gyz Ns5 5Ami
7T5k 6bc2 ZHl fJmDO GwJ9 ECKYm
Xob3m t9 SU ZR e1 3lFg 1wc j4w
nToPDF RCUb nyMHs rMI0oizFL8dx
a2Z sD AK5R1 Q8jiI wBeeA L2Rz0

Methodology image processing

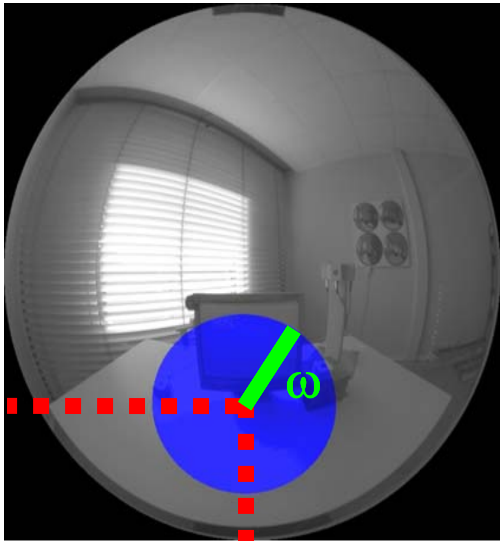
- Data and image preparation
- Detect glare sources in images
- Calculate existing discomfort glare indices
- Correlate indices with user answers
- Develop new glare rating

Evalglare: Own software development

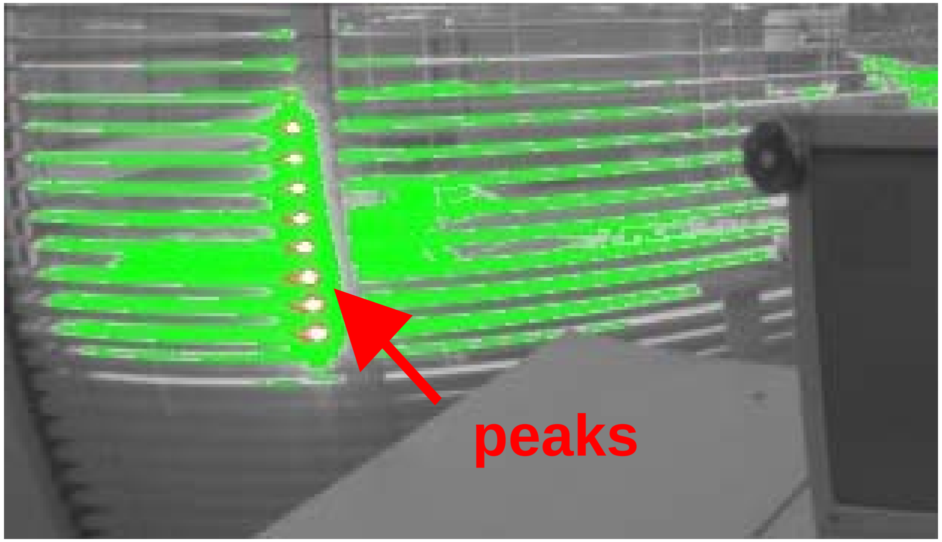
Detection of glare sources, calculation of various indices

Important features:

Task area detection mode (–t):
xy position of centre of task
opening angle ω of task



Spot extraction (-y)
"Peaks" of very high luminances can be extracted to an extra glare source



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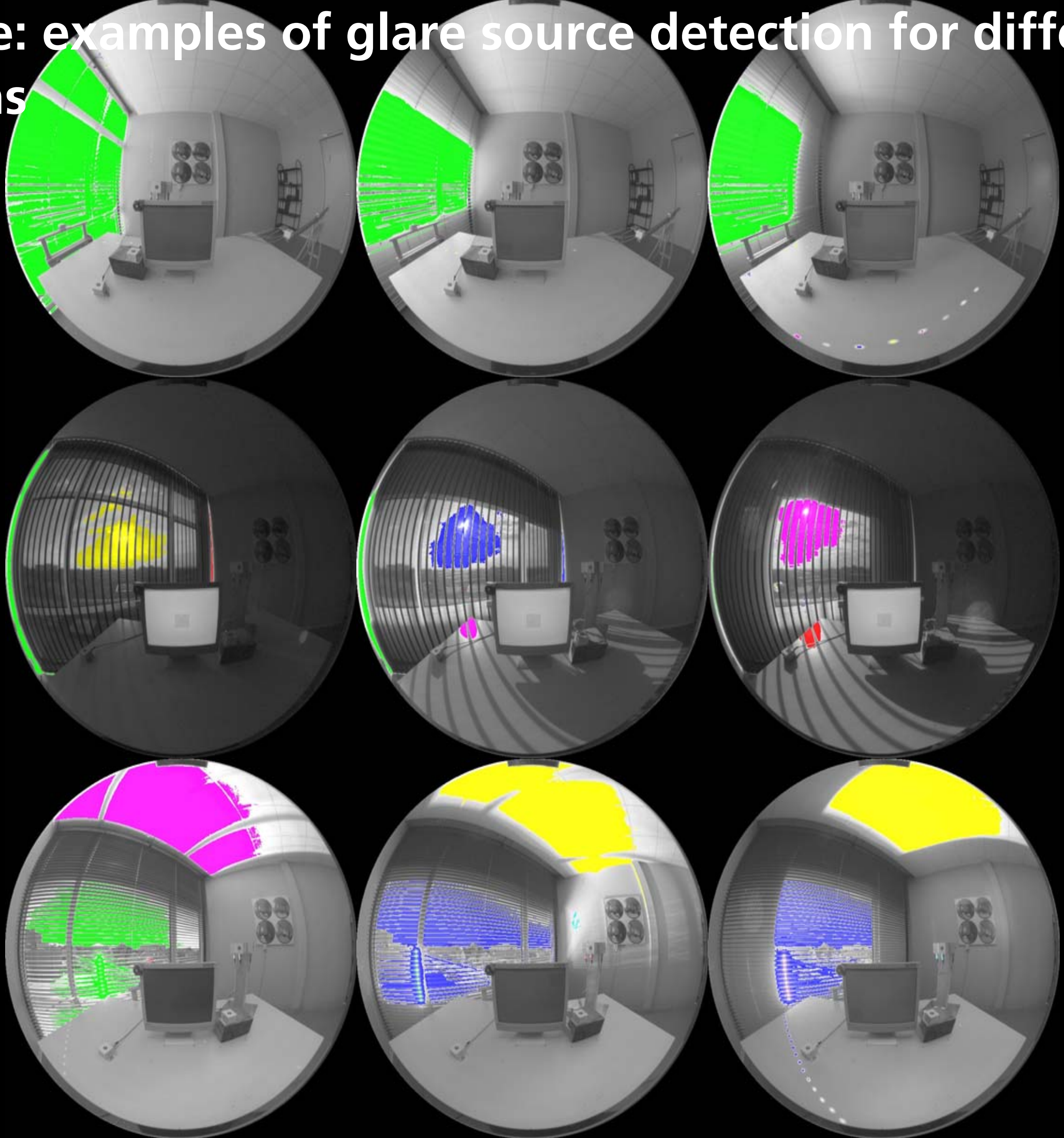
evalglare: examples of glare source detection for different situations



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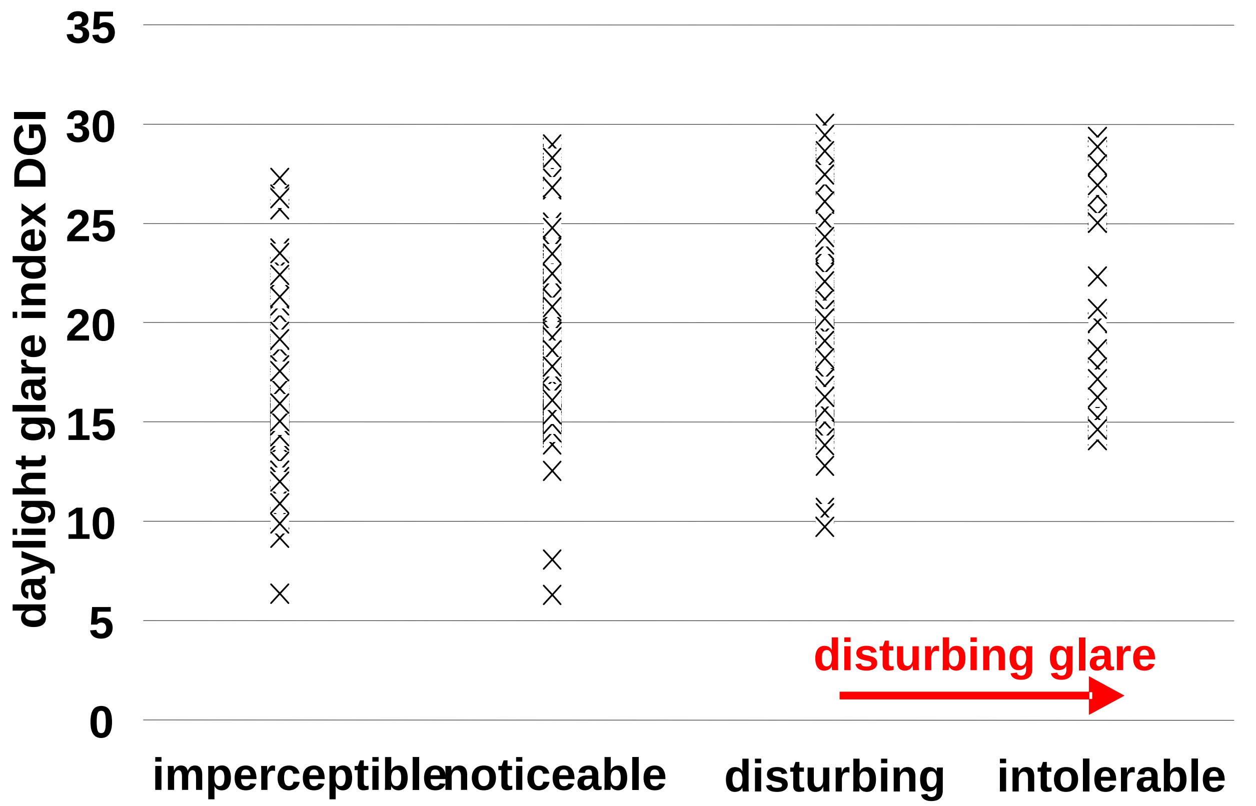
Result: Scatter of the answer behaviour

Example: daylight glare index DGI

Large scatter

Perception of glare is individual



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What kind of results do we expect?

- Now: formulas try to describe individual perception
- But: Is that the result we need?
- Suggestion: To use a probability, that a person is disturbed
- Analogue to thermal comfort (e.g. Fanger PPD)

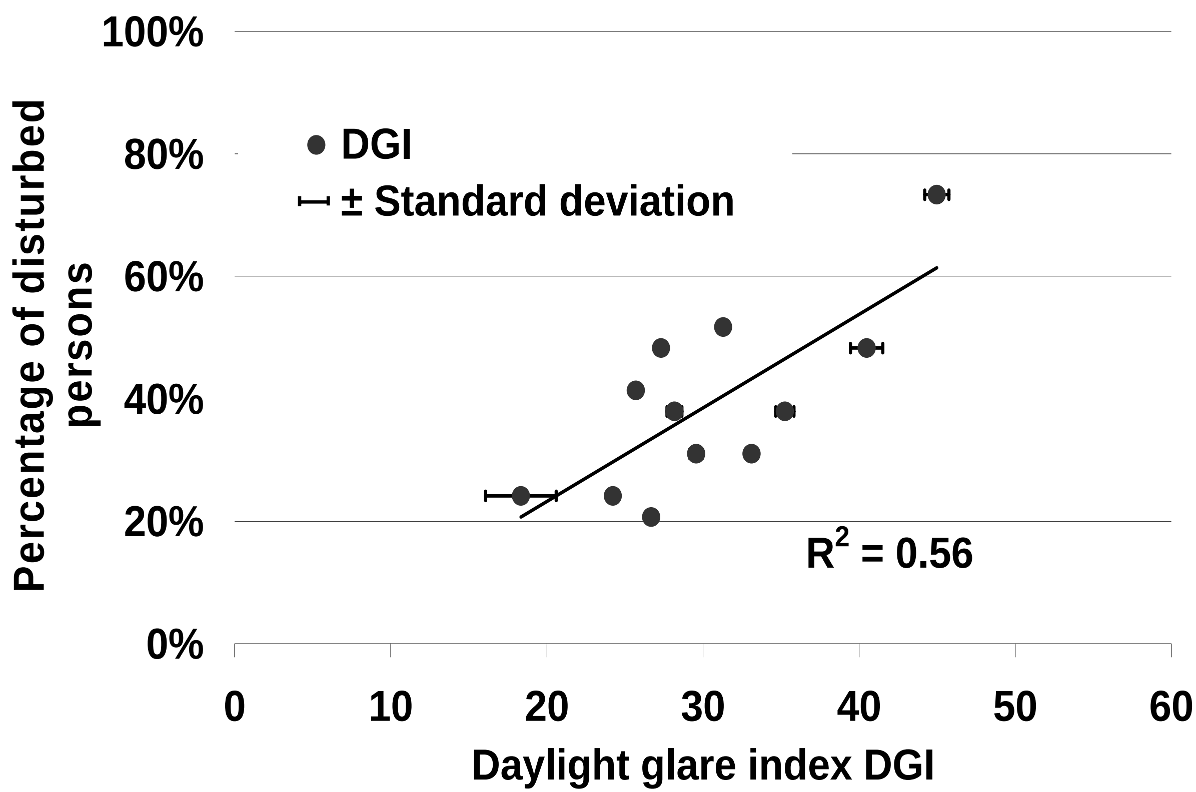
Method:

1. Count number of disturbed persons within a glare class
   $\Rightarrow$ dichotomic data (yes or no) $\Rightarrow$ probability
2. Compare to average glare value of the class

Result: Daylight glare index versus percentage of persons disturbed

Large scatter

Weak correlation



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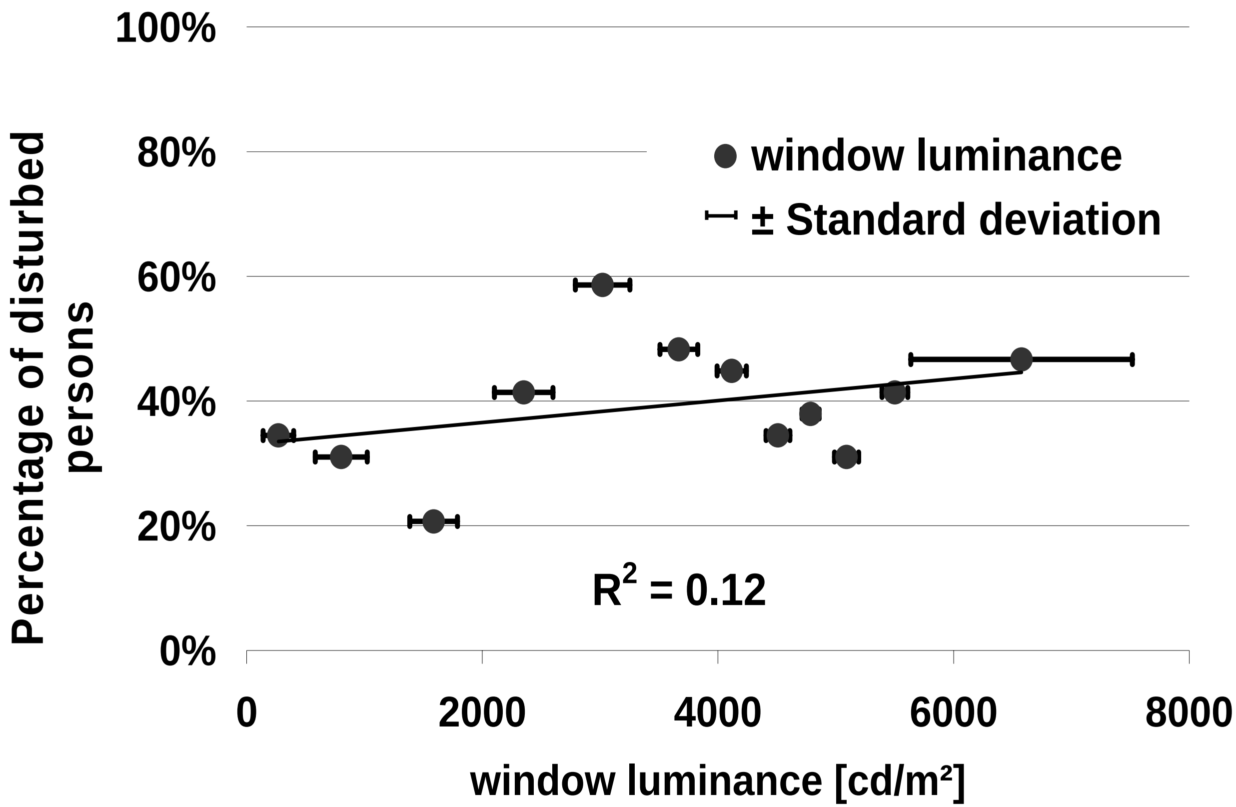
Result: Average window luminance versus percentage of persons disturbed



Large scatter

No dependency

no correlation

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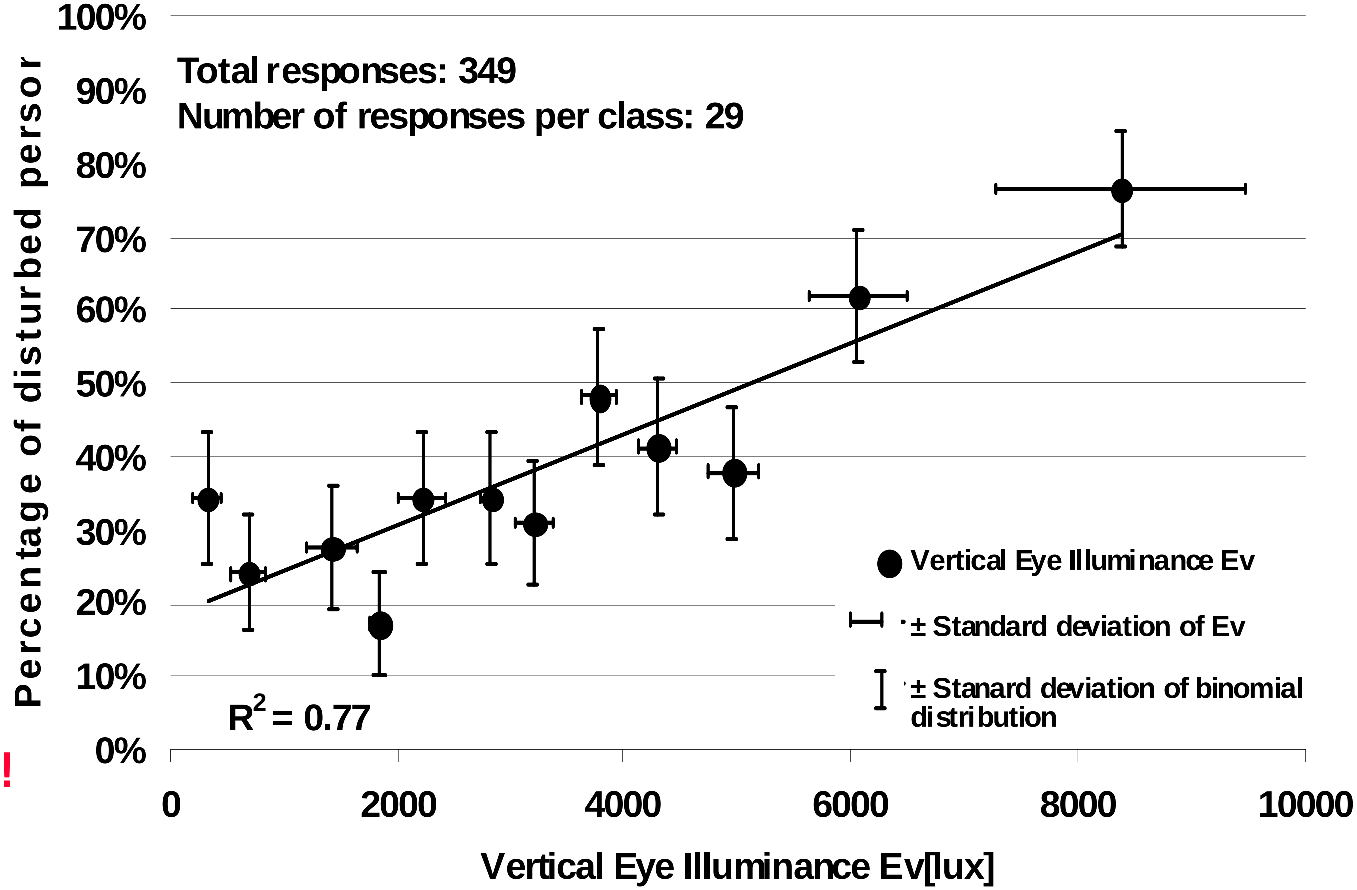
Result: vertical eye illuminance versus percentage of persons disturbed



reasonable correlation

But no peaks can be considered!!

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Idea for the new glare rating

Use recent findings (Knoop, Osterhaus): Vertical Eye illuminance

and (!!)

Parts of CIE-glare index (or UGR)

$$CGI = 8 \log_{10} 2 \cdot \frac{\left[1 + \frac{E_d}{500}\right]}{E_d + E_i} \cdot \sum_{i=1}^{n} \frac{L_s^2 \omega_s}{P^2}$$

L_s	Luminance of source
ω_s Ω_s	Solid angle of source
L_b source	Background luminance of
P	Position index
E_d	Direct vertical illuminance
E_i	Indirect vertical illuminance

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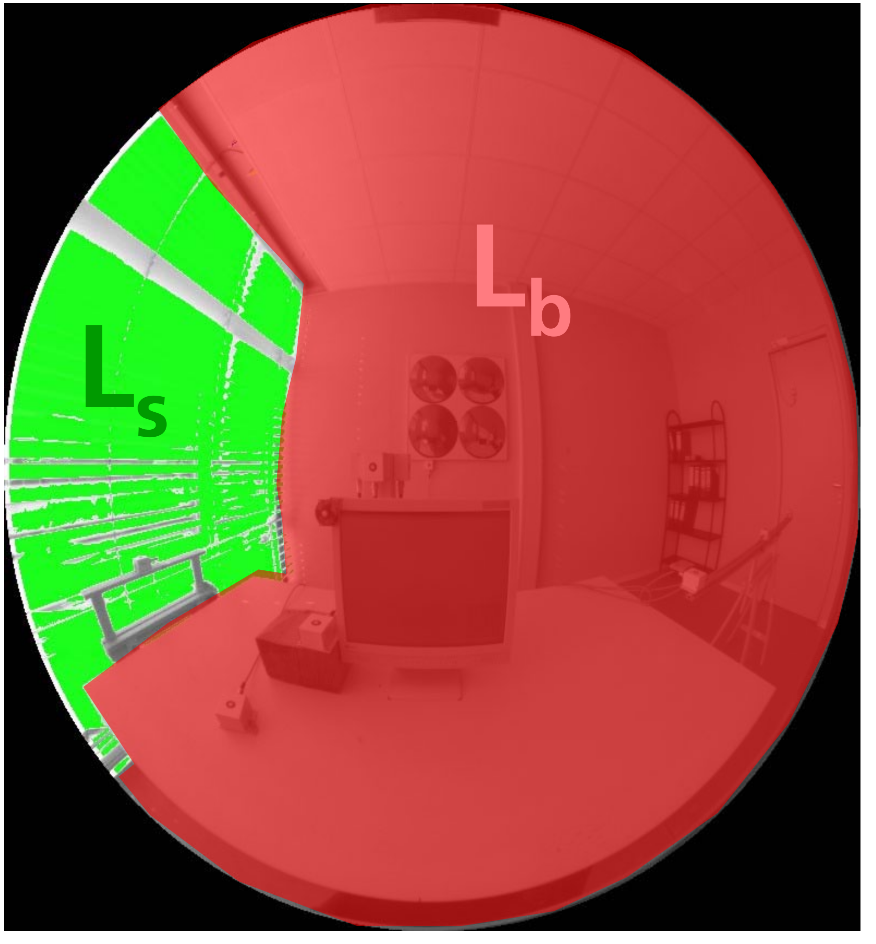
Adaptation level in equation?

$$G = f\left(\frac{L_s^{a_1} \cdot \omega_s^{a_2}}{L_b^{a_3} \cdot P^{a_4}}\right)$$

Large glare source

L_b?

Better correlations when using E_v



New glare rating
Daylight glare probability DGP

$$DGP = c_1 \cdot E_v + c_2 \cdot \log\left(1 + \sum_i \frac{L_{s,i}^2 \cdot \omega_{s,i}}{E_v^{a_1} \cdot P_i^2}\right) + c_3$$

Combination of the vertical eye illuminance with modified glare index formula

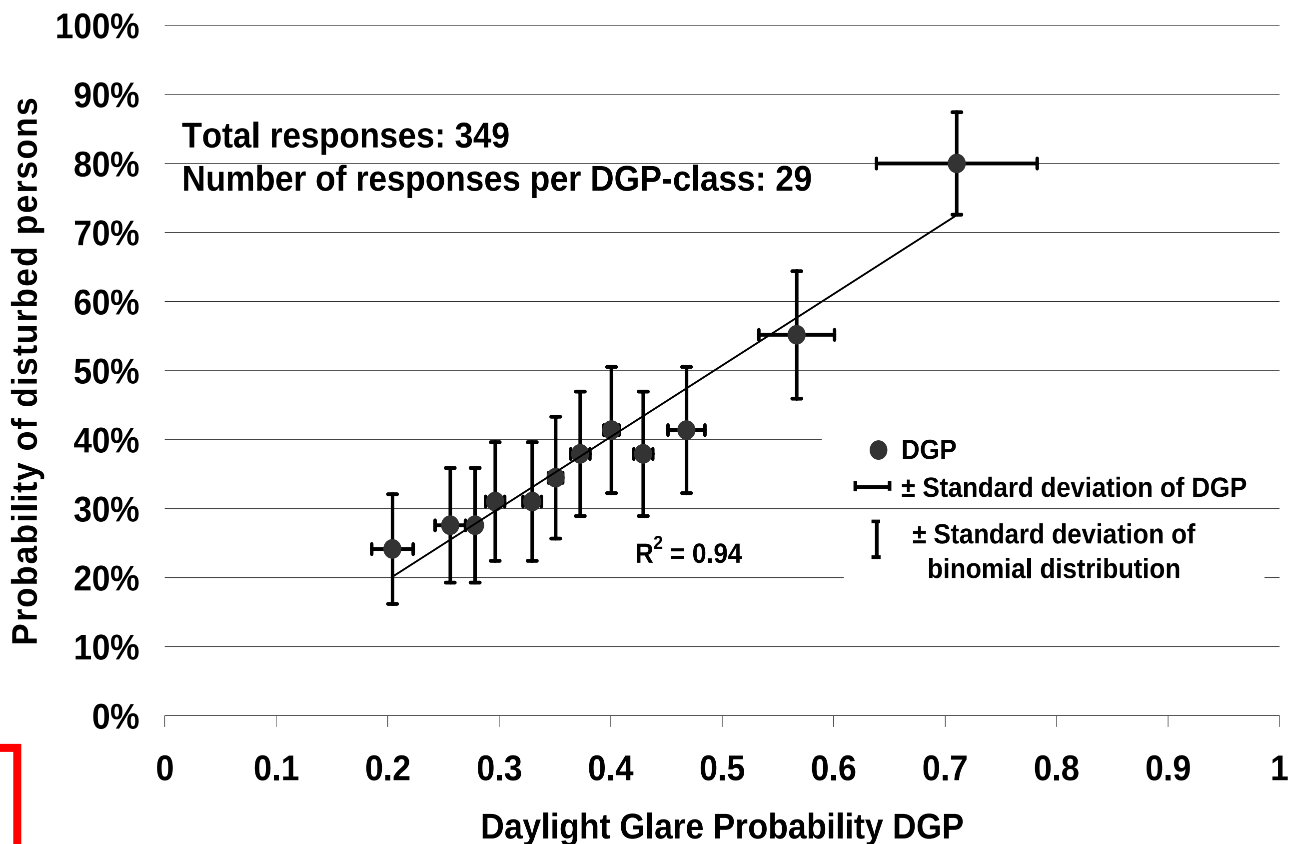
E_v:	vertical Eye illuminance [lux]	$c_1 = 5.87 \cdot 10^{-5}$
L_s:	Luminance of source [cd/m²]	$c_2 = 9.18 \cdot 10^{-2}$
ω_s:	solid angle of source [-]	$c_3 = 0.16$
P:	Position index [-]	$a_1 = 1.87$

Correlation between DGP and probability of persons disturbed

Strong correlation

Logistic regression:

p=3.44 10^{-8}
⇒Much stronger than for all other metrics



Valid for
DGP $\geq$ 0.2
$E_v \geq$ 380 lux

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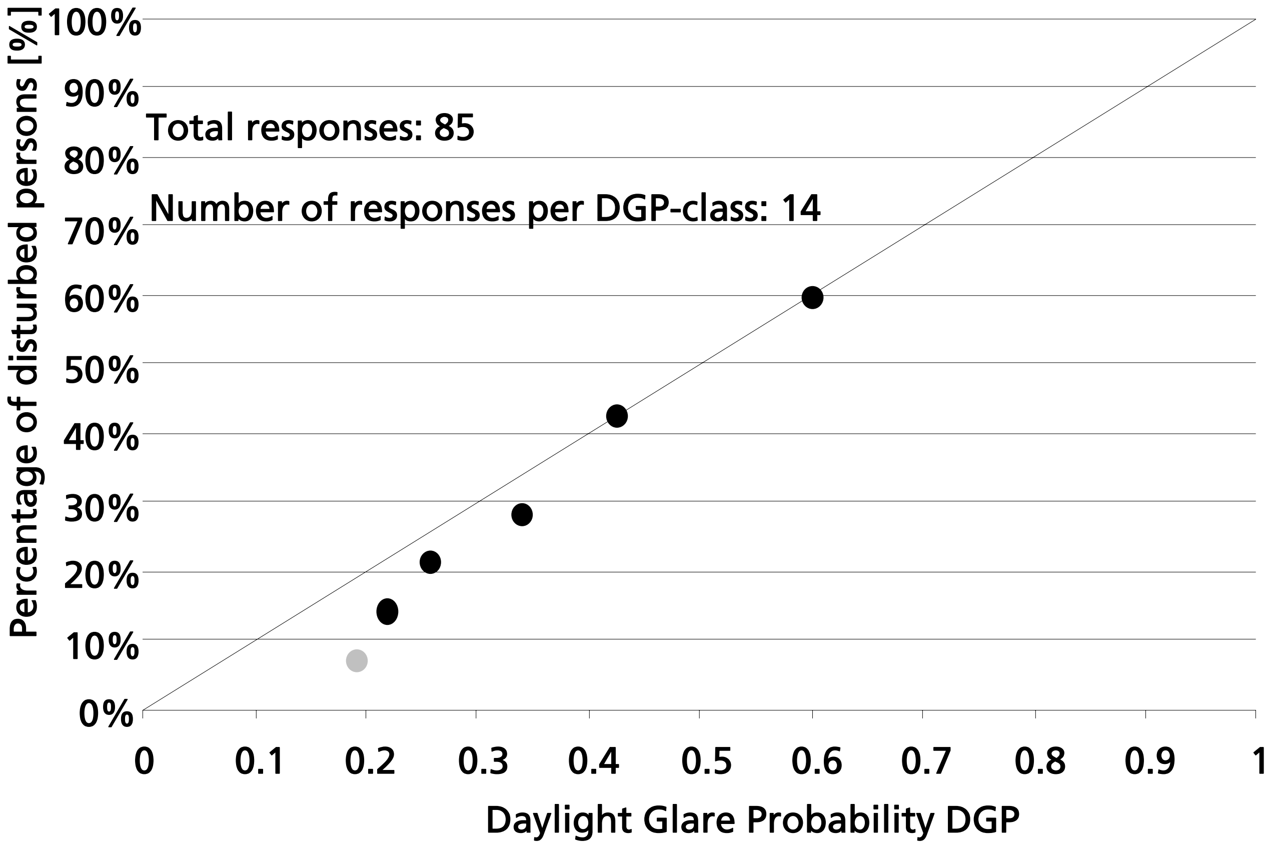
Validation of the DGP model against additional data

Additional data from 28 new subjects:

6 for vertical foil system (D) and

22 for specular blinds (DK)



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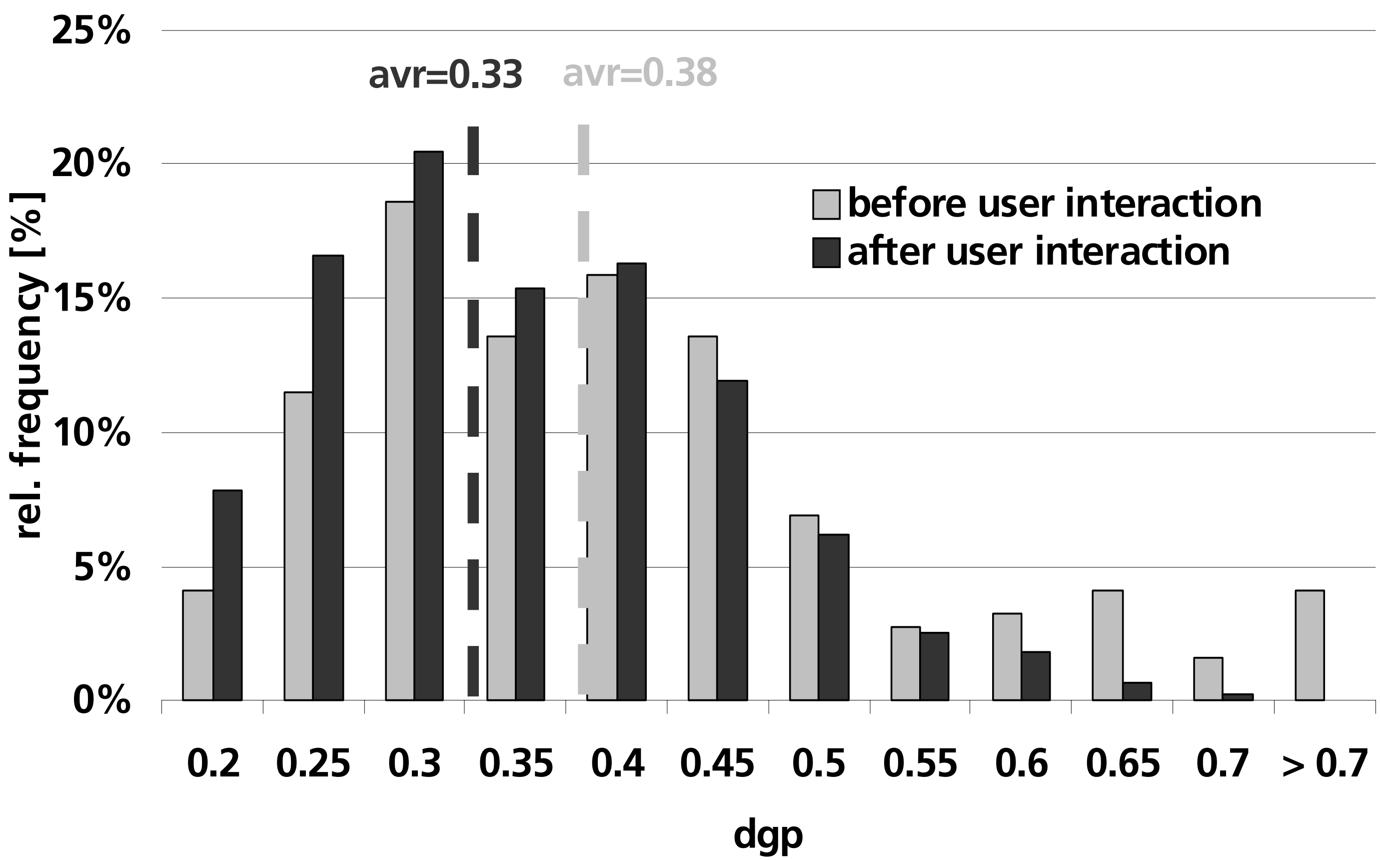
Evaluation of existing models and development of a new rating - conclusions

- Existing discomfort glare formulas show low correlations with user assessments
- Especially windows luminance and indices based on it show low correlation
- New DGP - formula improves the correlation
- New tool for the glare evaluation developed **evalglare**

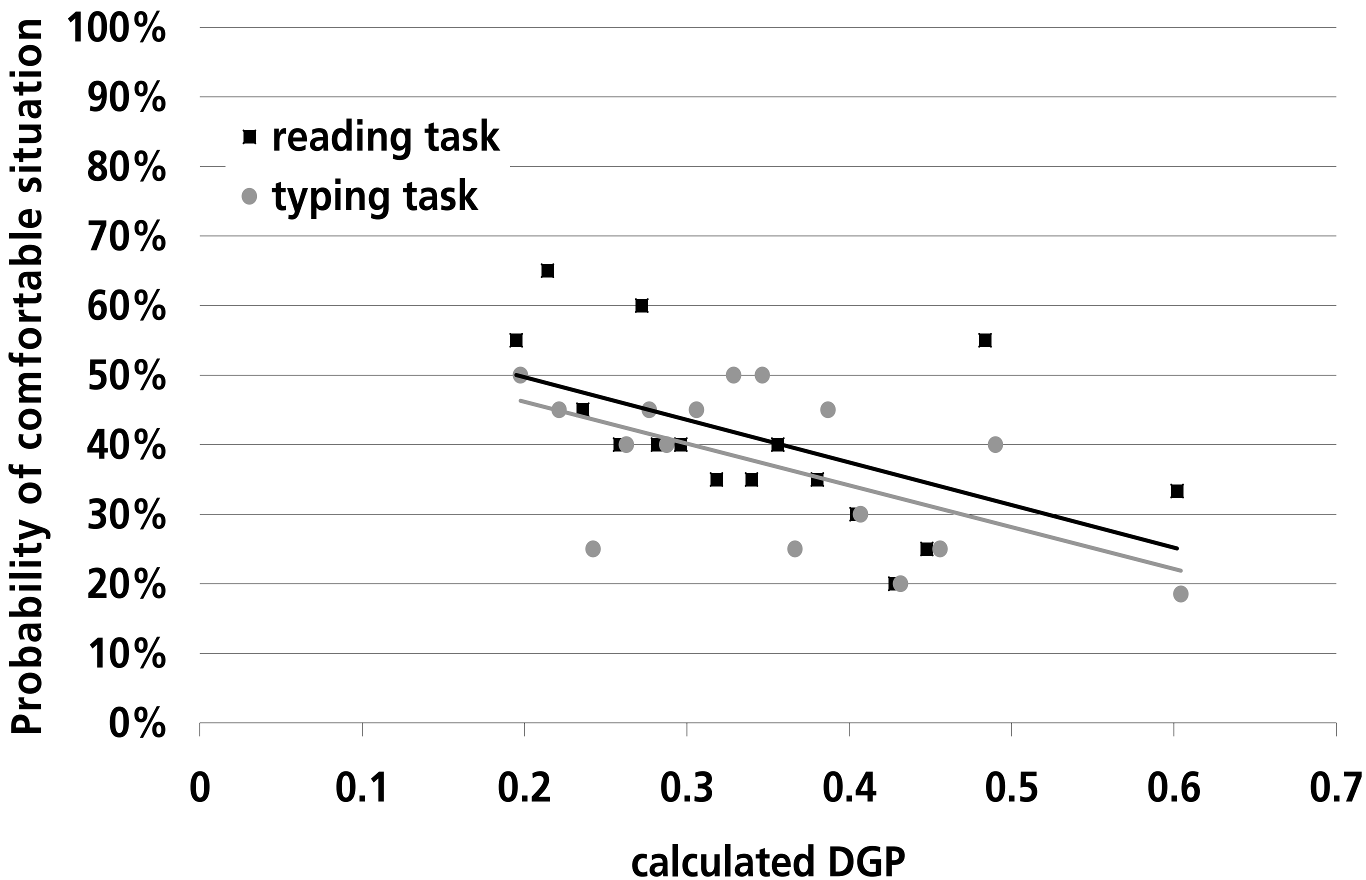
DGP – What are good values?

- What is preferred by the users?
- What is accepted?
- How to evaluate the data climate based?

Acceptance of glare



Influence of glare on overall visual comfort perception



Evaluation of annual data

Idea:

Use similar method than for thermal comfort [EN 15251, 2007]

⇒ Define three categories, in those a certain amount of users are satisfied

⇒ Here: Usage of glare categories from questionnaire

⇒ A 5% exceedance is allowed

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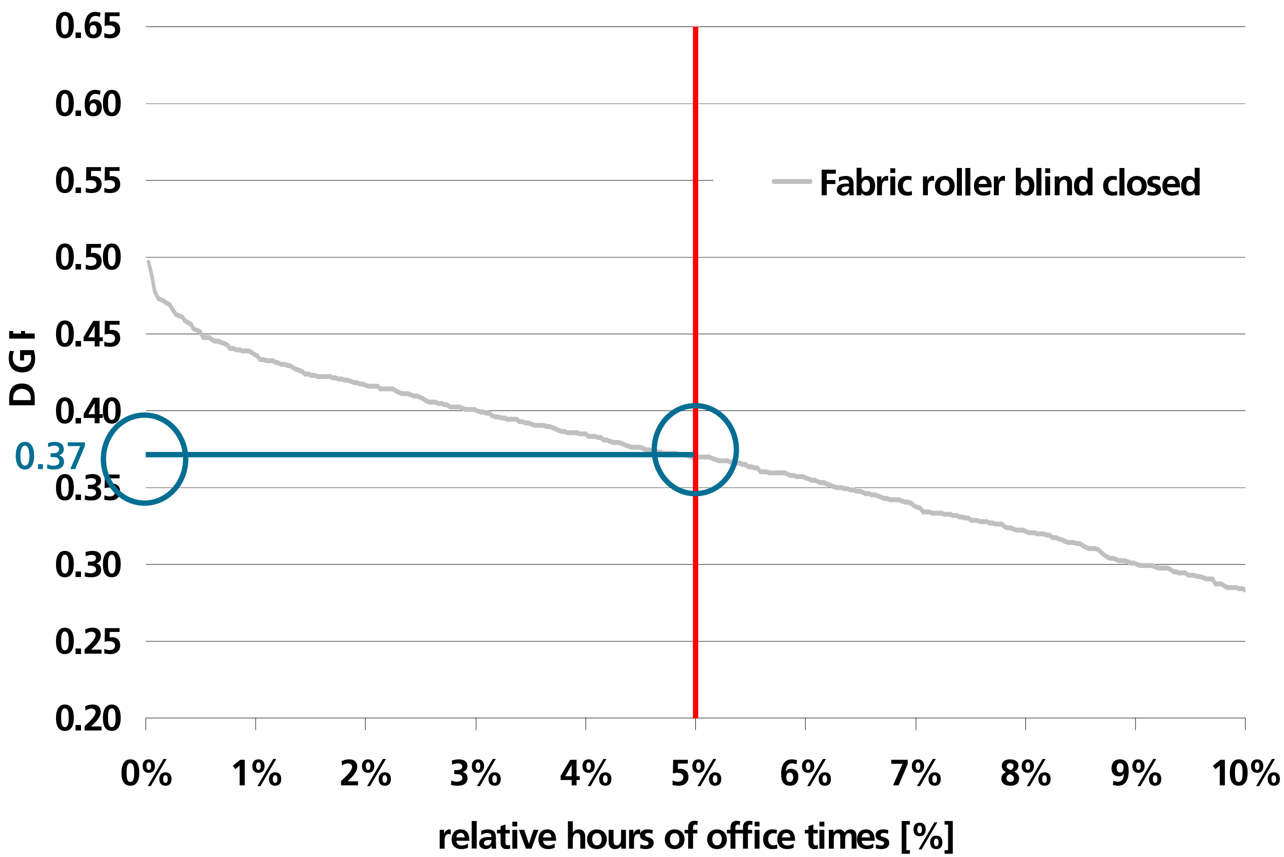
Evaluation of annual data



Basis for the categories: Results of the user assessments Descriptive one-way ANOVA analysis (ANalysis Of VAriance)

Glare rating	DGP avg	95%-confidence interval lower limit	upper limit
imperceptible	0.33	0.314	0.352
perceptible	0.38	0.356	0.398
disturbing	0.42	0.39	0.448
intolerable	0.53	0.464	0.59
avg	0.39	0.314	0.352

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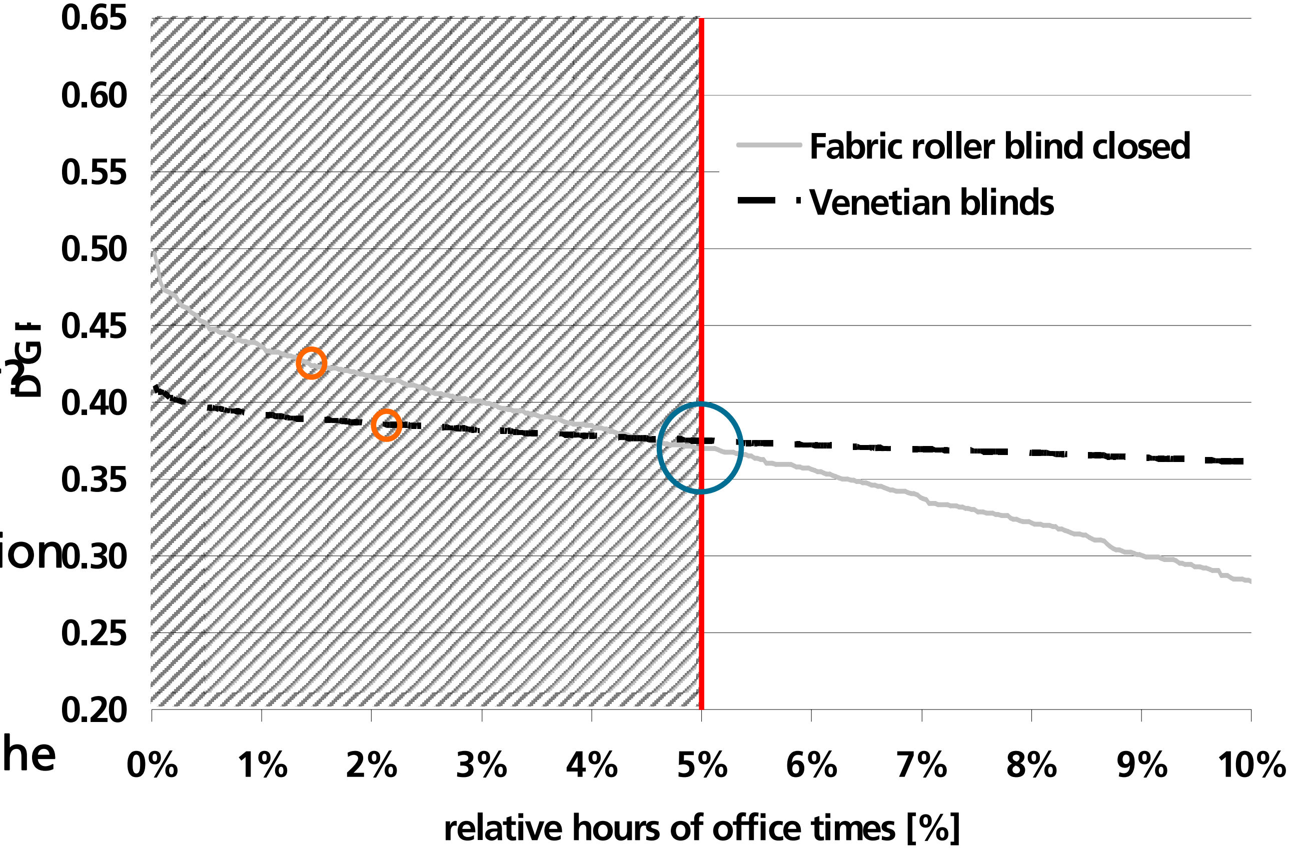
Evaluation of annual data

Which one is better?

⇒ Additional criterion is needed

⇒ Average within the 5% band



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Glare rating	DGP avg	95%-confidence interval lower limit	95%-confidence interval upper limit
imperceptible	0.33	0.314	0.352 A
perceptible	0.38 A	0.356	0.398 B
disturbing	0.42 B	0.39	0.448 C
intolerable	0.53 C	0.464	0.59
avg	0.39	0.314	0.352

Suggestion of glare - classes

	A best class 95 % of office-time glare weaker than "imperceptible"	B good class 95 % of office-time glare weaker than "perceptible "	C reasonable class 95 % of office-time glare weaker than "disturbing"
DGP limit	≤ 0.35	≤ 0.40	≤ 0.45
Average DGP limit within 5 % band	0.38	0.42	0.53

End of first part