Small glare sources in the periphery of the field of vision

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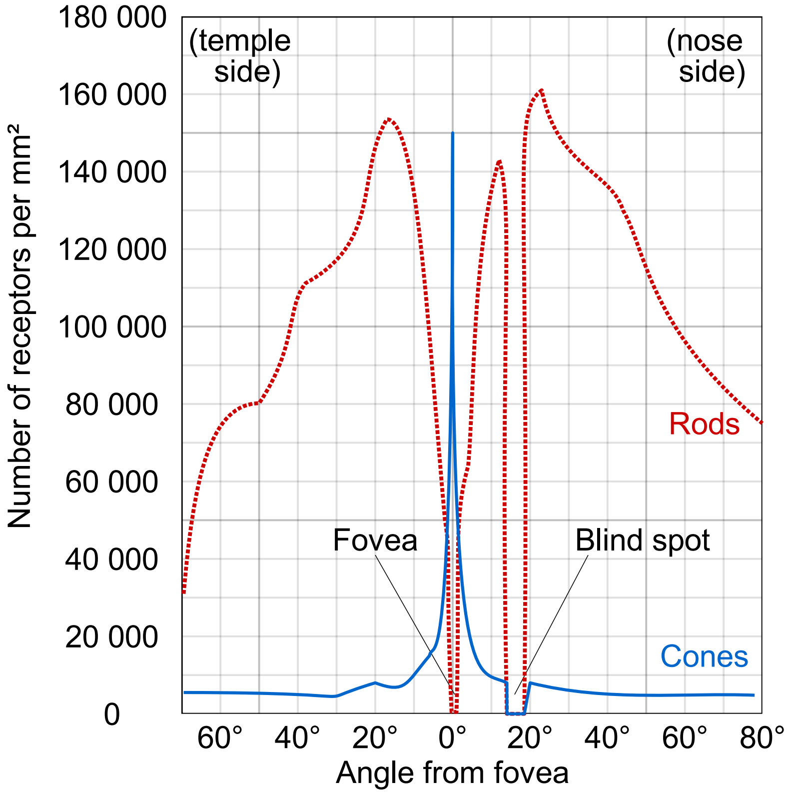
Glare and acuity



The distribution of human photoreceptor cells on the retina, Cmglee / Wikimedia

Hypothesis: Two visual stimuli that are indistinguishable cannot lead to different glare sensations.

The discriminability of visual stimuli depends on their position in the visual field. The different distribution of photoreceptors on the retina and the optical imaging properties of the eye cause a strong decrease of visual acuity in the periphery.

⇒ Even **visual stimuli** with **clearly different sizes cannot be distinguished** in the peripheral visual field.

Objective: To account for this effect in glare assessment for daylight.

Unified Glare Rating UGR: Small sources

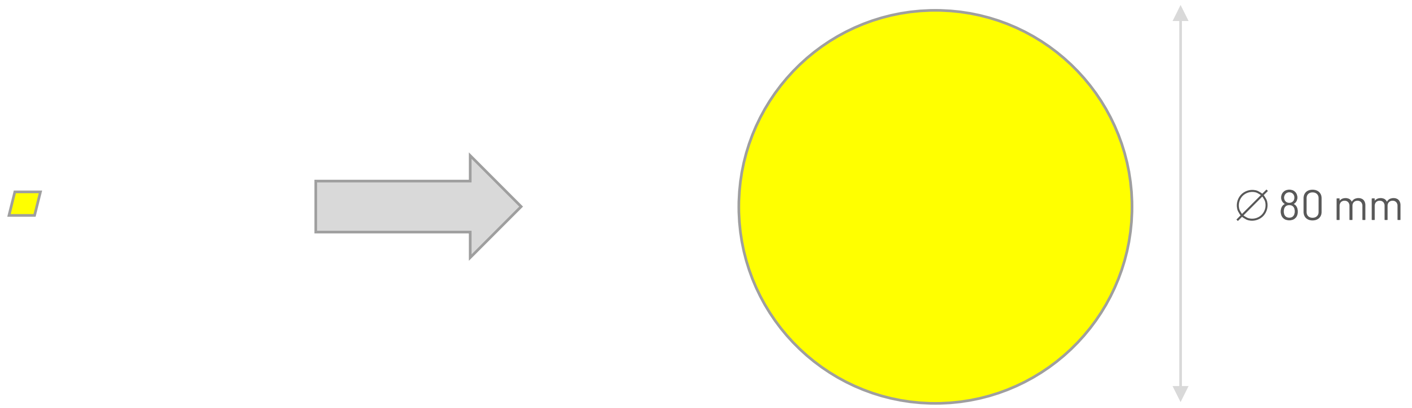
„**UGR** system shoud **not be used** for sources **smaller than 0.0003 sr**" [CIE 117-1995]: $\omega \geq 0.0003$ sr (cone 2 x 0.56°, ~2x sun)

$$UGR = 8 \ \log_{10}\left(\frac{0.25}{L_b}\Sigma\frac{L_{s,i}^2 \cdot \omega_i}{p_i^2}\right)$$

Small sources: Unrealistically high UGR values.

[CIE 147-2002] (CIE TC 3-01 report): The projected area of small sources is „perceived as of size $A_p = 0.005$ m², not smaller".
This implies to replace these sources by a **sphere with a diameter of 80 mm**. This has not yet been implemented in practice.

Example:



[CIE 117-1995] "Discomfort glare in interior lighting", CIE: Wien, 1995
[CIE 147-2002] "CIE Collection on Glare 2002. Glare from Small, Large and Complex Sources", CIE: Wien, 2002.

Unified Glare Rating UGR: Luminaires with a non-uniform source luminance

Luminaires with a non-uniform source luminance: Discomfort is often higher than predicted by UGR.

Average luminance of light-emitting surface (or even of luminaire casing) is used and local peaks are neglected. The Technical Report [CIE 232-2019] proposes to **correct UGR** based on **luminance images of the light-emitting surface**. Detailed description of the elaborate procedure in [LiTG 46-2022].

Physiological basis: **Angular resolution** $\approx \frac{1+\varepsilon}{100}$ [°] ε ... angle to viewing direction [°]

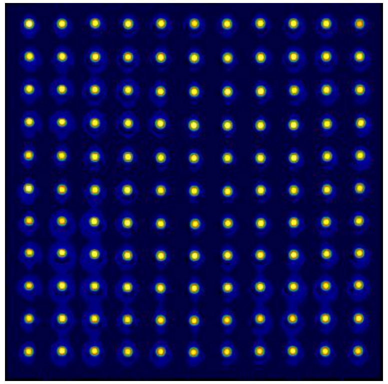
Used to argue the **blurring** of the luminance distribution of the light-emitting surface with a **Gaussian filter** function of 12 mm full-width at half maximum (glare sources: L > 500 cd/m^2).

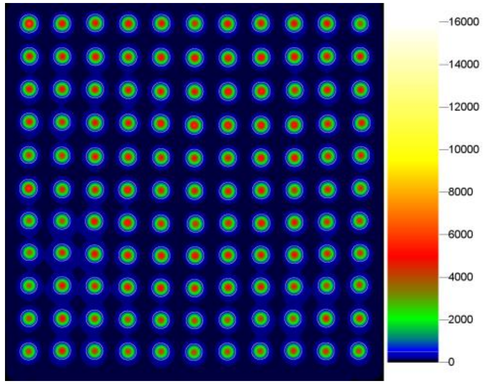
Example 15 [CIE 232-2019]

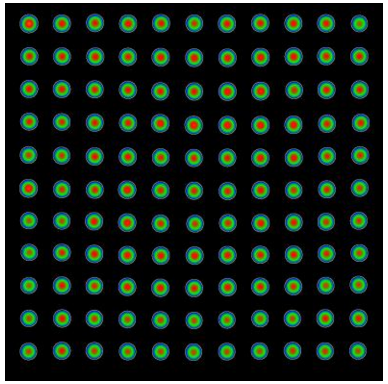
- data from C. Funke
- pictures from BB

Corrigendum 1, 2020-02

$UGR_{corrected}$ = UGR + DUGR







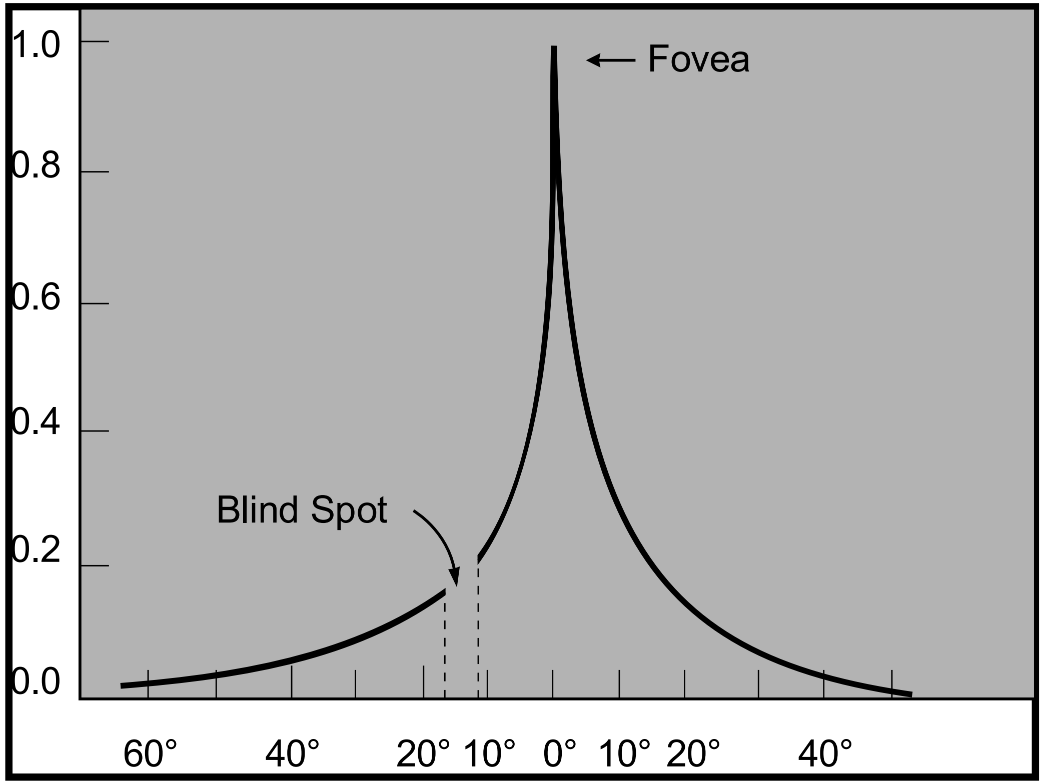
$L_m \approx 500$ cd/m^2
$A = 0.36$ m^2

$L_{eff} \approx 1900$ cd/m^2
$A_{p,eff} \approx 0.072$ m^2

DUGR = 3.56

[CIE 232-2019] "Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Luminance", CIE: Wien, 2019.
[LiTG 46-2022] Funke, Carsten: „Das UGR-Verfahren nach CIE 232:2019. Praktische Anwendung des korrigierten Verfahrens", LiTG, 2022.

Visual acuity



relative acuity of the human eye on the horizontal meridian, Vanessa Ezekowitz / Wikimedia

angular resolution ≈ (1 + ε)/100 [°]

approximation from [CIE 232-2019]
ε ... angle to viewing direction [°]

examples:

- viewing direction (ε = 0°)
  angular resolution 0.01°, visual acuity 1.67
- ε = 60°
  angular resolution 0.61°, ~2 x 0.3°, ~ angular diameter of sun, factor 61, visual acuity 0.027

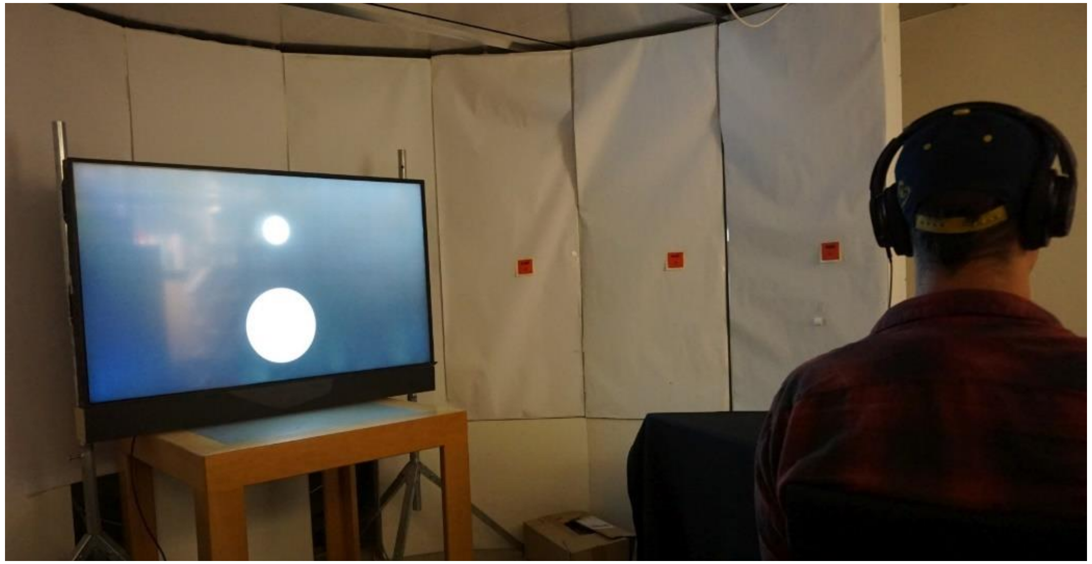
Visual acuity $\approx \frac{1.67}{1+\varepsilon}$

[CIE 232-2019] “Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Luminance”, CIE: Wien, 2019.

Visual perception test concernining glare in the periphery of the field of vision

Daylight Glare Probability DGP ([WIE 2010], [DIN EN 17037-2019]): $DGP = 5.87\ 10^{-5}\ E_v + 0.0918\ \log_{10}\left(1 + \sum \frac{L_{s,i}^2\ \omega_i}{E_v^{1.87}\ p_i^2}\right) + 0.16$

- no range of validity specified for solid angles of glare sources
- aspired goal: method to account for tiny glare sources without changing results for other situations (DGP highly successful)



Monitor with circular discs in the peripheral field of view, viewing direction 75° horizontal to the right

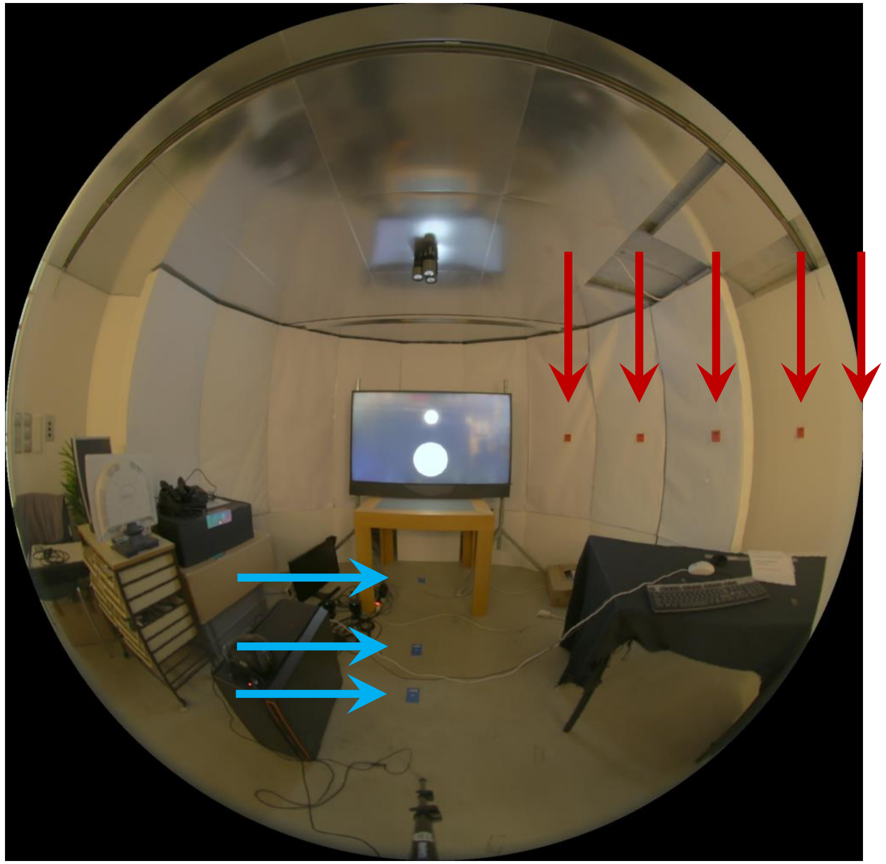
Question: At what size can a visual stimulus in the peripheral visual field be clearly distinguished from smaller visual stimuli?

Visual stimuli: circular discs on an ultra-high bright monitor (luminance up to 5000 cd/m^2)

five horizontal viewing directions (30° / 45° / 60° / 75° / 90°)
three vertical viewing directions (30° / 45° / 55°)

[WIE 2010] Wienold, Jan: „Daylight Glare in Offices“, Fraunhofer Verlag: Stuttgart, 2010.
[DIN EN 17037-2022] „Tageslicht in Gebäuden“, DIN: Berlin, 2022.

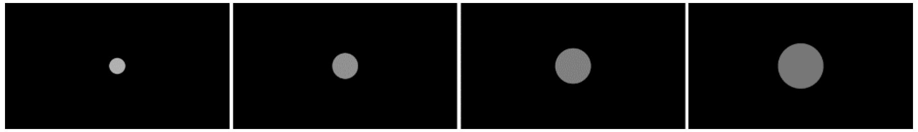
Visual perception test, experimental design



horizontal and vertical viewing directions

horizontal viewing directions: 30° / 45° / 60° / 75° / 90° to the right
vertical viewing directions: 30° / 45° / 55° down

experimental design 1:
Continuous change of size of the circular discs

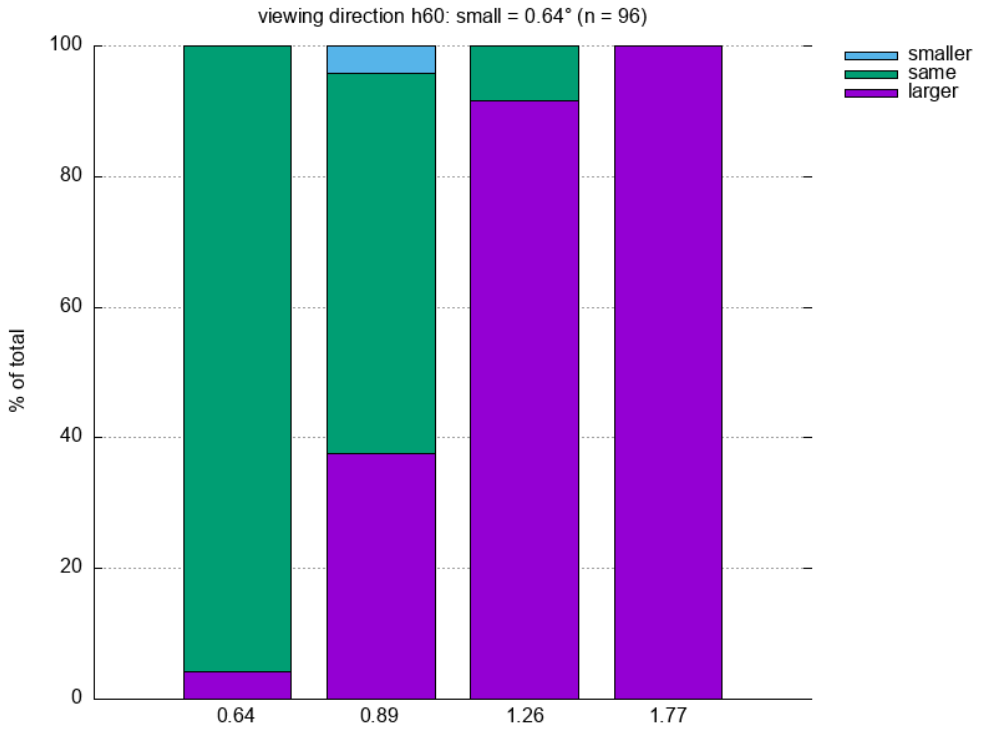


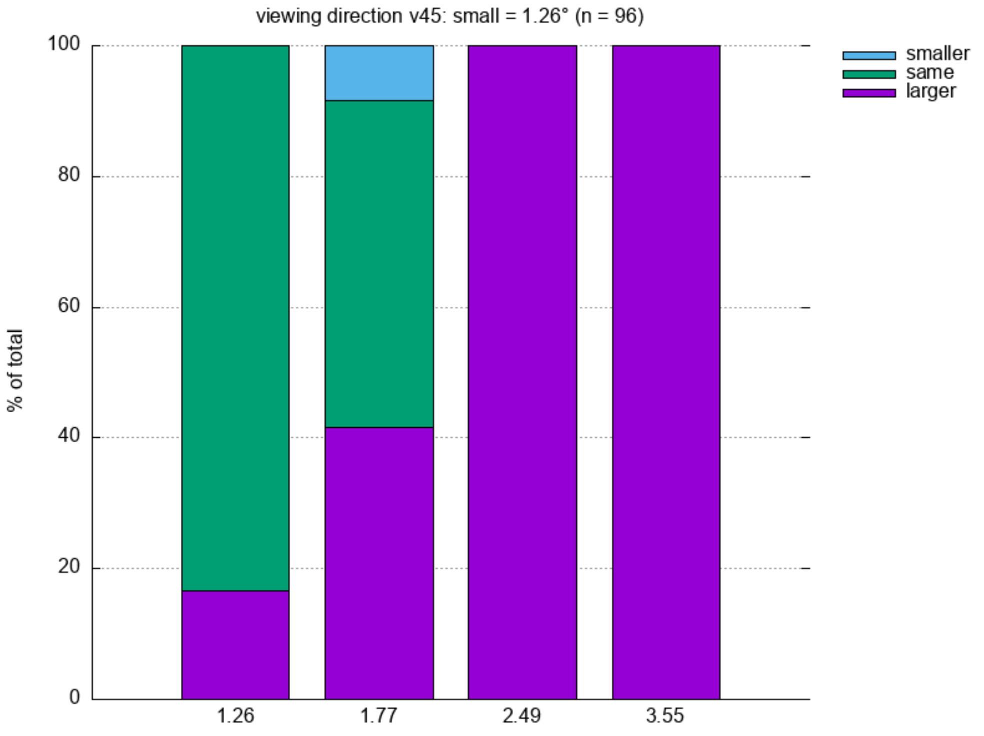
Avoiding the dark phase between the presentation of the first and the second circular disc.

experimental design 2:
Simultaneous presentation of the circular discs.
See photo.

Experimental design 1: Continuous change of size of the circular discs

Decision whether the visual stimulus becomes larger or smaller or remains the same size.

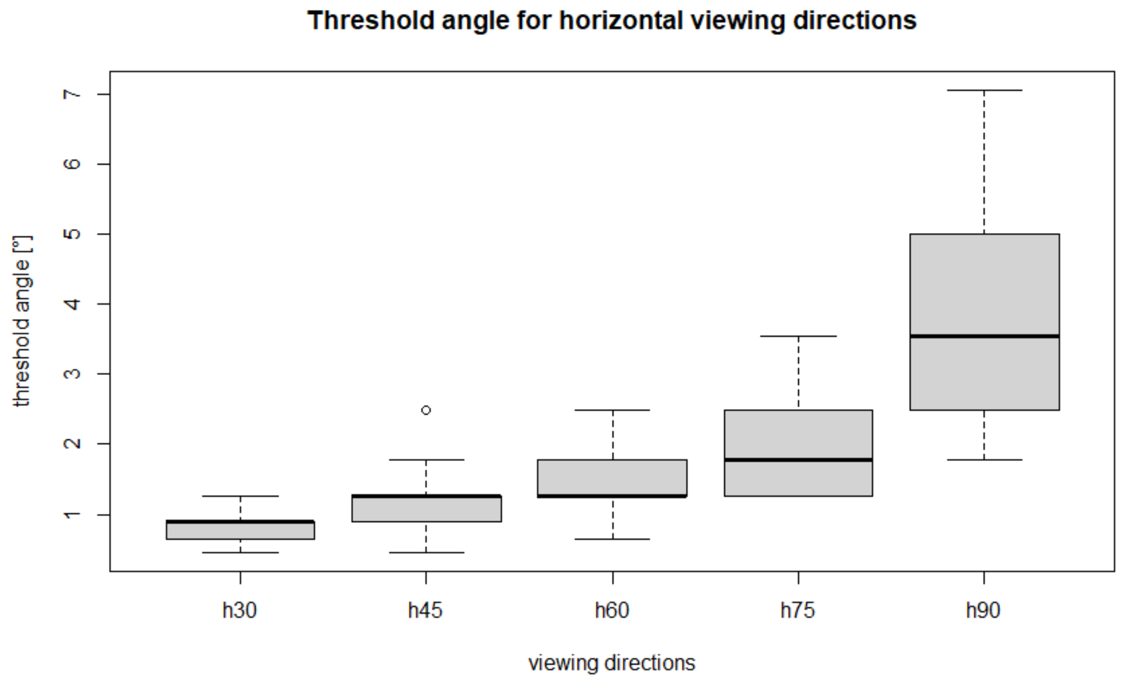




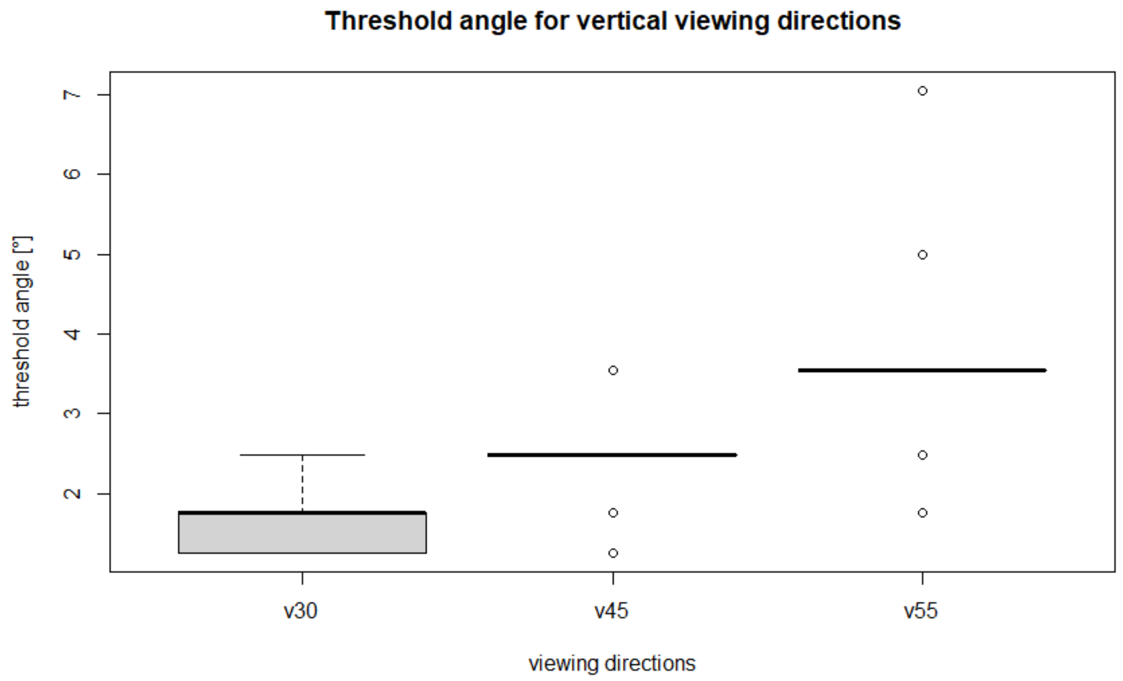
Experimental design 1: One subject each for viewing directions 60° to the right and 45° downward for (96 trials per subject and viewing direction; examples).

Experimental design 1: Continuous change of size of the circular discs

Statistical analysis



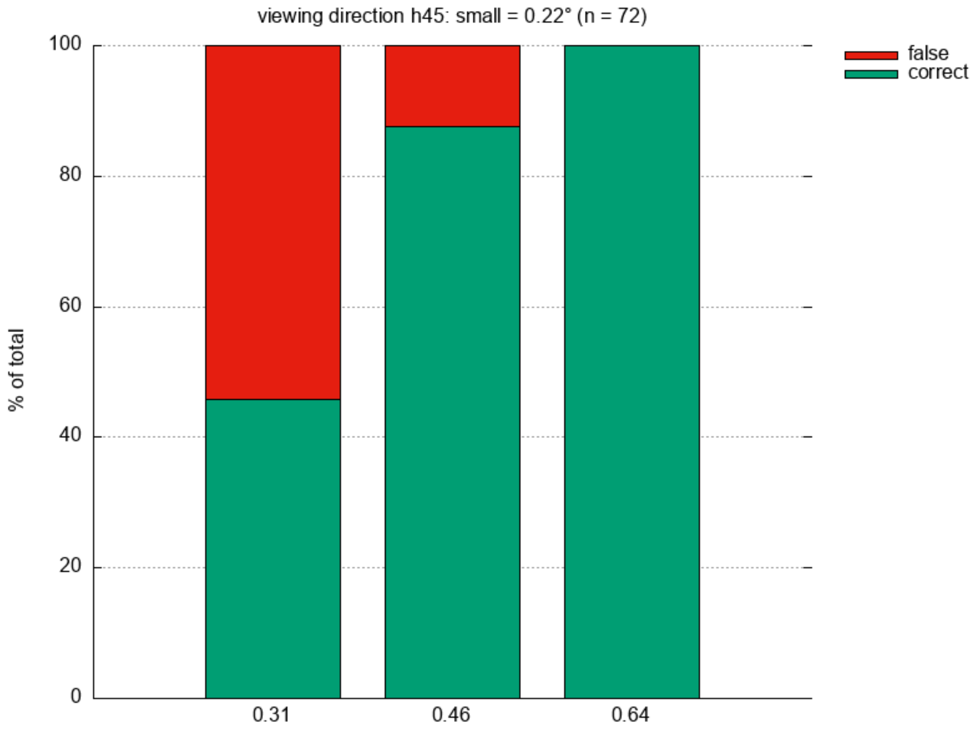
Boxplots threshold angles: Horizontal viewing directions (30°/45°/60°/75°/90°)

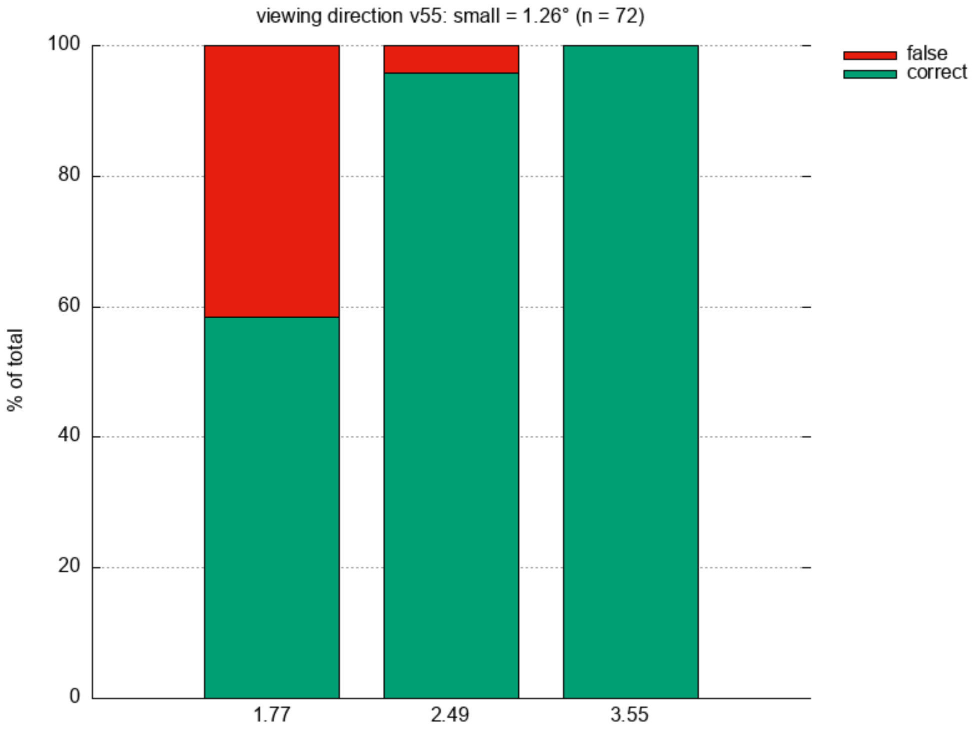


Boxplots threshold angles: Vertical viewing directions (30°/45°/55°)

Experimental design 2: Simultaneous representation of the circular discs

Specify arrangement of circular disks (small ⇒ large, large ⇒ small), circular disks of different sizes.

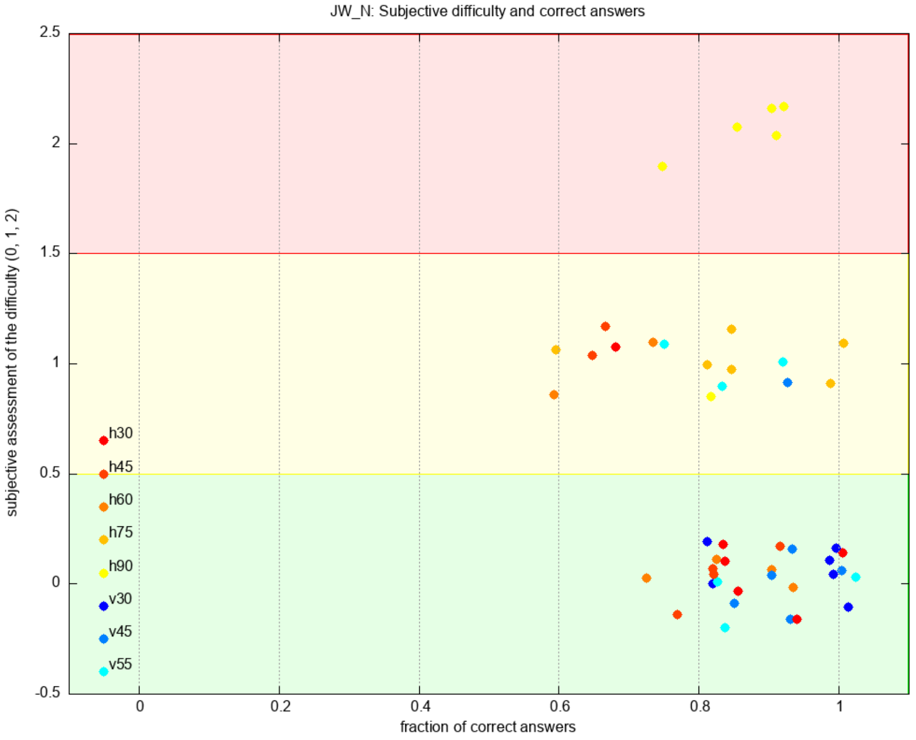


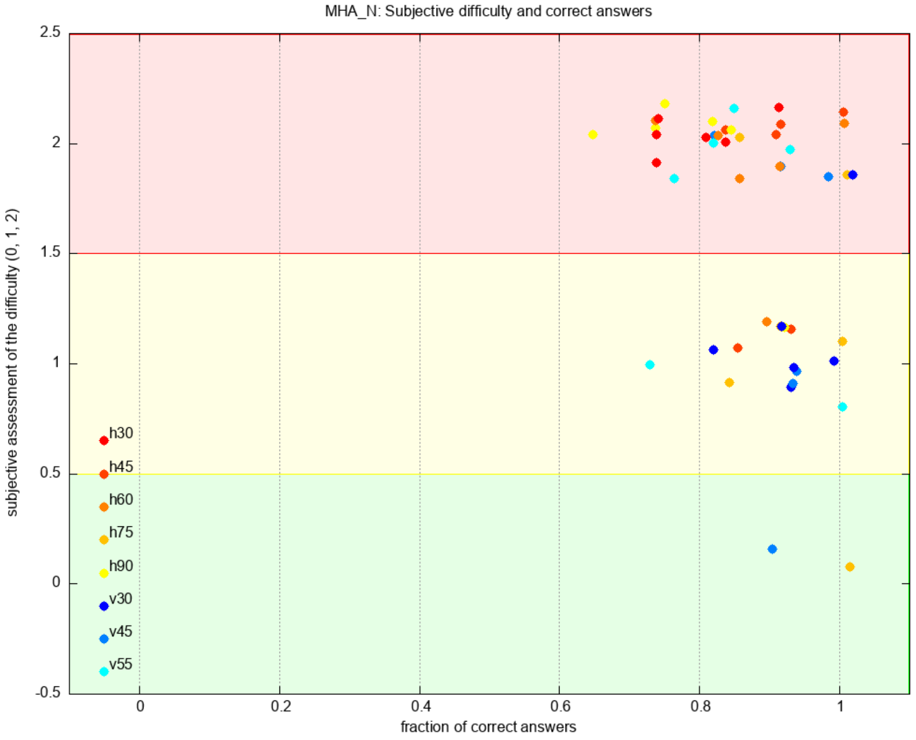


Experimental design 2: One subject each for gaze directions 45° to the right and 55° downward (72 trials per subject and gaze direction; examples).

Experimental design 2: Subjective judgment of the difficulty of the task and correct answers

Task was: 0 .. easy, 1 .. moderate, 2 .. difficult

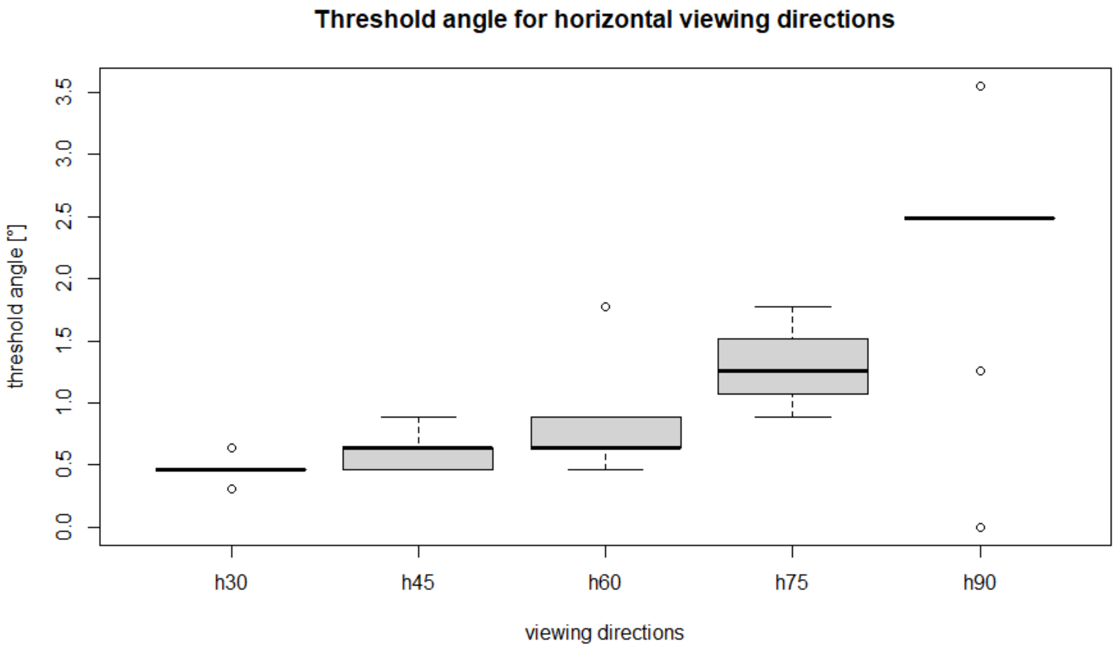




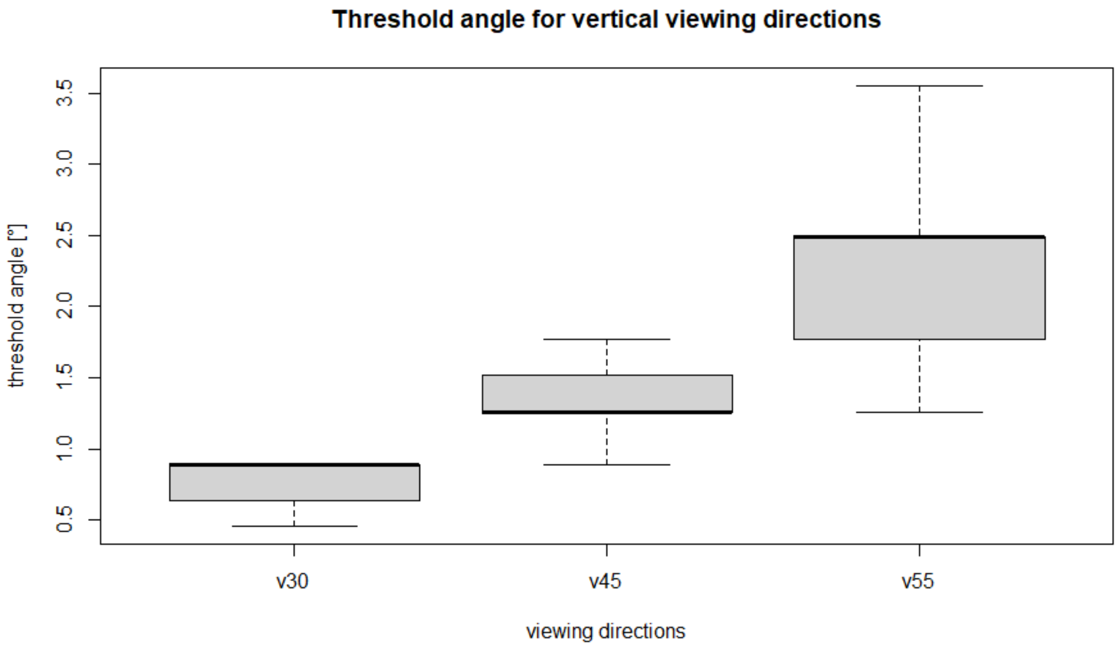
Experimental design 2: Subjective judgments of task difficulty (2 subjects from previous graph; examples).

Experimental design 2: Simultaneous representation of the circular discs

Statistical analysis



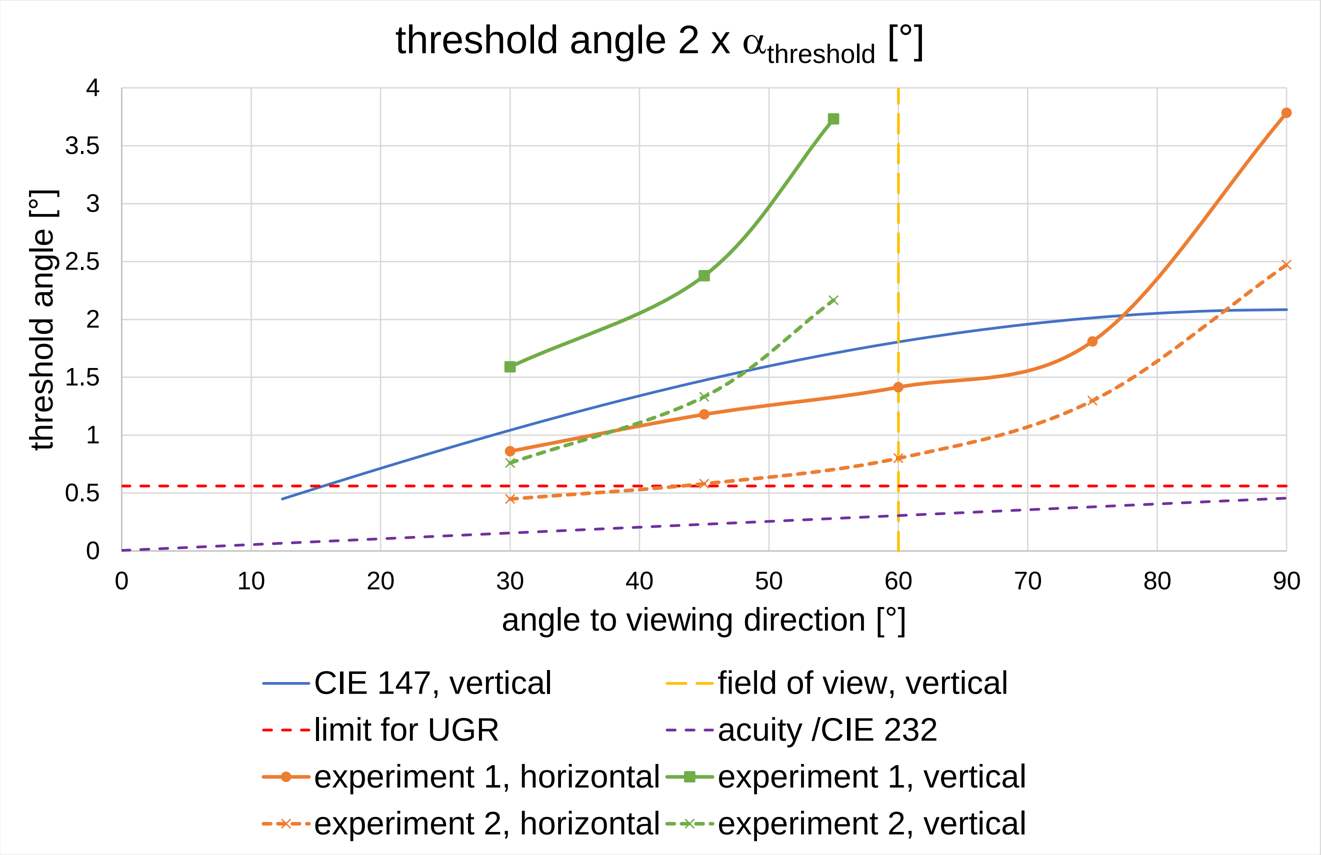
Boxplots threshold angles: Horizontal viewing directions (30°/45°/60°/75°/90°)



Boxplots threshold angles: Vertical viewing directions (30°/45°/55°)

Threshold angles in the periphery of the field of vision

Summary:



Threshold angles resulting from experimental designs 1 and 2 in comparison with previous approaches.

Modification of Daylight Glare Probability DGP

Daylight Glare Probability DGP

$$DGP = 5.87\ 10^{-5}\ E_v + 0.0918\ \log_{10}\left(1 + \sum \frac{L_{s,i}^2\ \omega_i}{E_v^{1.87}\ p_i^2}\right) + 0.16$$

E_v ... vertical eye illuminance [lx] (glare sources and background)

$L_{s,i}$ ... luminance of glare source [cd/m²]

ω_i ... solid angle of glare source [sr]

p_i ... position index of glare source

Modification

$$DGP_{modified} = DGM = 5.87\ 10^{-5}\ E_v + 0.0918\ \log_{10}\left(1 + \sum \frac{L_{s,i}^2\ \omega_i^2}{E_v^{1.87}\ p_i^2\ \omega_i^*}\right) + 0.16$$

where $\omega_i^* = \omega_i$ for $\omega_i \geq \omega_{threshold,i}$ and $\omega_i^* = \omega_{threshold,i}$ otherwise, with $\omega_{threshold,i} = 2\pi\left(1 - \cos\alpha_{threshold,i}\right)$

[CIE 117-1995]: „discomfort glare for very small sources is determined by intensity rather than by luminance“; $L_{s,i}\ \omega_i = E_{v,i} \cos\varepsilon_i$ with $E_{v,i}$ ... vertical eye illuminance glare source

Fit for $\alpha_{threshold}$ based on experimental design 2

$$\alpha_{threshold} = (\cos\alpha\,(\beta - 0.2309142785194501) + \beta - 0.284455917535076)^{2.026090437860844\,\beta} + 0.2386581294127632$$

α, β [rad]

$\alpha_{threshold}$ [°]

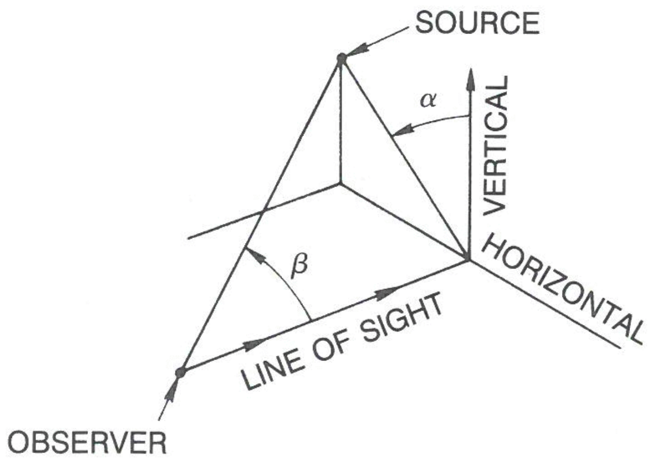
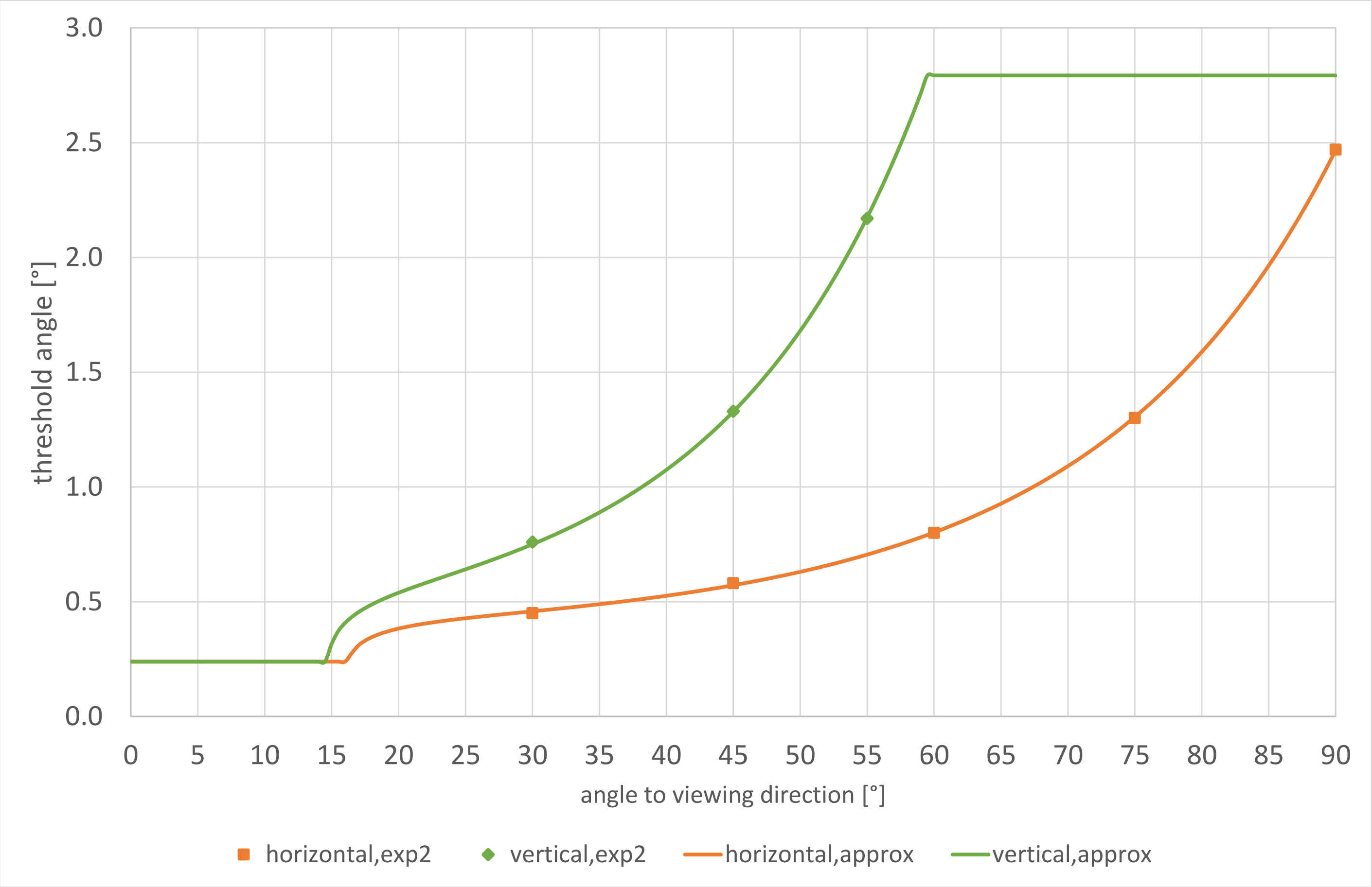


Fig. 9-17. Geometry defining position index as used in VCP calculations.

IES Lighting Handbook 1993, Ed. 8: angles used in defining the position index

Idea: Determine scaling factor for threshold to fit results of additional perceptual studies (designed to daylight situations).

Comparison fit for $\alpha_{threshold}$ with results experimental design 2



$\alpha_{threshold}$ [°] ≥ 0.24° (see constant term in fit)

scale with factor 1.75:

Maximum threshold comparable to experimental design 2

scale with factor 2.346:

$\alpha_{threshold} \geq 0.56°$

$$\omega^* \geq 2\pi\,(1 - \cos\alpha_{threshold}) = 0.0003$$

scale factor to be determined (study)

Next steps

The **proposed modification** of the **Daylight Glare Probability DGP** to better account for the effects of reduced visual acuity in the peripheral visual field will be **investigated in more detail** in a **perceptual study** as part of the still ongoing research project "Daylight glare and virtual reality " (GLARE, „Tageslicht-Blendung und Virtual Reality“).

The basic idea could also be applied to the **Unified Glare Rating UGR** and complement the adjustments described in [CIE 147-2002] and [CIE 232-2019].

Project team

Bartenbach GmbH, Research & Development

David Geisler-Moroder, Christian Knoflach, Wilfried Pohl, Claudia Teodora Konrad-Soare, Tobias Fischer (persons involved so far)

Research Project

"Daylight Glare and Virtual Reality" (FFG Early Stage, Project GLARE 878958)

[CIE 147-2002] “CIE Collection on Glare 2002. Glare from Small, Large and Complex Sources”, CIE: Wien, 2002.
[CIE 232-2019] “Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Luminance”, CIE: Wien, 2019.

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