What is the (relevant) size of the sun?

Glare in the peripheral field of view

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Motivation

There are situations where we like having direct sun in the field of view…

Motivation

… but there are other situations in which this is not the case.

Motivation

Users react …

Motivation

Users react …

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 17037

December 2018

ICS 91.160.01

English Version

Daylight in buildings

5.4 Protection from glare

5.4.1 General

Glare is a negative sensation and the cause is br
luminance to which the eyes are adapted to

Annex E
(informative)

Glare

...t areas are located within the visual field or
... The perception of glare is dependent on the
strongly dependent on the spatial position ...

Table A.7 — Proposed different levels of threshold $DGP_{e<5\,\%}$ for glare protection

Level of recommendation for glare protection	$DGP_{e<5\,\%}$
Minimum	0,45
Medium	0,40
High	0,35

$$DGP = 5,87 \times 10^{-5} \times E_v + 9,18 \times 10^{-2} \times \log\left(1 + \sum_i \frac{L_{s,i}^2 \times \omega_{s,i}}{E_v^{1,87} \times P_i^2}\right) + 0,16$$

… and standardization follows, and calls for accurate daylight and glare simulations.

In cases of multiple possible positions of activities, the expected worst case position should be investigated. These positions are usually close to the façade and/or where you can expect view connection to a low sun position. If the glare criteria are fulfilled for the worst case position(s) within a space, they are fulfilled within the utilized area of space.

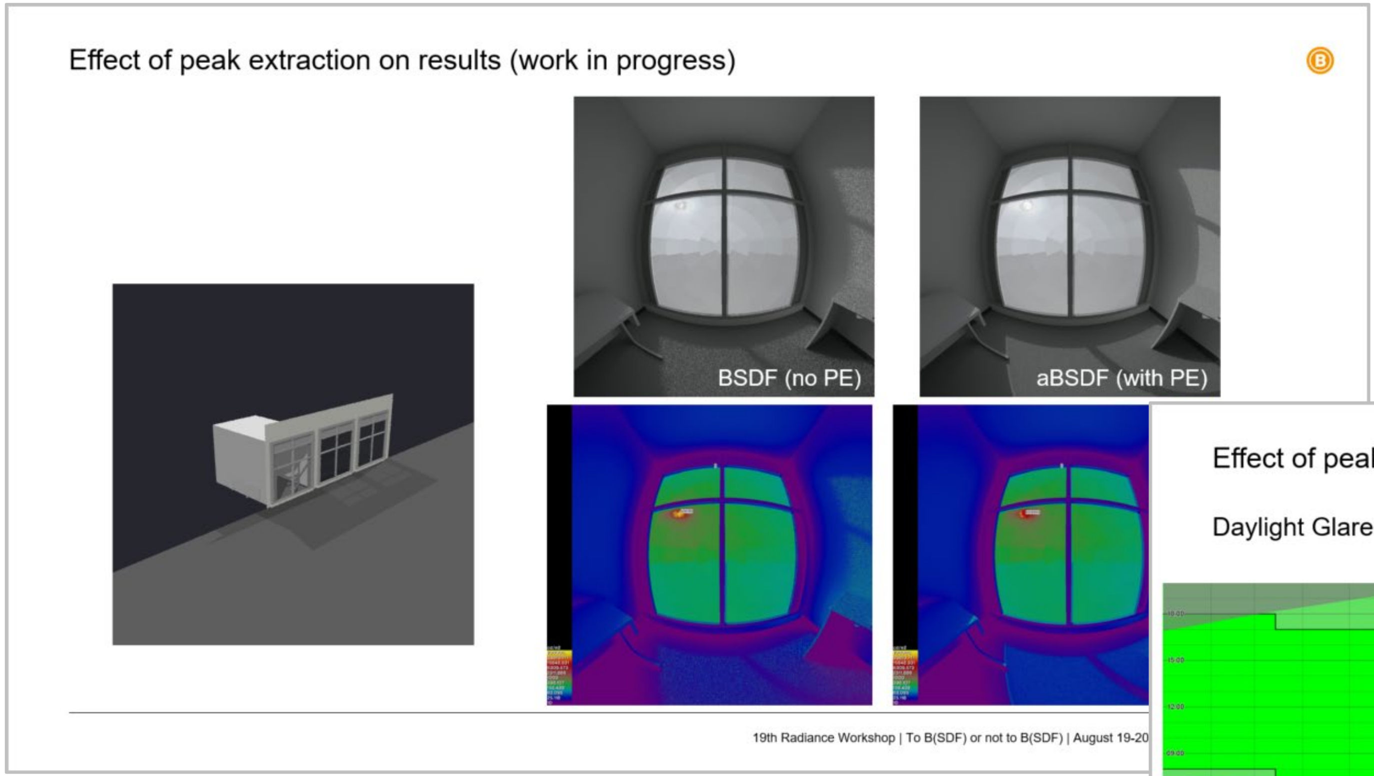
NOTE 1 *DGP* can be applied to any daylight oriented indoor space which is mainly side-lit and where the expected activities are comparable to reading, writing or using display devices. *DGP* is not applicable to assess daylight glare for spaces with horizontal daylight openings.

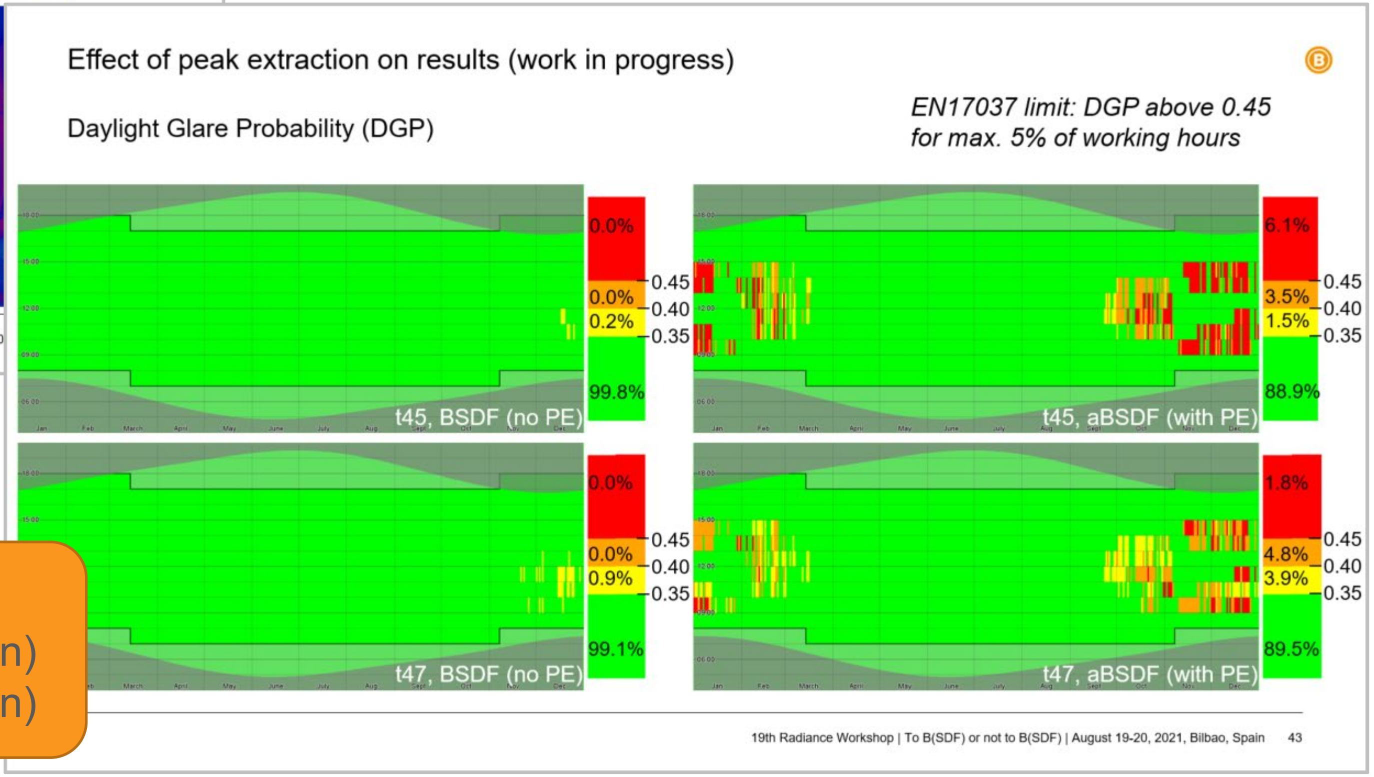
NOTE 2 *DGP* cannot be applied to situations, where it can be expected that the vertical illuminance is not a good indicator for the glare perception; such situations include for example vending areas of shops, sport halls and deep or dark spaces with very small openings. Furthermore, the *DGP* method cannot be applied to positions in a space, which are far away from the daylight openings or which have low daylight levels.

E.3 Annual evaluation

E.3.1 General

Workshop 2021





- Sun: ~ 2x0.25°
- t45: ~ 2x2.53° (~ 90x sun)
- t47: ~ 2x0.63° (~5.6x sun)

LBNL Tests: Simulation vs. HDR photography

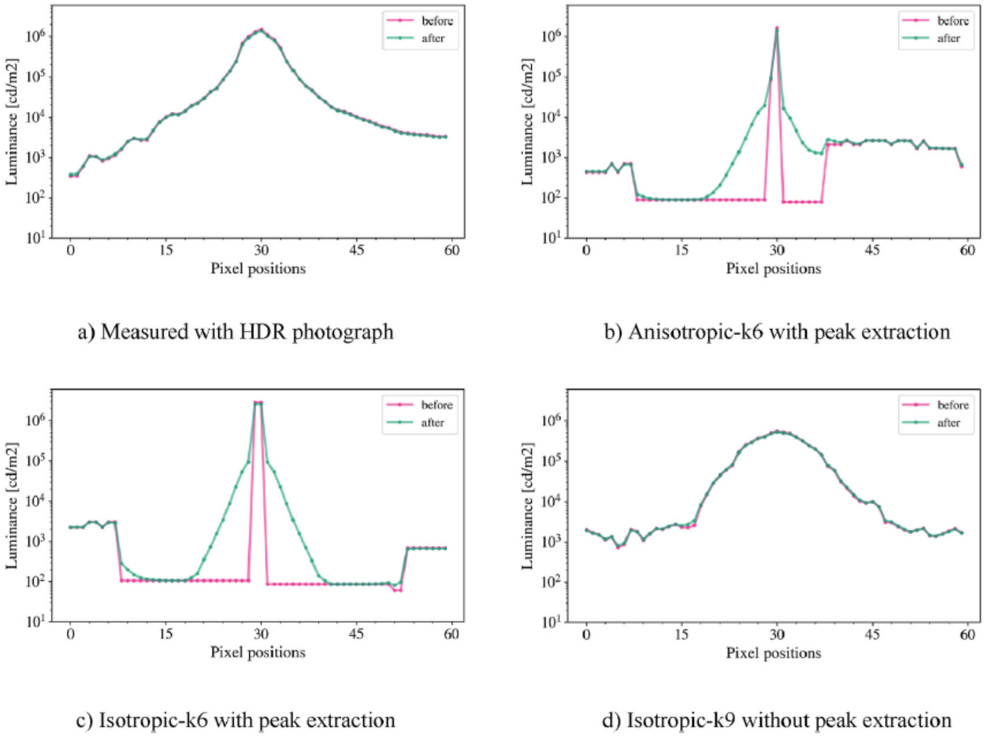
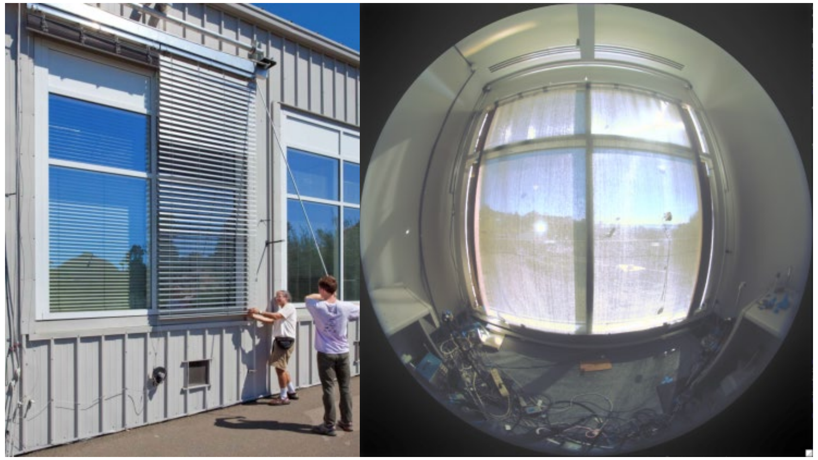


Fig. 10. Luminance (cd/m^2) profile before and after the blur filter was applied. The profile is for a section through the sun and circumsolar region of an HDR image generated by photography in the field (a) or by simulation (b–d) using various high-resolution BSDFs. The pink line is the luminance from the original HDR image. The green line is the luminance after the blur function was applied. If there is a sharp peak in the original distribution (as in the cases with peak extraction (b and c above), the blur function spreads the flux, reduces the peak, and conserves energy. The x-axis is pixel position, where pixel ~30 corresponds to the location of the solar disk and a 60 pixel width represents a 10° subtended angle. The y-axis is pixel luminance (cd/m^2). Label "k6" denotes BSDF resolution of k = 6. Source: LBNL. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)



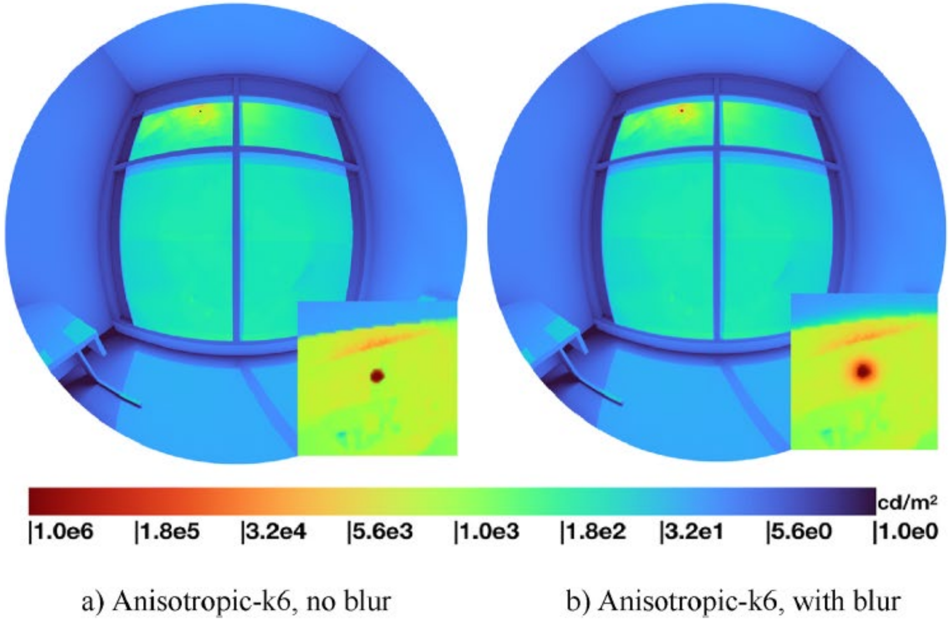


Fig. 11. Simulated HDR image before (left) and after (right) the blur filter was applied. The inset shows an enlarged view of the exclusion zone resulting from triggering of peak extraction (PE) with the sun orb in its center. Source: LBNL.

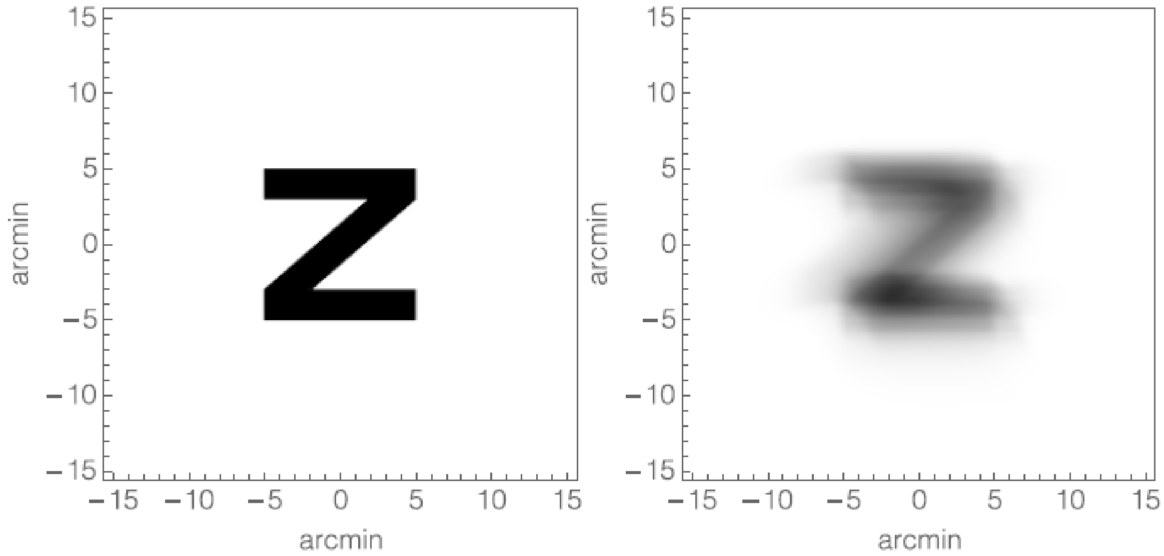
G: Ward et al., Modeling specular transmission of complex fenestration systems with data-driven BSDFs, Building and Environment 196, 2021

Related research

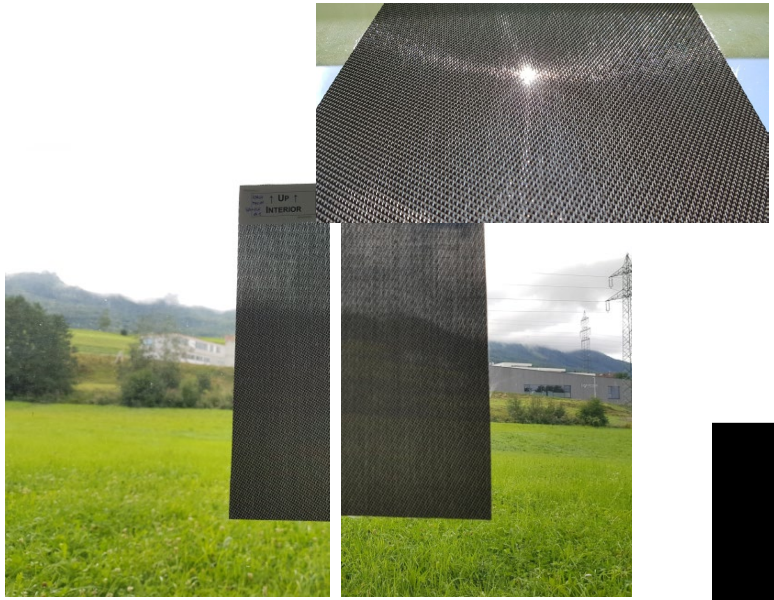
Point spread function of the human eye

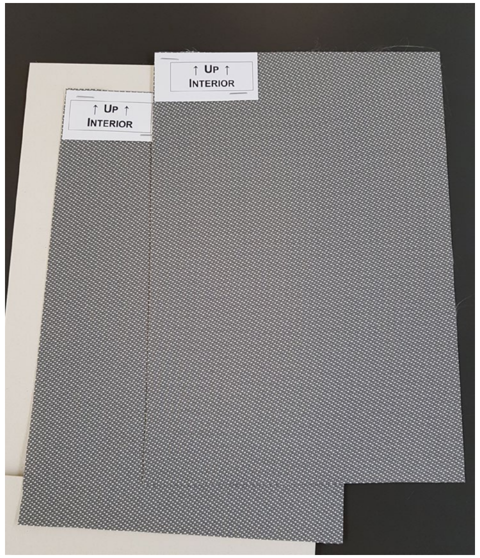
E.g.:

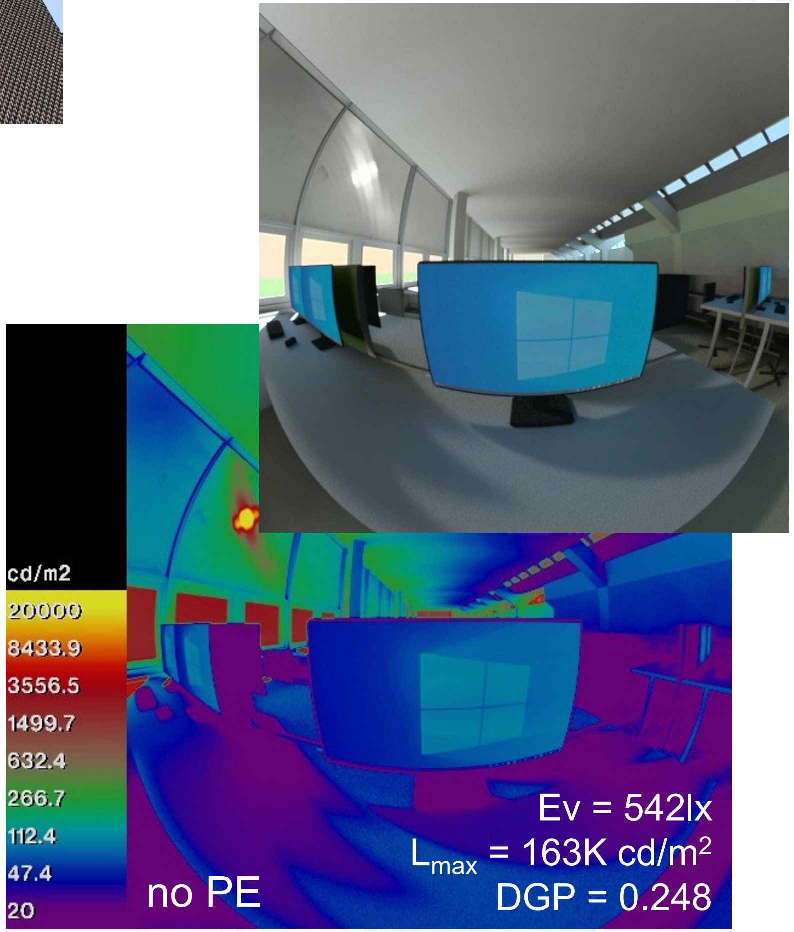
- Watson, A. B. (2015). Computing human optical point spread functions. Journal of Vision, 15(2):26, 1–25, http://www.journalofvision.org/content/15/2/26, doi:10.1167/15.2.26.

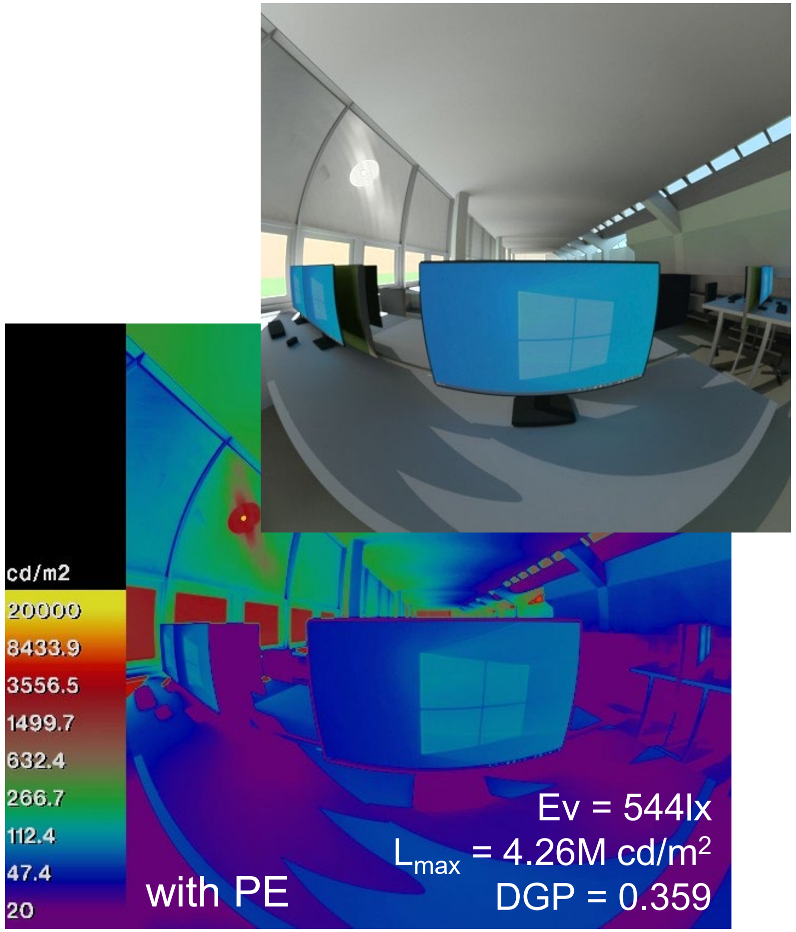


IEA SHC Task 61 Round Robin Test







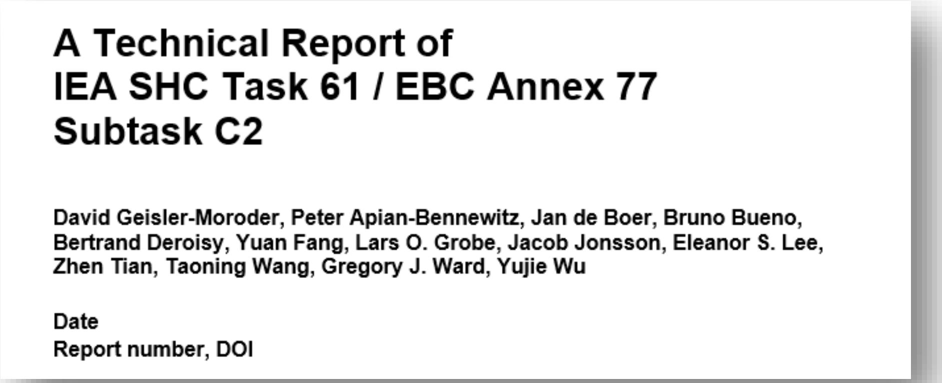


IEA SHC Task 61 / Annex 77
(Radiance Workshop 2021)

Report C.2 to be finished soon and published on

https://task61.iea-shc.org/publications

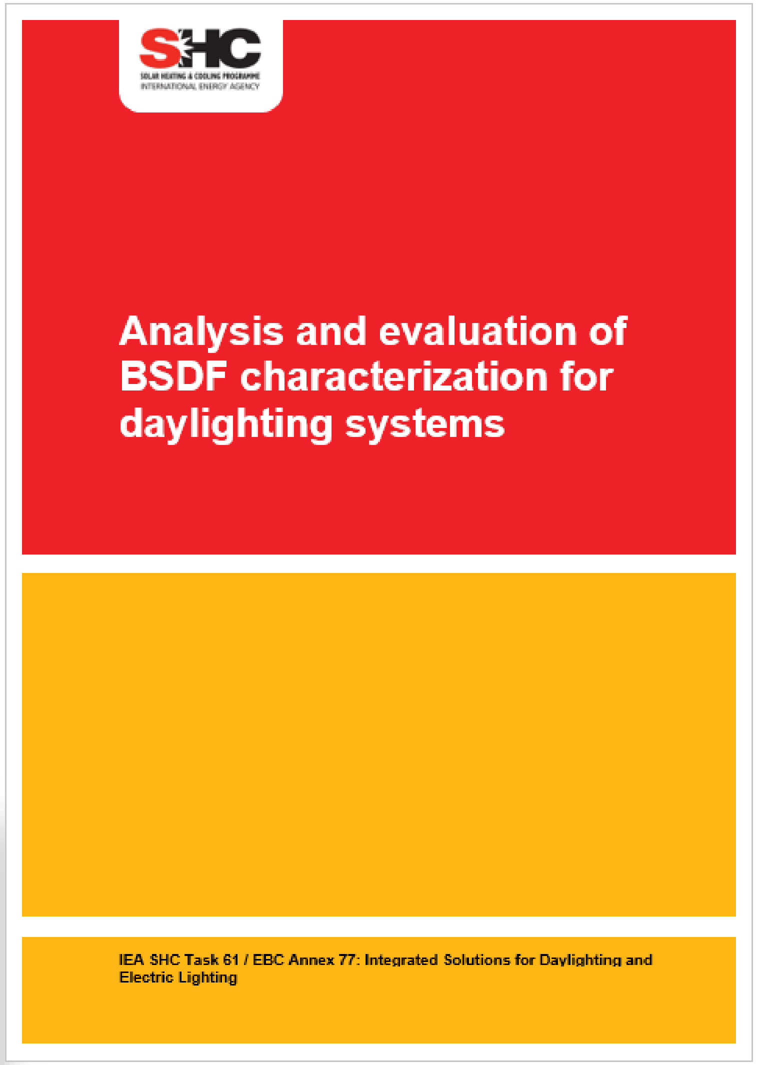
Stay tuned!



A Technical Report of
IEA SHC Task 61 / EBC Annex 77
Subtask C2

David Geisler-Moroder, Peter Apian-Bennewitz, Jan de Boer, Bruno Bueno, Bertrand Deroisy, Yuan Fang, Lars O. Grobe, Jacob Jonsson, Eleanor S. Lee, Zhen Tian, Taoning Wang, Gregory J. Ward, Yujie Wu

Date
Report number, DOI



IEA SHC Task 61 / Annex 77
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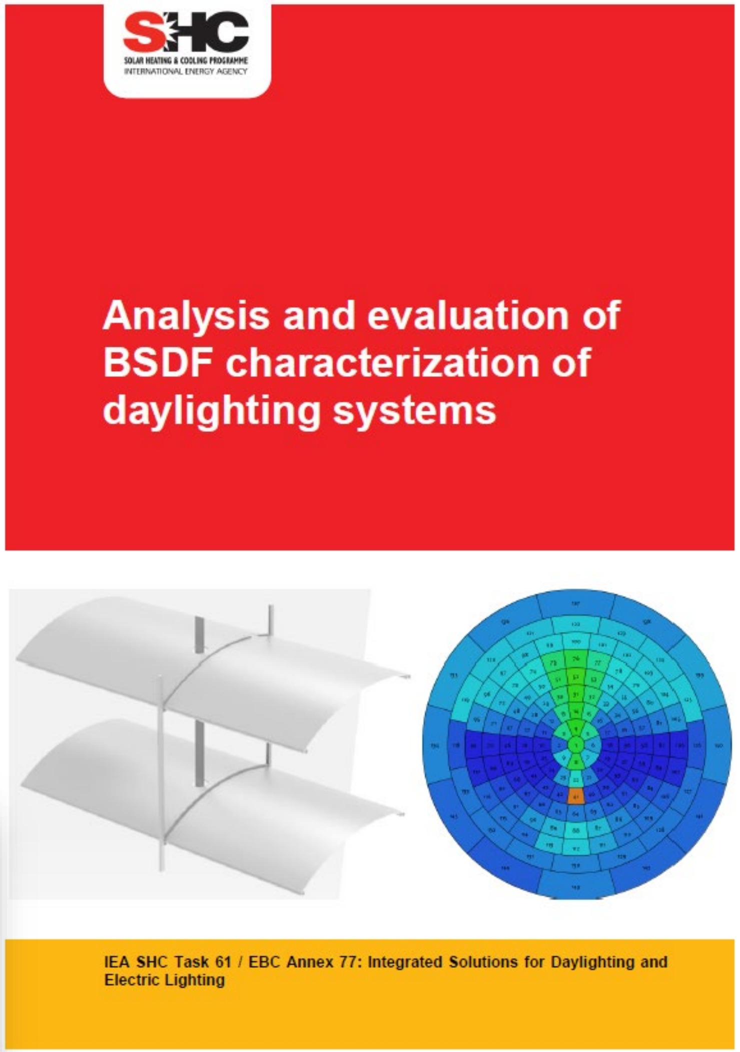

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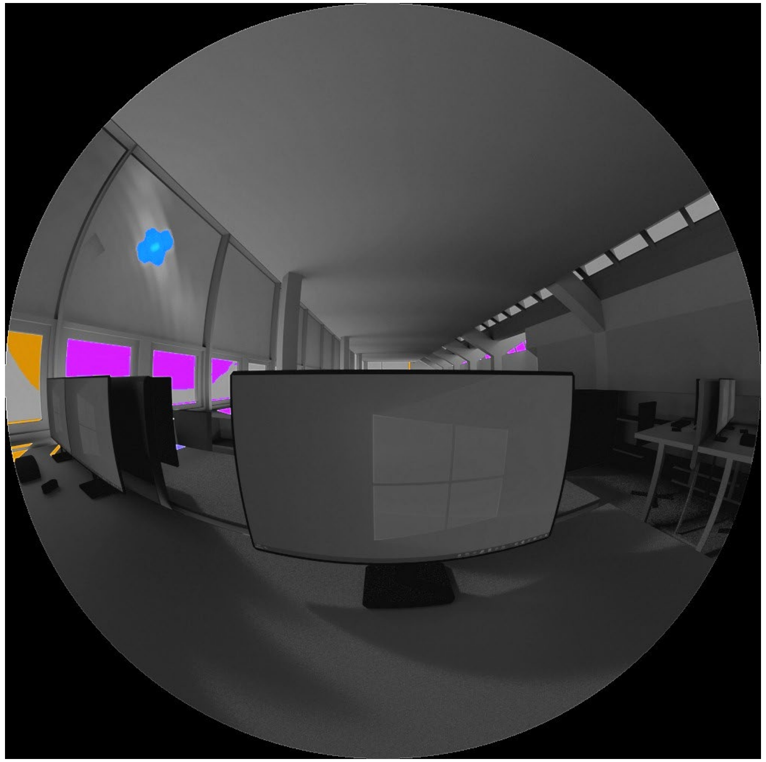
Date
Report number, DOI

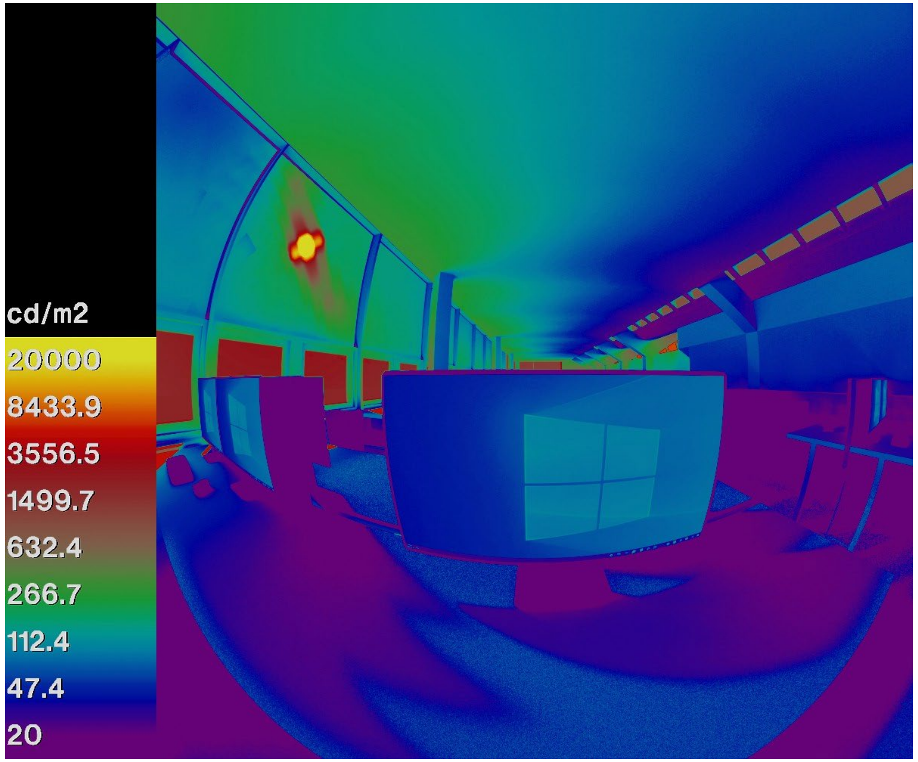
Test evaluations: averaging over area around glare source (without peak extraction (BSDF))

BSDF resolution:
-tt46, i.e. max. 4096x4096, ca. 2.53° (2 x 1.27°)

Averaging: none

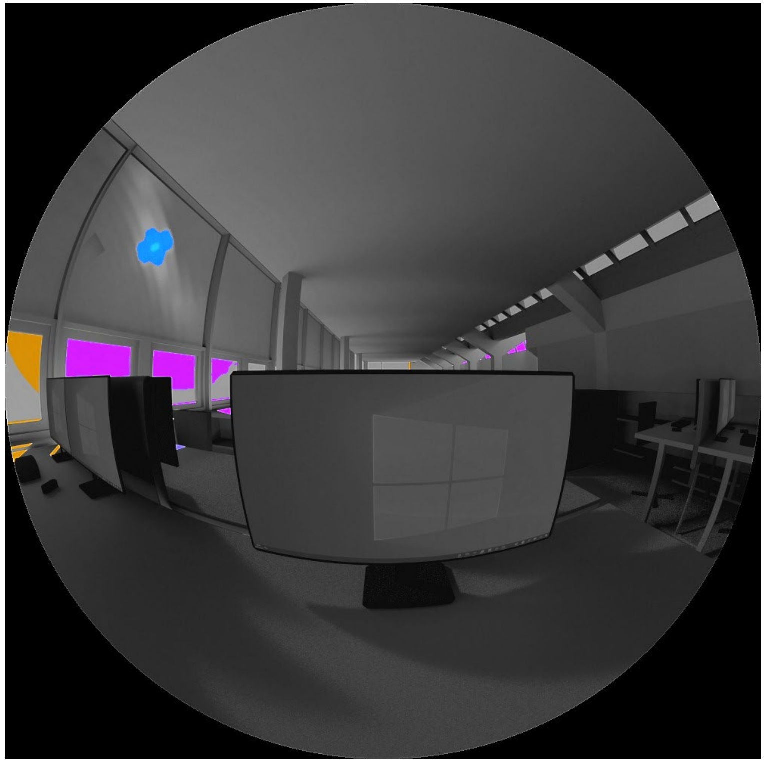


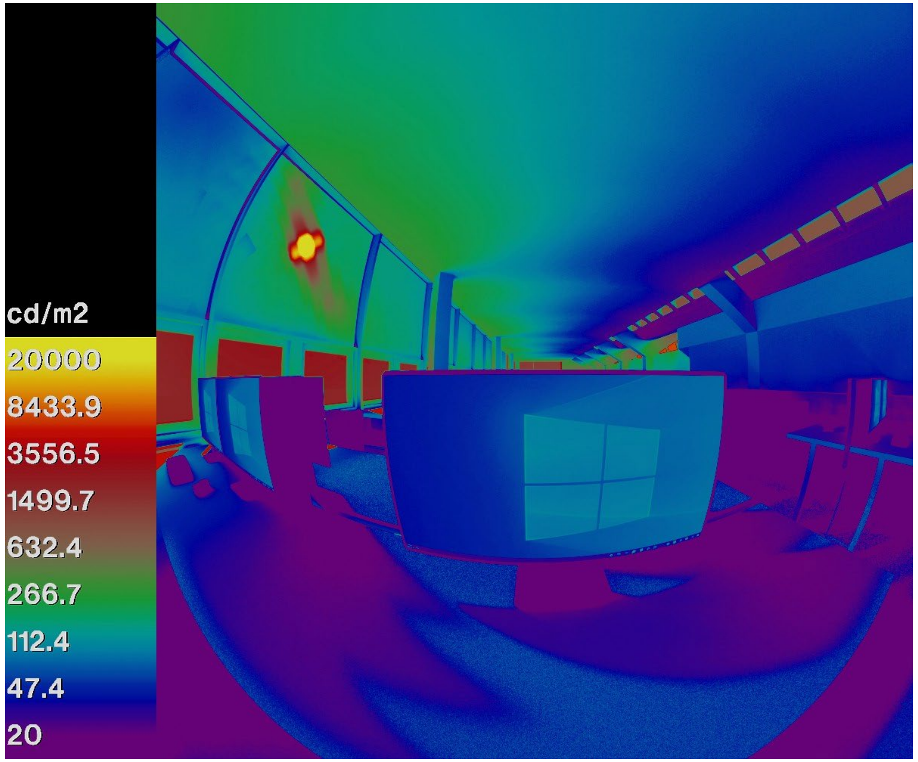
Ev = 542 lx
Ev_dir = 231 lx
DGP = 0.248



Test evaluations: averaging over area around glare source (without peak extraction (BSDF))

BSDF resolution:
-tt46, i.e. max. 4096x4096, ca. 2.53° (2 x 1.27°)





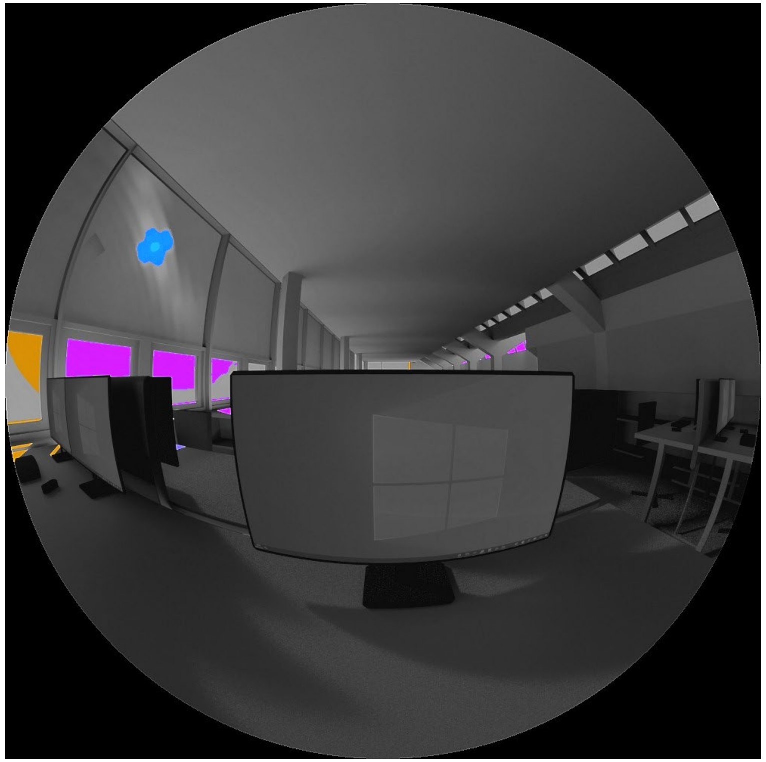
Averaging: 1° (2 x 0.5°)

Ev = 542 lx
Ev_dir = 231 lx
DGP = 0.248

Test evaluations: averaging over area around glare source (without peak extraction (BSDF))

BSDF resolution:
-tt46, i.e. max. 4096x4096, ca. 2.53° (2 x 1.27°)

Averaging: 2° (2 x 1.0°)



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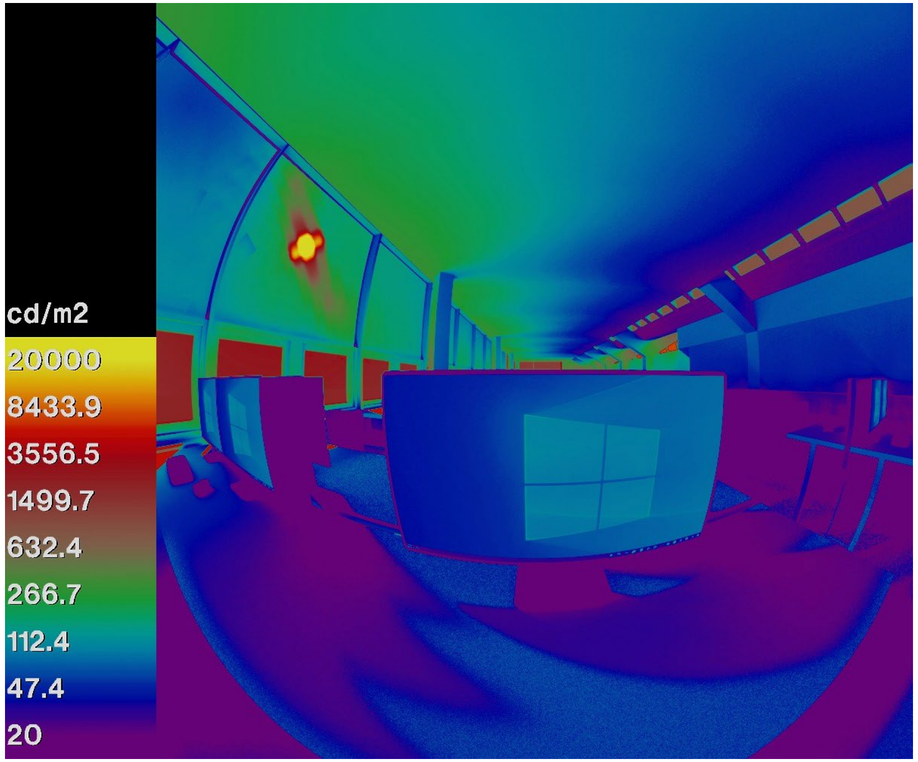
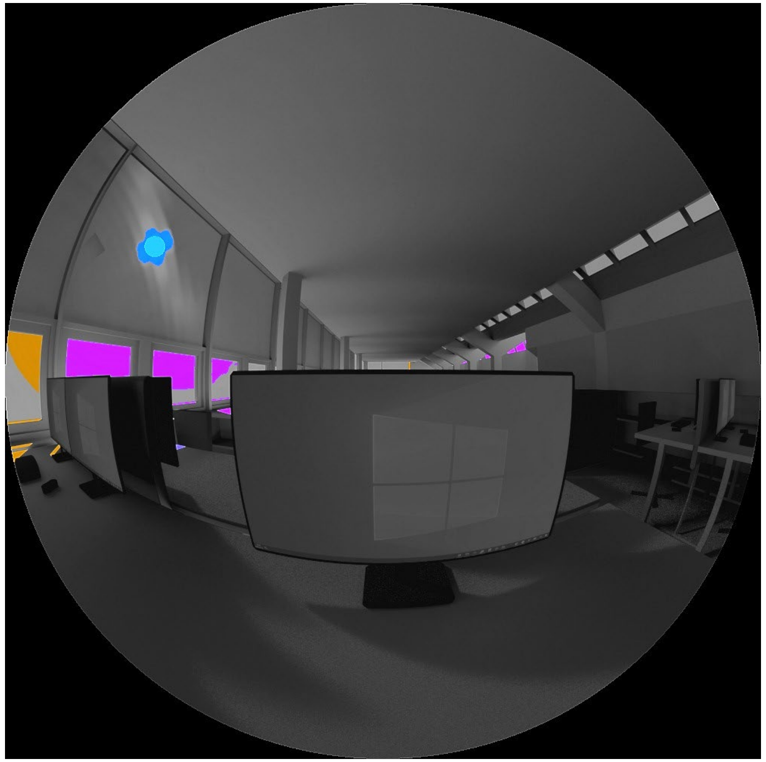


Test evaluations: averaging over area around glare source (without peak extraction (BSDF))

BSDF resolution:
-tt46, i.e. max. 4096x4096, ca. 2.53° (2 x 1.27°)

Averaging: 5° (2 x 2.5°)



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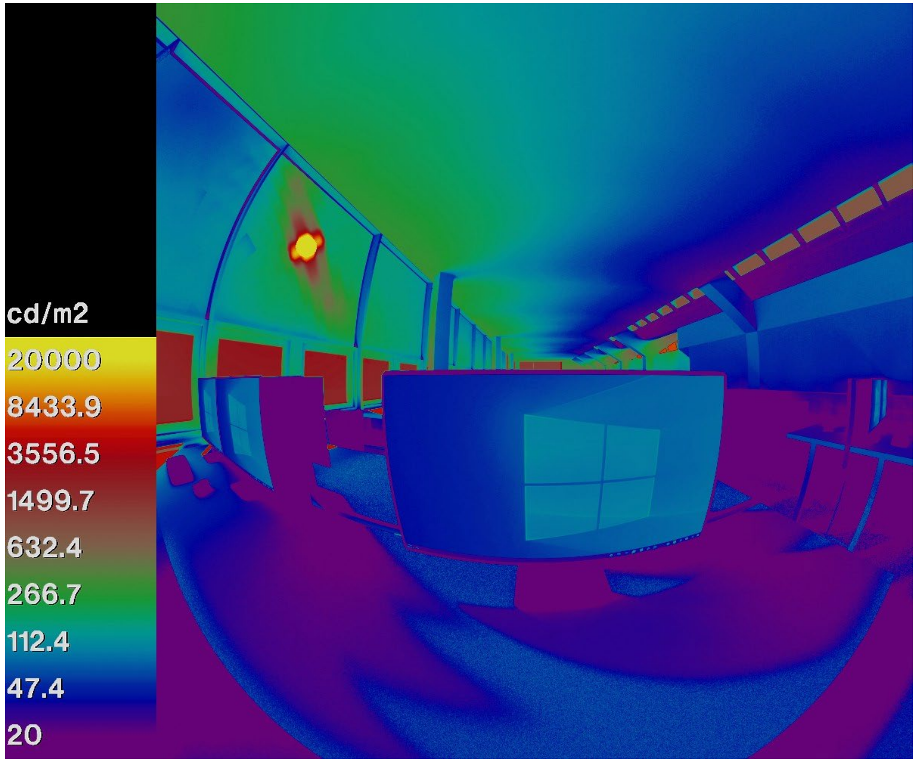
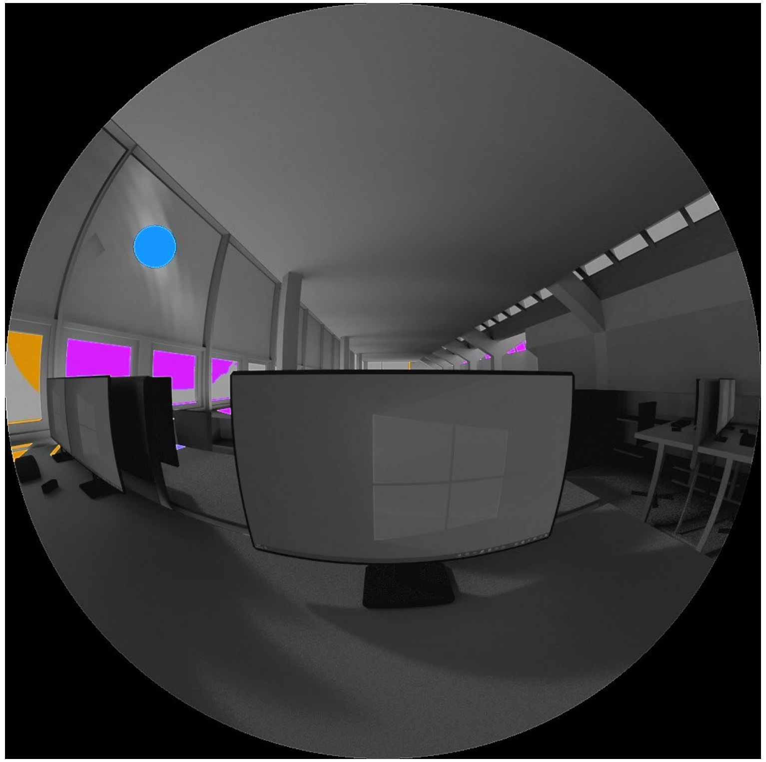


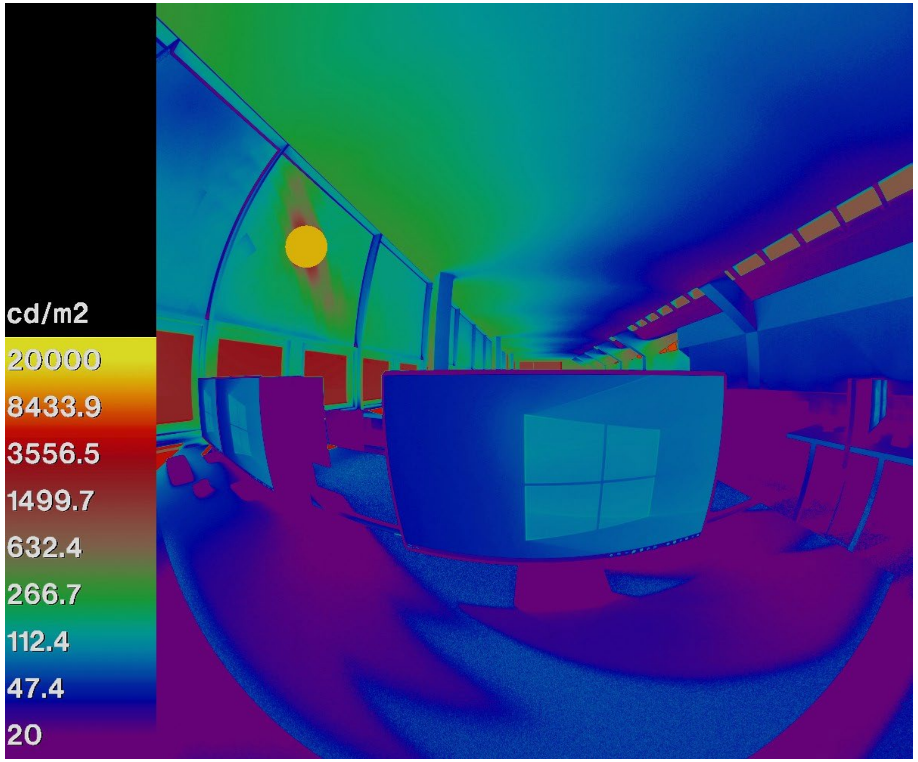
Test evaluations: averaging over area around glare source (without peak extraction (BSDF))

BSDF resolution:
-tt46, i.e. max. 4096x4096, ca. 2.53° (2 x 1.27°)

Averaging: 10° (2 x 5.0°)



Ev = 514 lx
Ev_dir = 206 lx
DGP = 0.217



Test evaluations: averaging over area around glare source (with peak extraction (aBSDF))

BSDF resolution:
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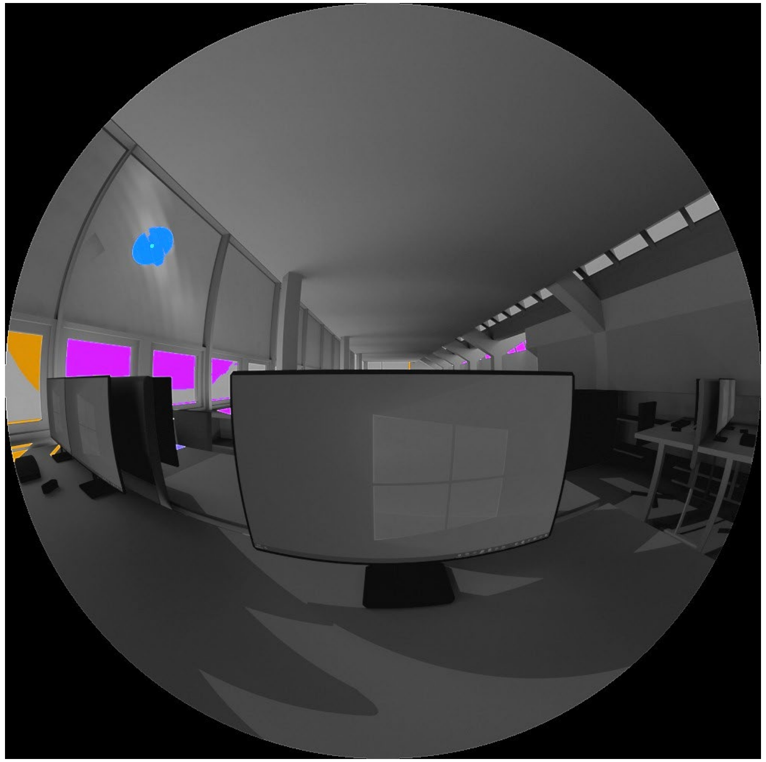
Averaging: none



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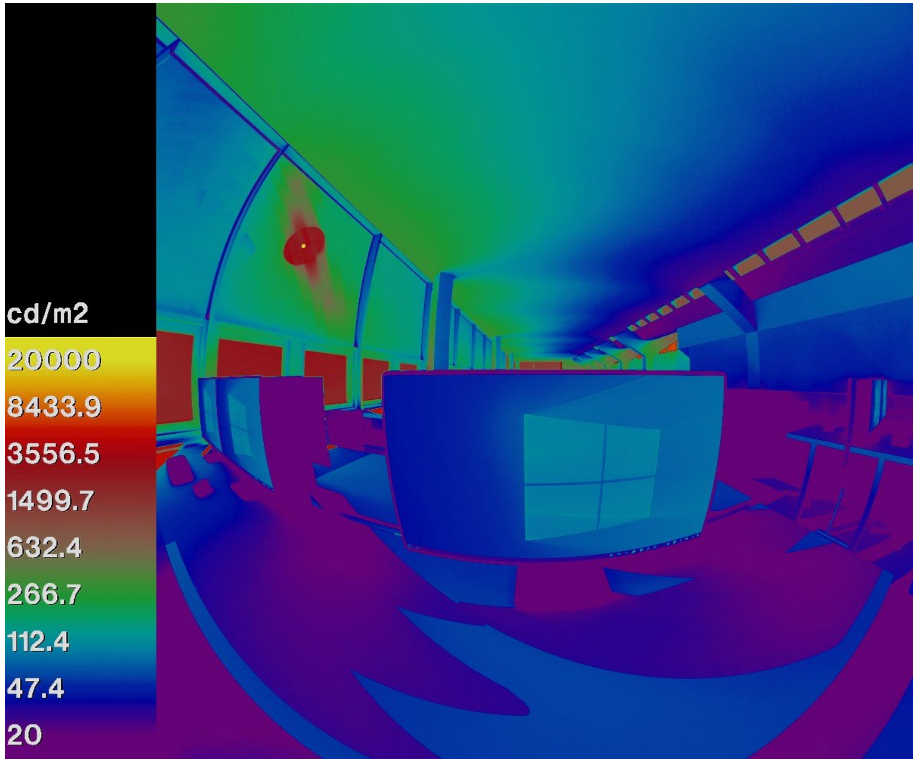

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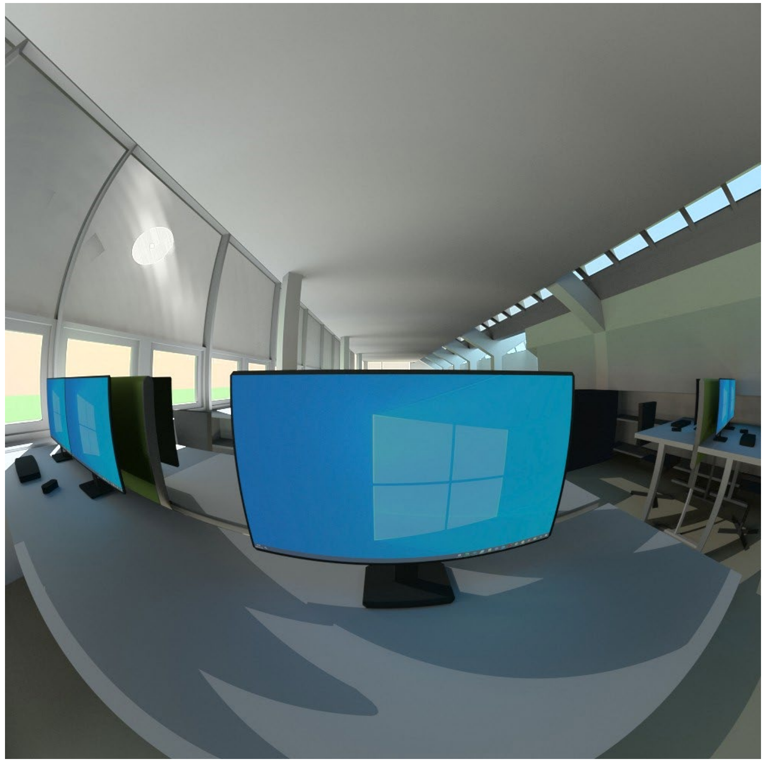
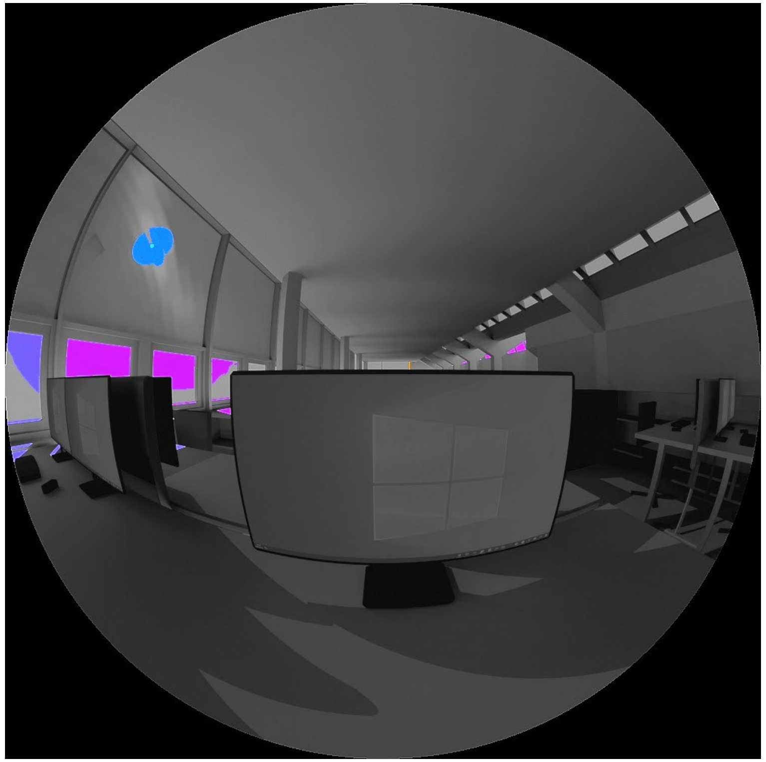
BSDF resolution:
-tt46, i.e. max. 4096x4096, ca. 2.53° (2 x 1.27°)



Averaging: 1° (2 x 0.5°)



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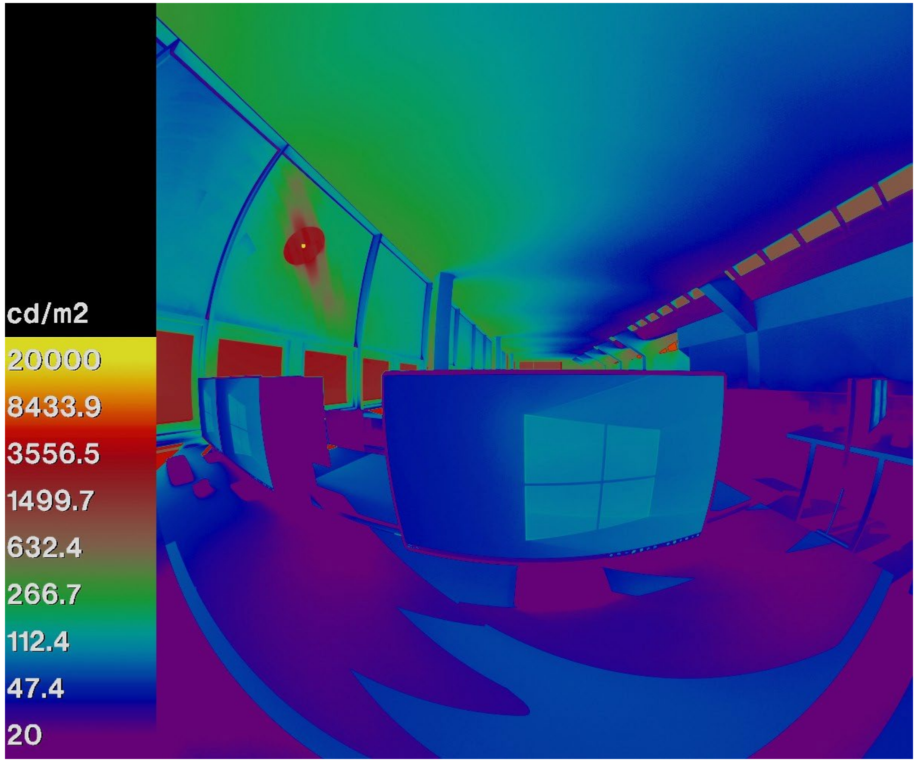
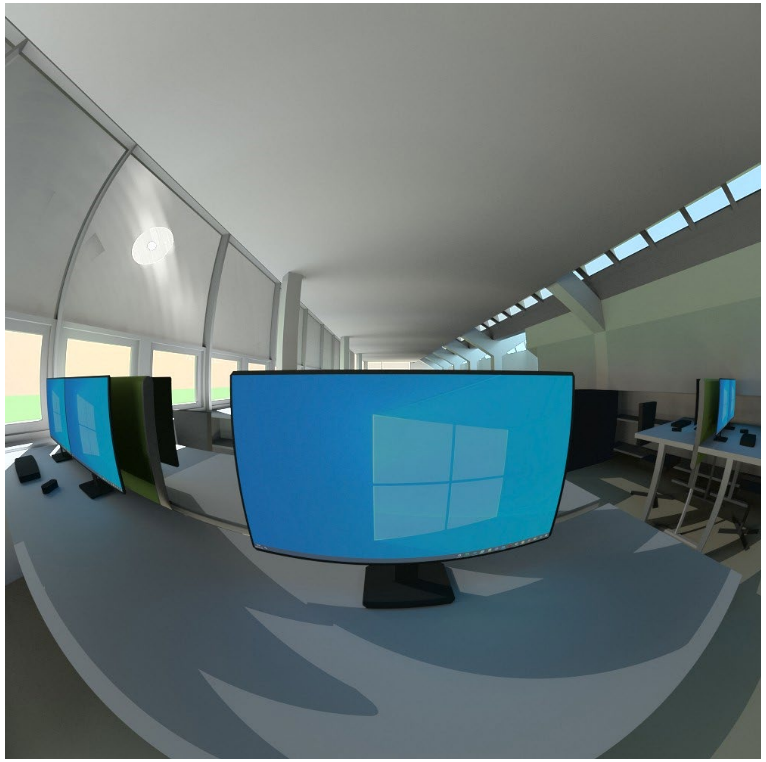
DGP = 0.33

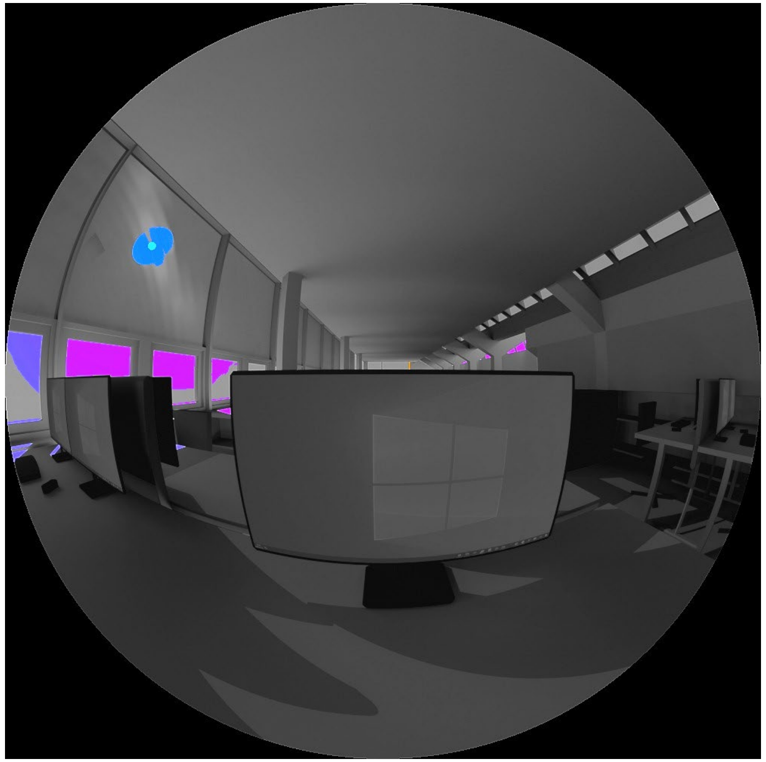


Test evaluations: averaging over area around glare source (with peak extraction (aBSDF))

BSDF resolution:
-tt46, i.e. max. 4096x4096, ca. 2.53° (2 x 1.27°)



Averaging: 2° (2 x 1.0°)



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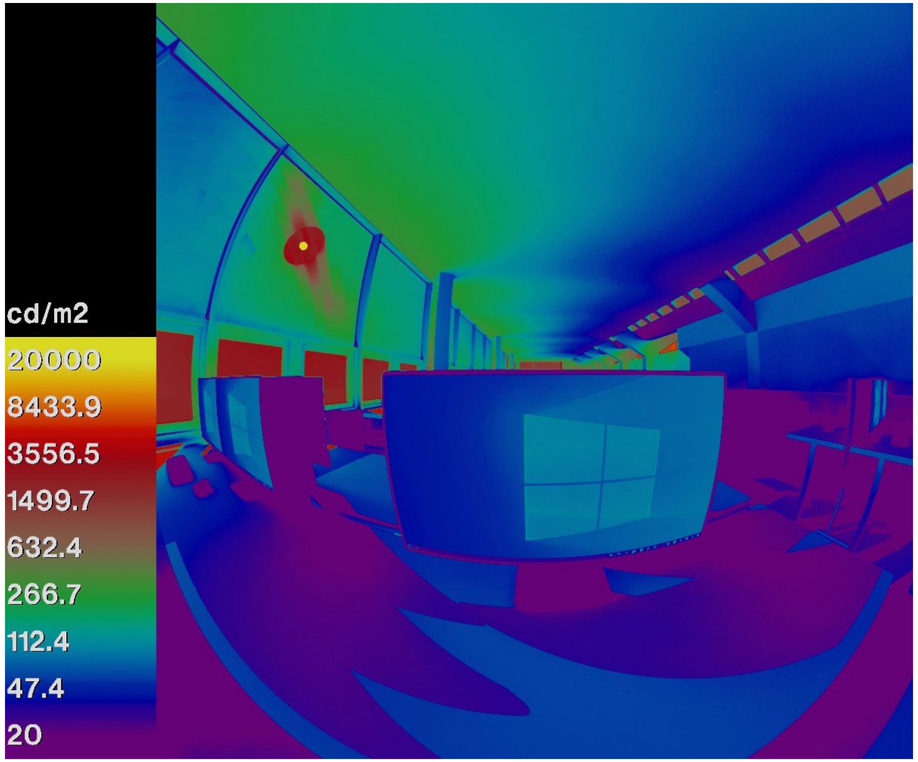
Ev_dir = 195 lx
DGP = 0.279



Test evaluations: averaging over area around glare source (with peak extraction (aBSDF))

BSDF resolution:
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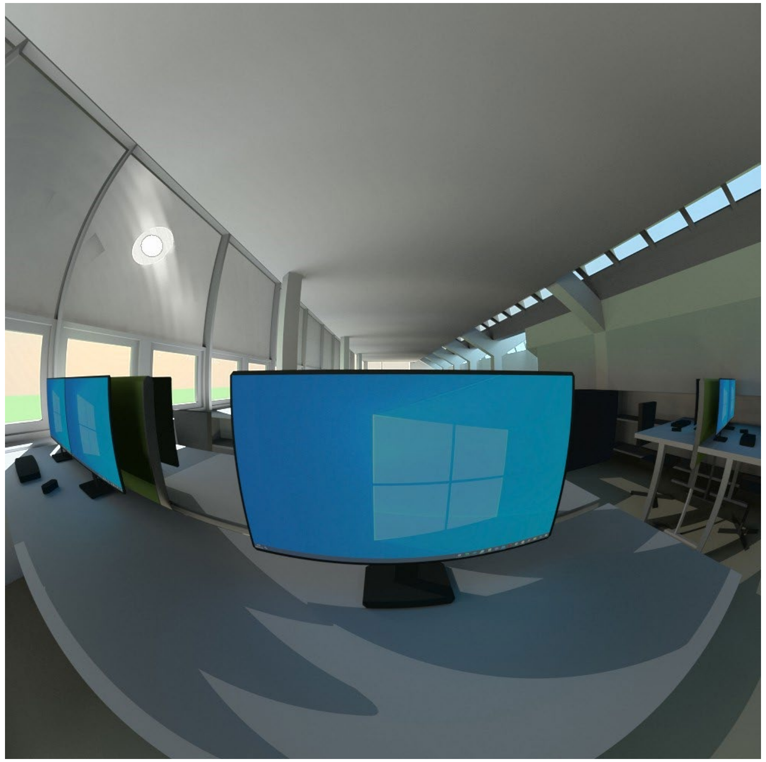
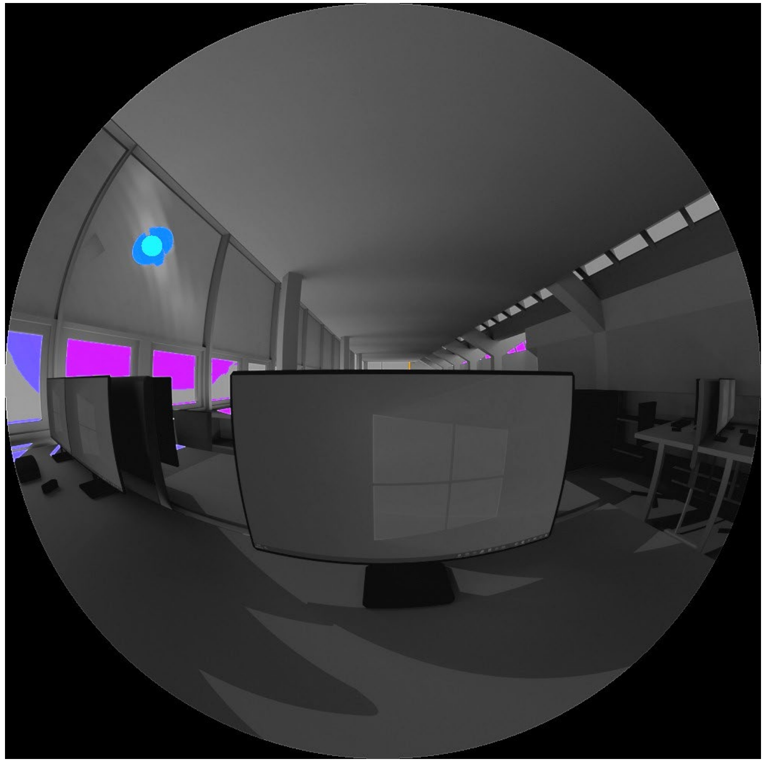
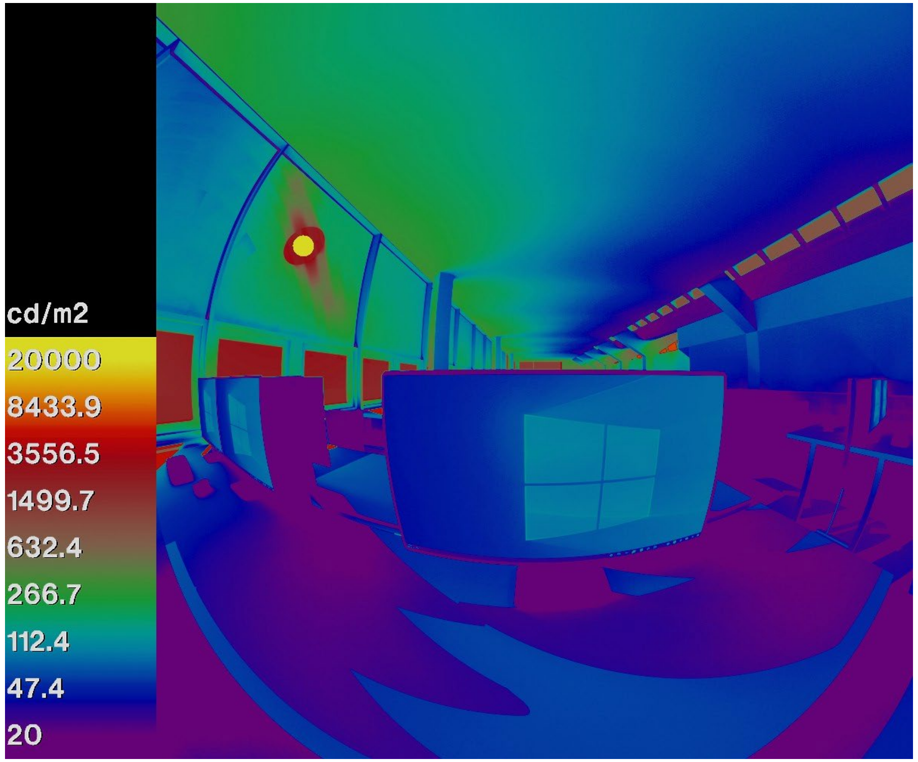


Averaging: 5° (2 x 2.5°)



Ev = 508 lx
Ev_dir = 193 lx
DGP = 0.217



Test evaluations: averaging over area around glare source (with peak extraction (aBSDF))

BSDF resolution:
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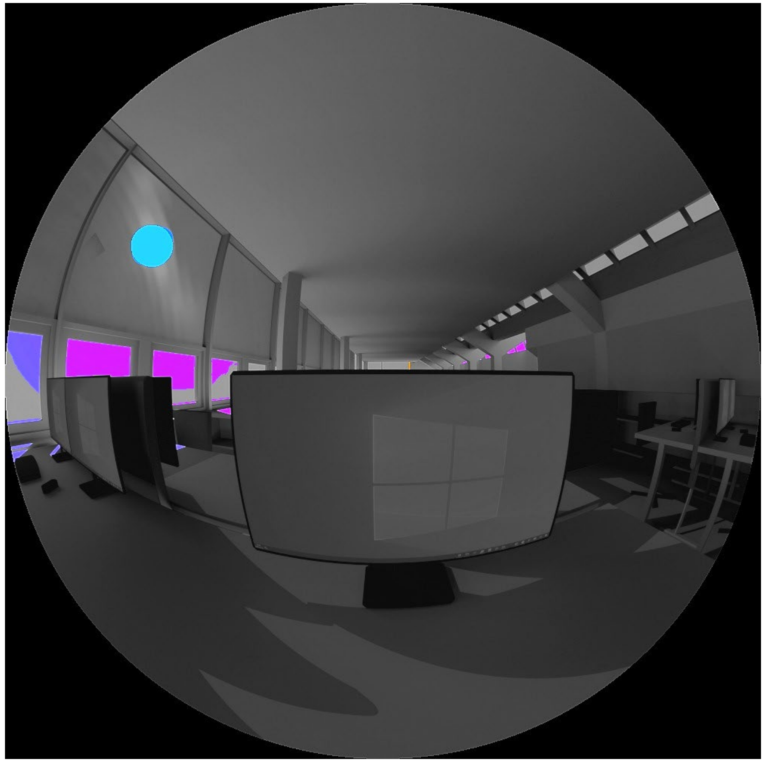
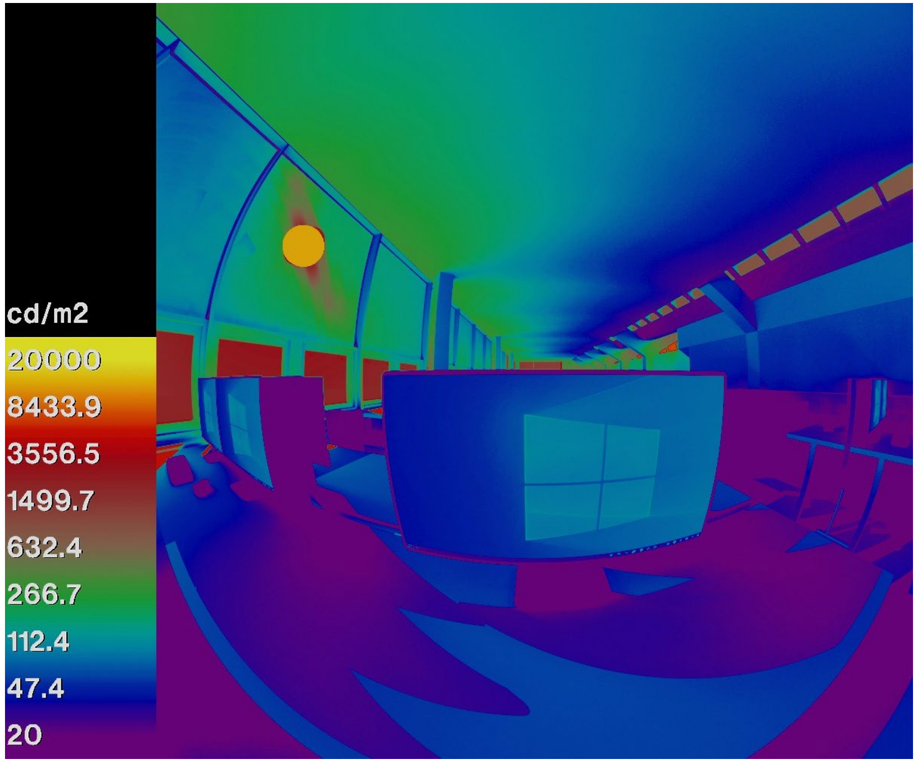
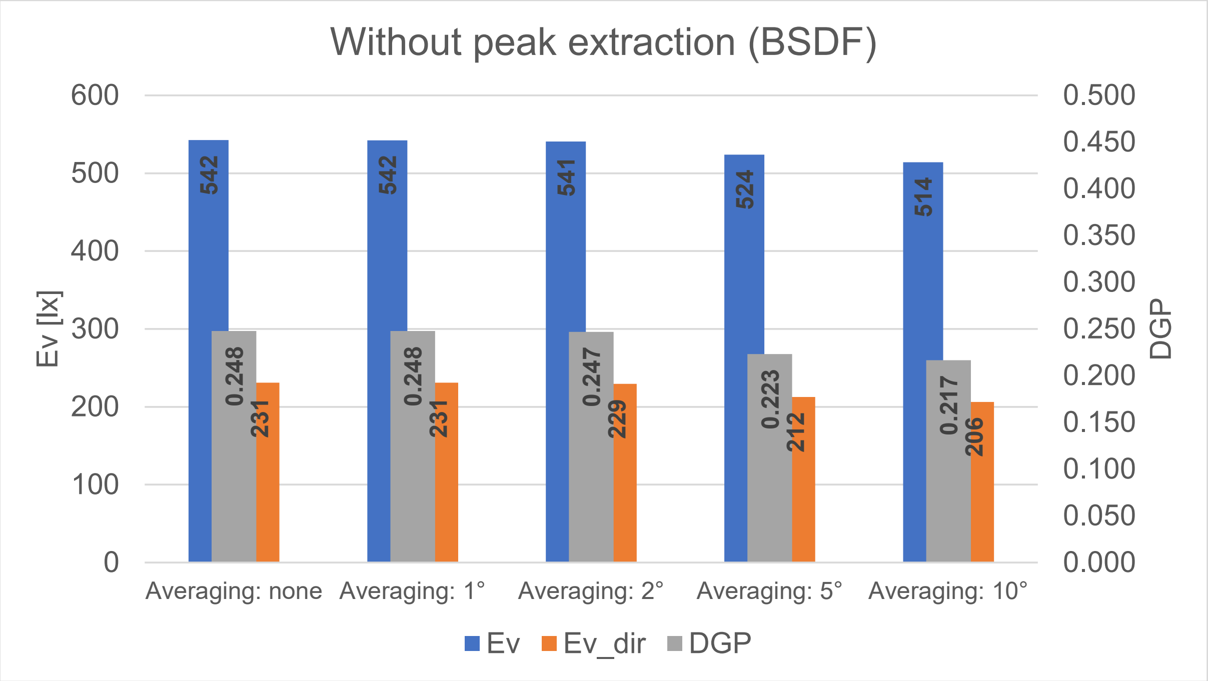


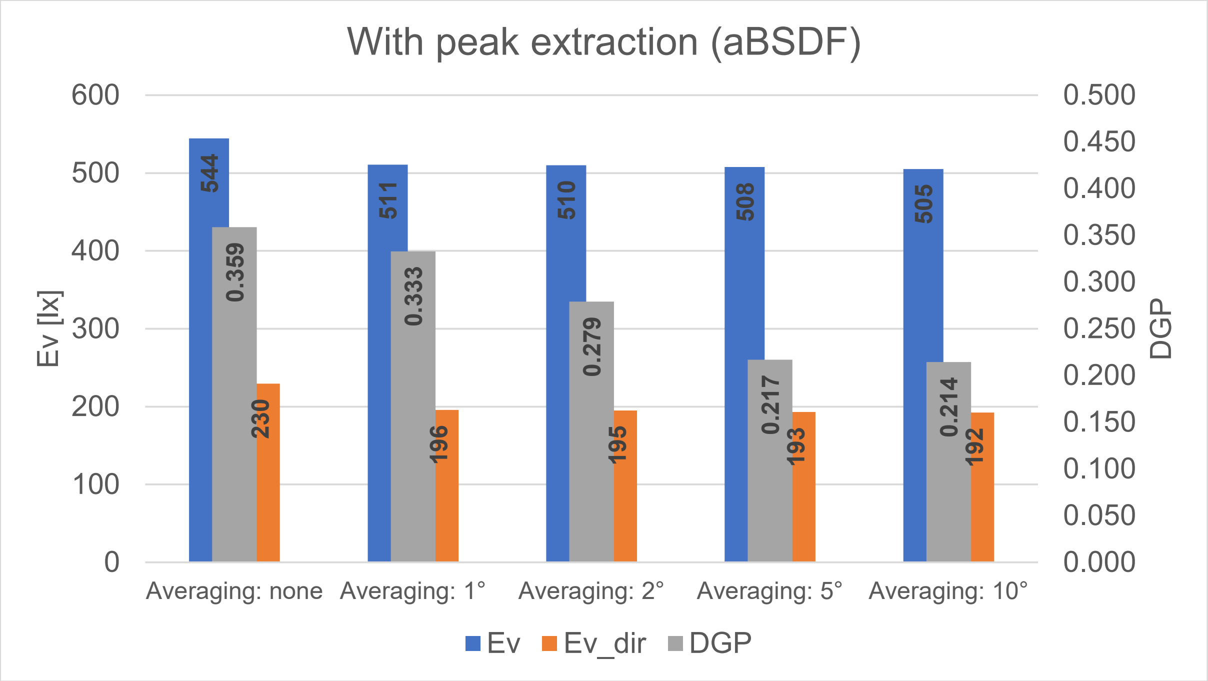


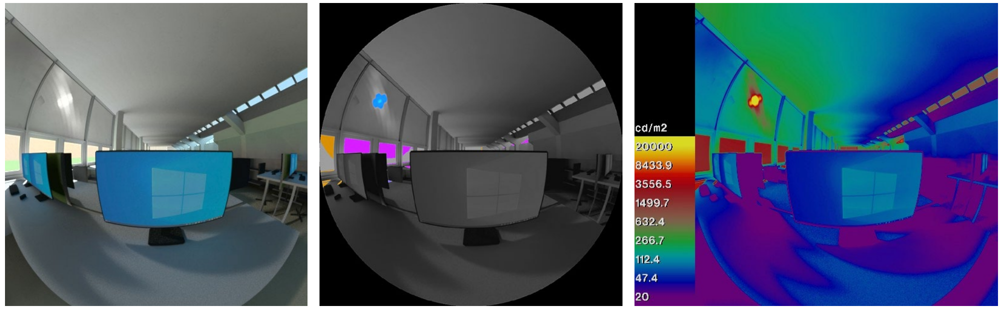
Averaging: 10° (2 x 5.0°)

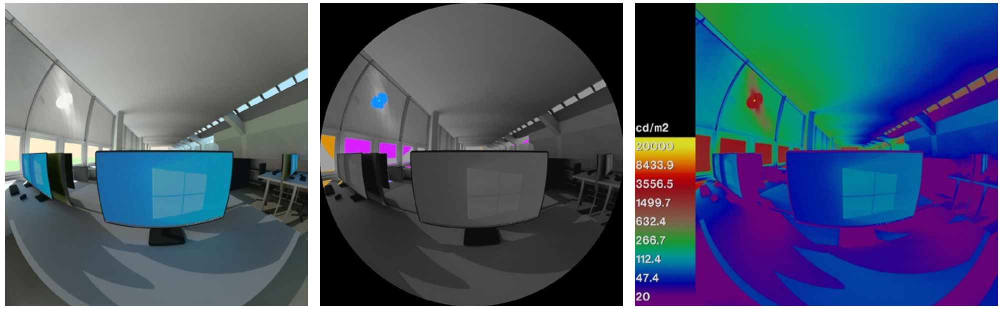
Ev = 505 lx
Ev_dir = 192 lx
DGP = 0.214

Test evaluations: comparison









Peripheral field of view: Decrease of visual acuity

Typical **visual acuity** in viewing direction: 1, i.e. objects with an angular size of 1‘ can be recognized.

Visual acuity: Decreases depending on angle α [°] to viewing direction.

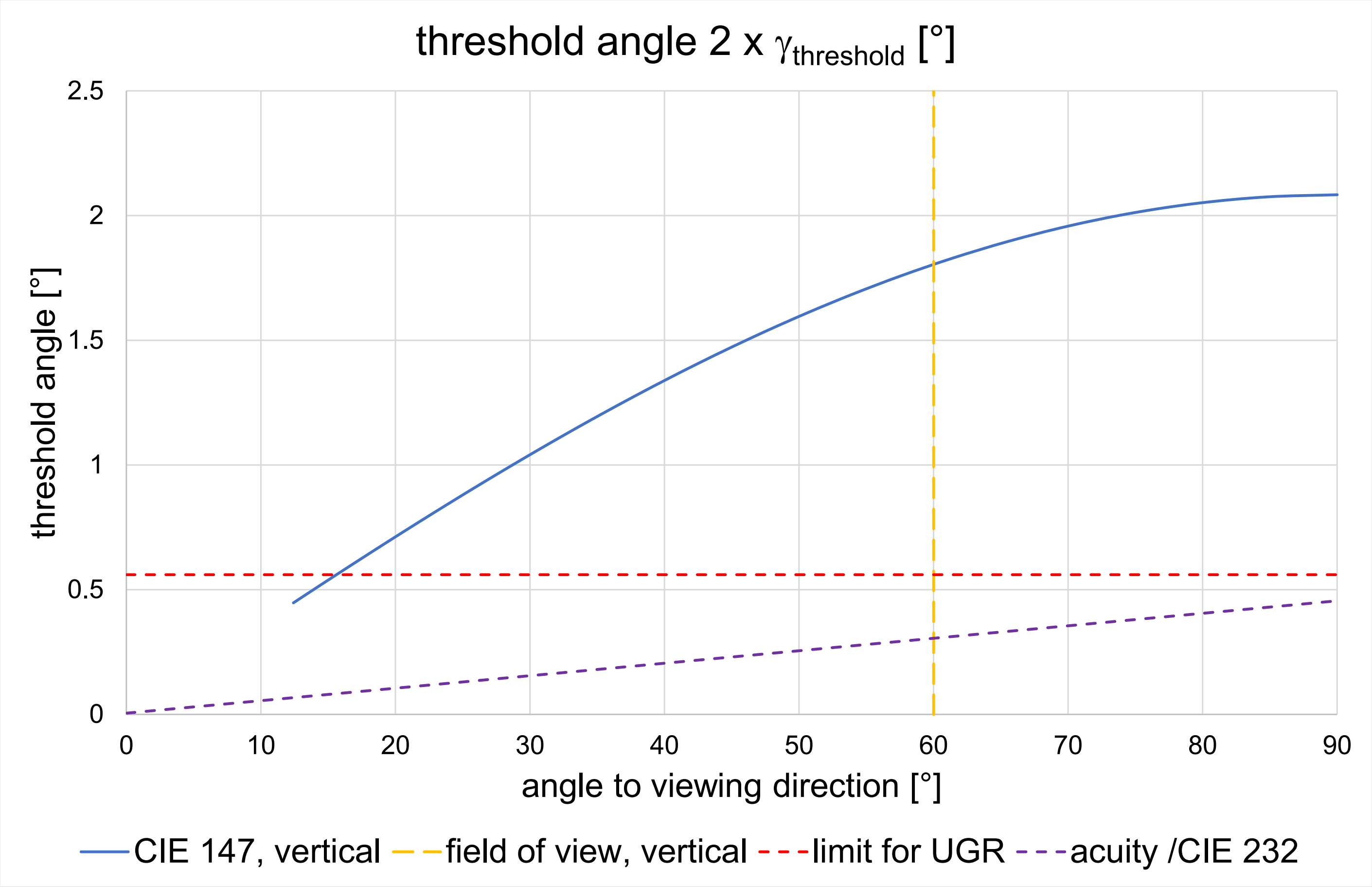
Maximum resolution of the human visual system:

$\beta \approx (1 + \alpha)/100$ [°]

$\alpha = 0°$: 2 x 0.3‘ (acuity 1.67)
$\alpha = 60°$: 2 x 0.3° (factor 61, ref. to $\alpha = 0°$)

Limit for UGR: 2 x 0.56° (0.0003sr)

CIE 232-2019: “Discomfort Caused by Glare from Luminaires with a Non-Uniform Source Luminance”
CIE 147-2002: “Glare from Small, Large and Complex Sources”
CIE 117-1995: “Discomfort Glare in Interior Lighting”



Glare formulae

Unified Glare Rating UGR

$$UGR = 8\log_{10}\left(\frac{0.25}{L_b}\sum\frac{L^2\,\omega}{P^2}\right)$$

UGR limits: $0.0003sr < \Omega < 0.1sr$
(i.e., $2 \times 0.56° < 2 \times \gamma < 2 \times 10.2°$)

Daylight Glare Probability DGP

$$DGP = 5.87\,10^{-5}\,E_v + 0.16 + 9.18\,10^{-5}\log_{10}\left(1 + \frac{1}{E_v^{1.87}}\sum\frac{L^2\,\omega}{P^2}\right)$$

DGP limits ?

Important part of contrast term: $L^2\,\omega = L\,E / \cos\varepsilon$

⇒ ~ illuminance at the observers‘s eye + **additional factor** luminance **L**

⇒ meaningful if **not** distinguishable?

Peripheral field of view: Decrease of visual acuity

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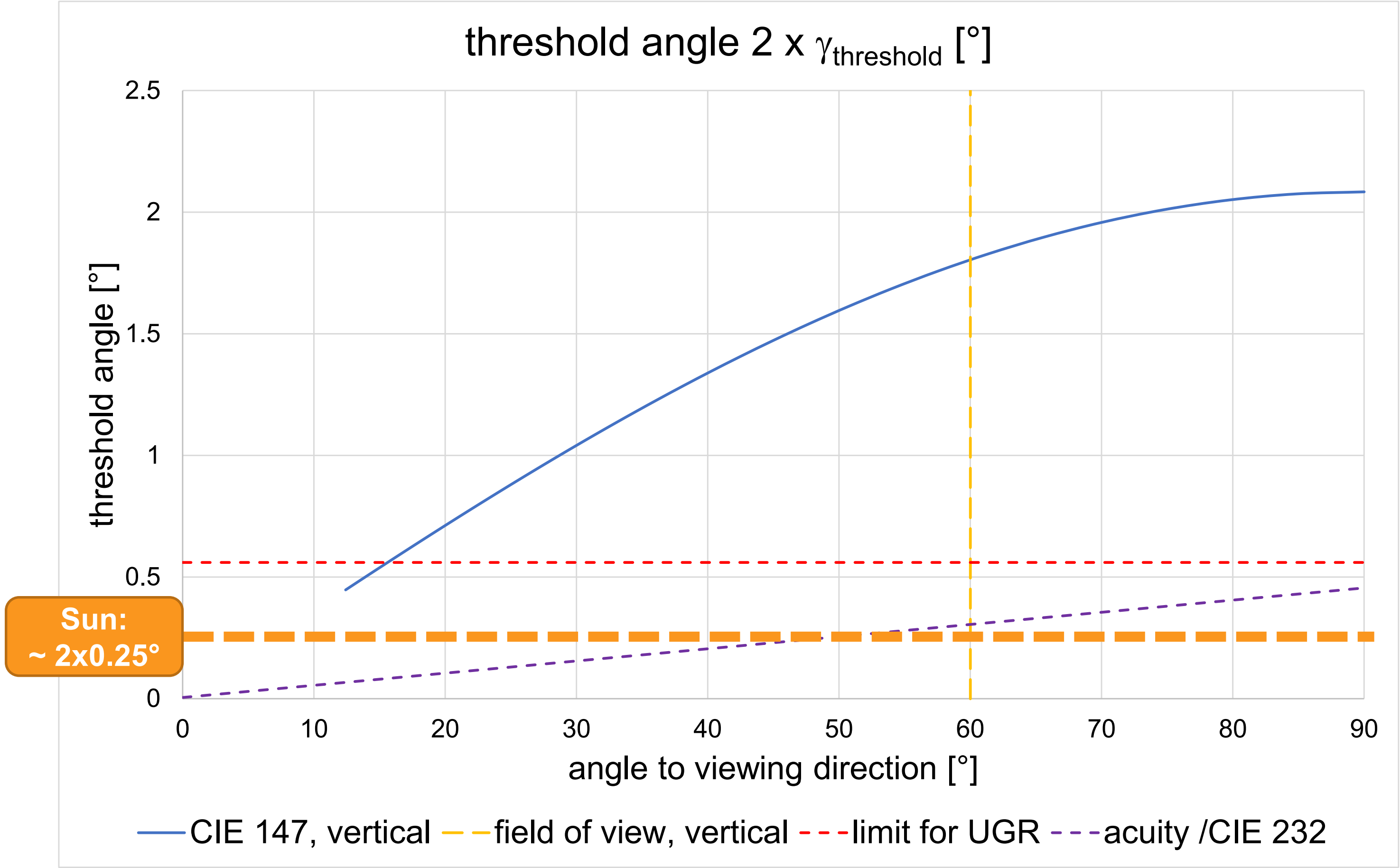
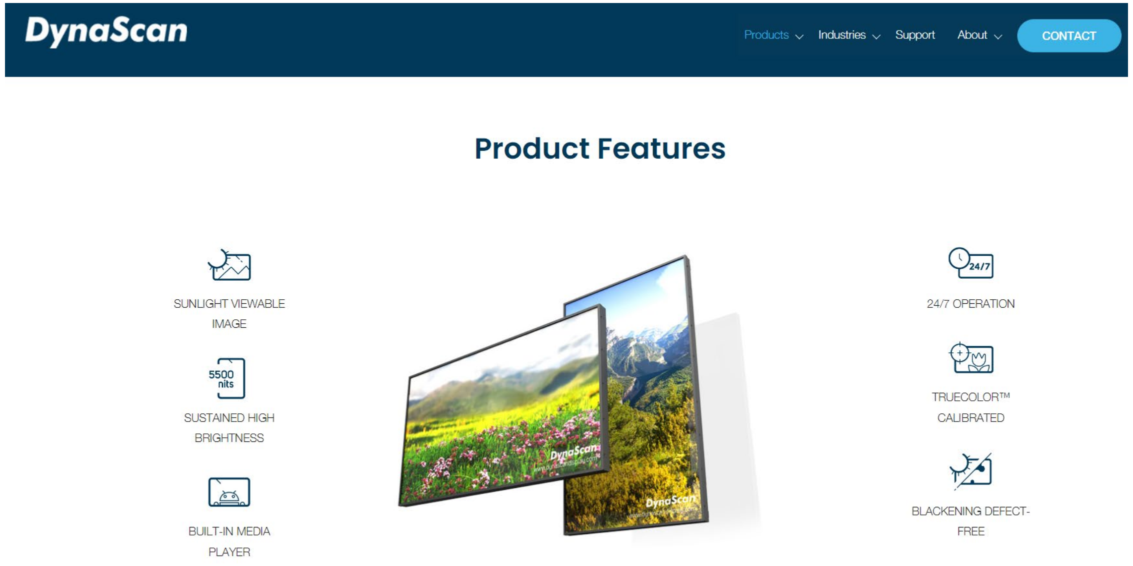


Ultra High Brightness Display: DynaScan DS55LT6

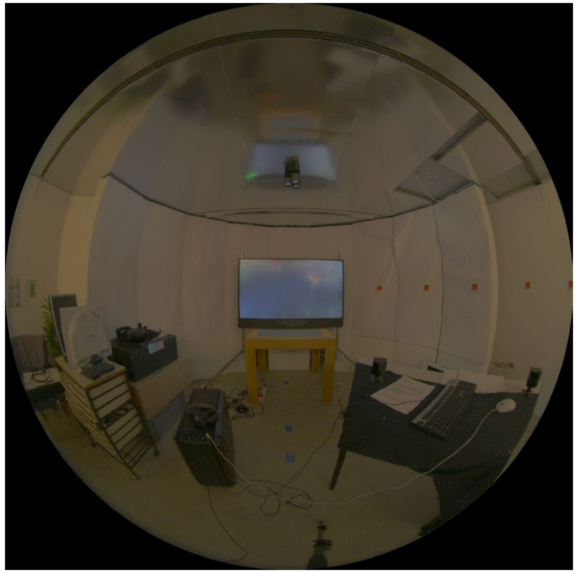
55" Ultra-High Bright LED-Backlit Narrow Bezel LCD

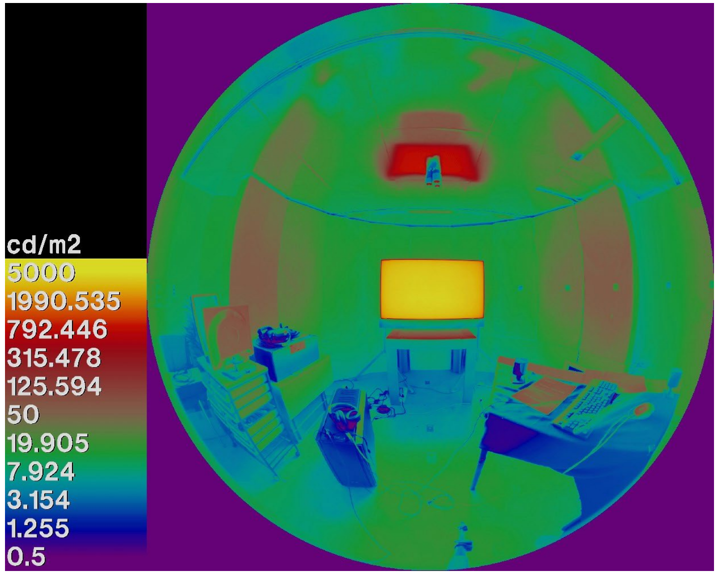
Maximum luminance (datasheet):	5000 cd/m^2 (whole monitor white, T_n = 6500 K)
Size of display:	1217.6 x 688.4 mm
Display resolution:	1920 x 1080 pixel (Full HD)
	size of a pixel: 0.634 x 0.637 mm)

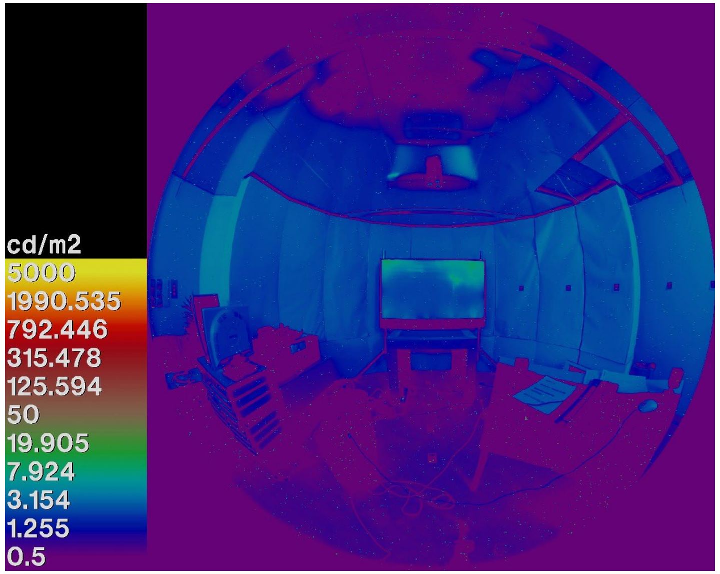
https://www.dynascandisplay.com/



Ultra High Brightness Display: DynaScan DS55LT6

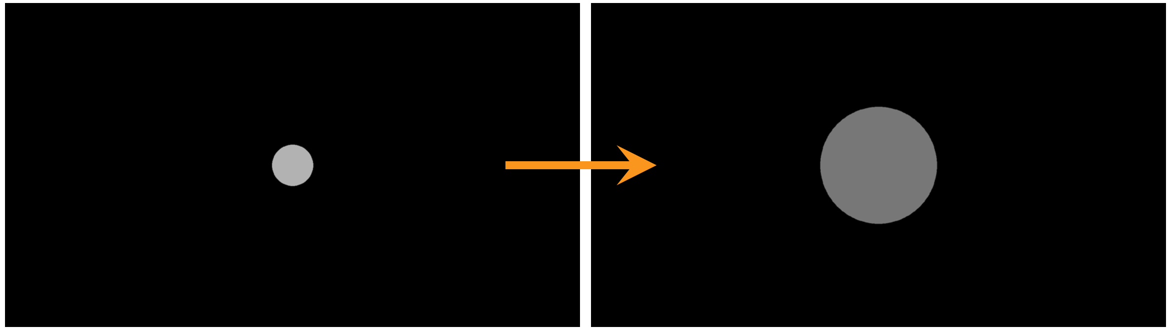




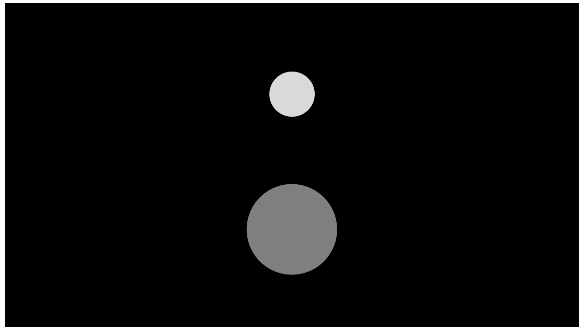


Peripheral field of view: Experimental setups

- **Present discs that get larger or smaller**
  - Maintain equal illuminance at observers‘s eye
  - Viewing distance: 2 m
  - Viewing angles horizontal: 30°, 45°, 60°, 75°, 90°
  - Viewing angles vertical: 30°, 45°, 55°



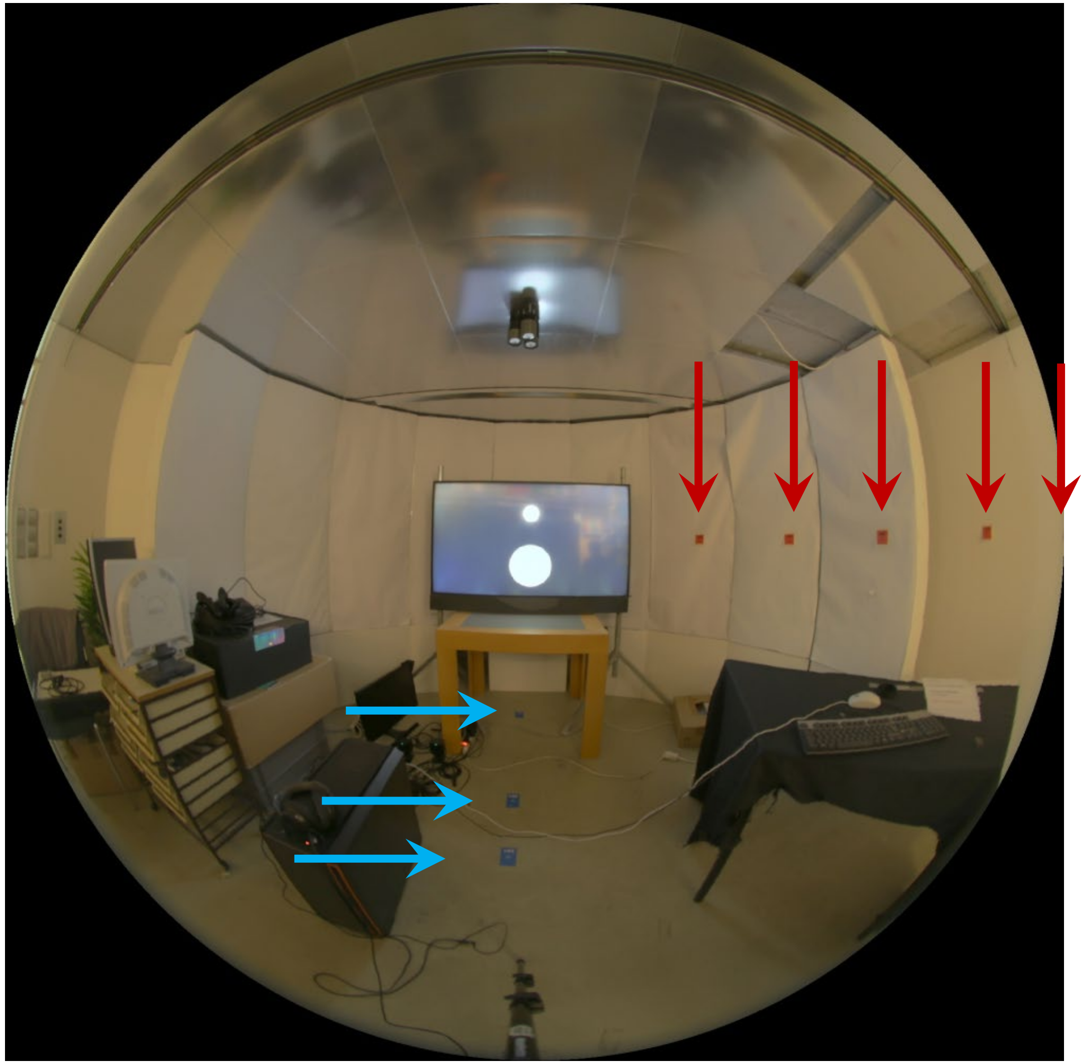
- **Present two discs of different size at the same time**
  - Both discs scaled to create equal illuminance at observers‘s eye
  - Viewing distance: 2 m
  - Viewing angles horizontal: 30°, 45°, 60°, 75°, 90°
  - Viewing angles vertical: 30°, 45°, 55°



Peripheral field of view: Experimental setups

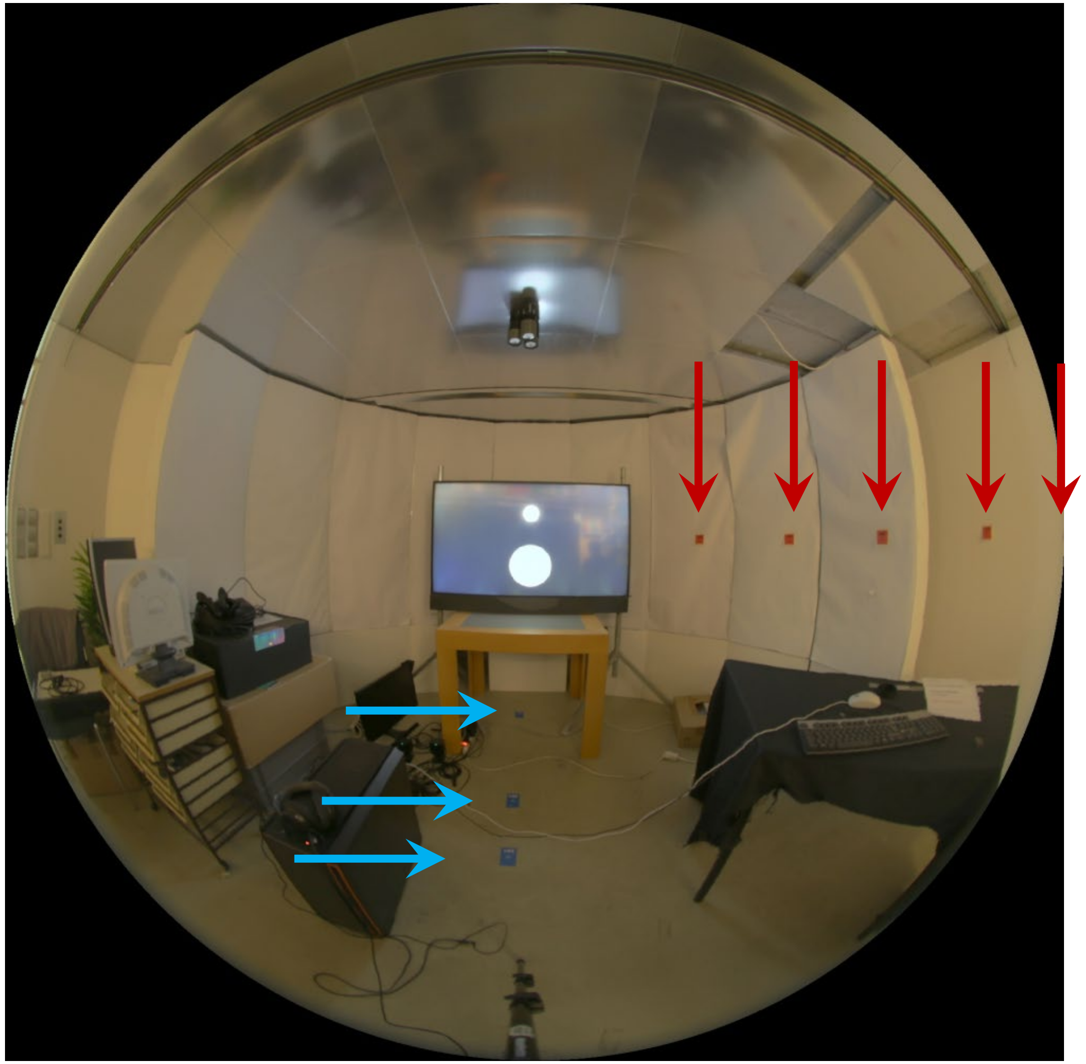
- **Present discs that get larger or smaller**
  - Maintain equal illuminance at observers‘s eye
  - Viewing distance: 2 m
  - Viewing angles horizontal: 30°, 45°, 60°, 75°, 90°
  - Viewing angles vertical: 30°, 45°, 55°

- **Present two discs of different size at the same time**
  - Both discs scaled to create equal illuminance at observers‘s eye
  - Viewing distance: 2 m
  - Viewing angles horizontal: 30°, 45°, 60°, 75°, 90°
  - Viewing angles vertical: 30°, 45°, 55°



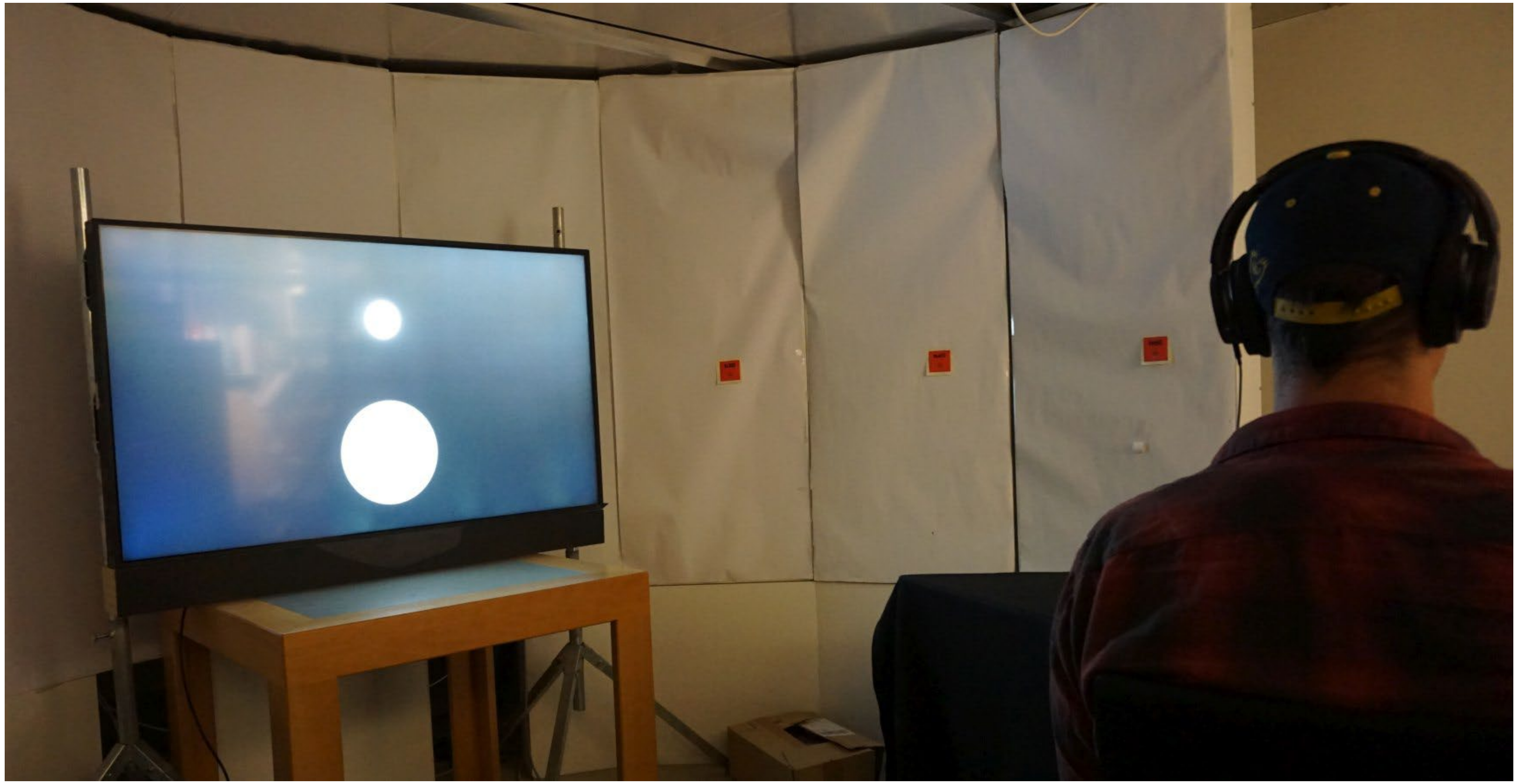
Peripheral field of view: Experimental setups

- Calibration run
  - Determine minimum distinguishable size (A_{min}) for each viewing direction h30, h45, h60, h75, h90, v30, v45, v55
- Define test setup for each subject using $0.5*A_{min} – A_{min} – 2*A_{min} – 4*A_{min}$
- Test duration about 35-45 min
  - 8 directions
  - 12 pairs
  - 6 runs
  - → 576 answers / test / subject



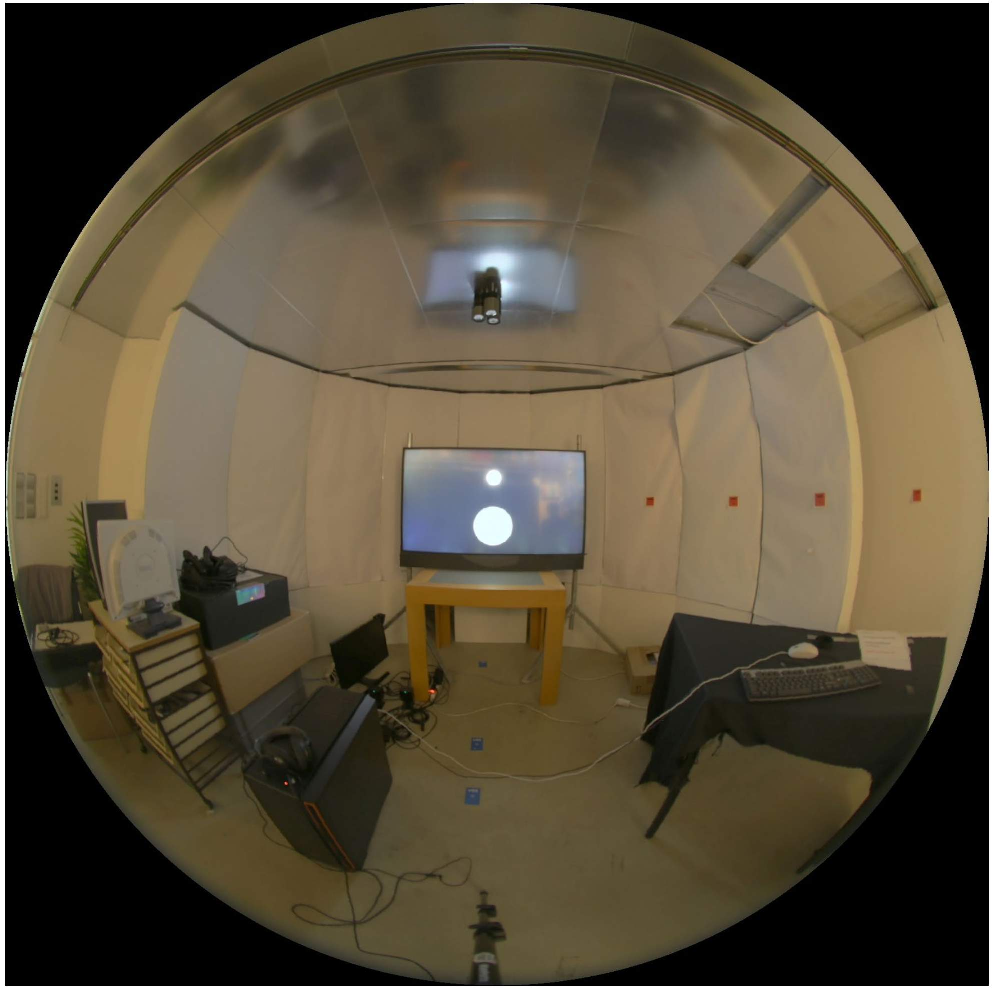
Peripheral field of view: Experimental setup 1

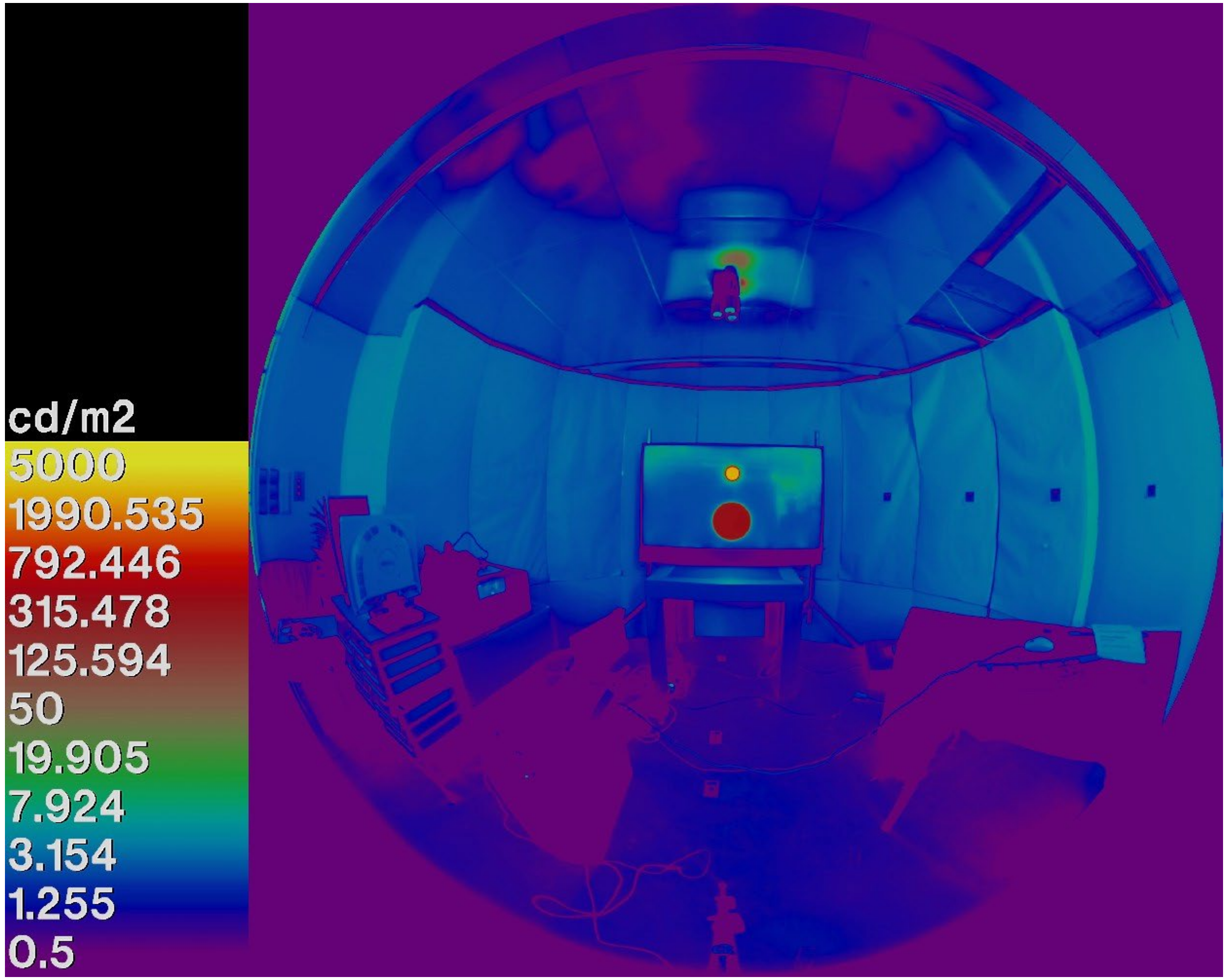
Two discs that create the same illuminance at the observers‘s eye



Peripheral field of view: Experimental setup 1

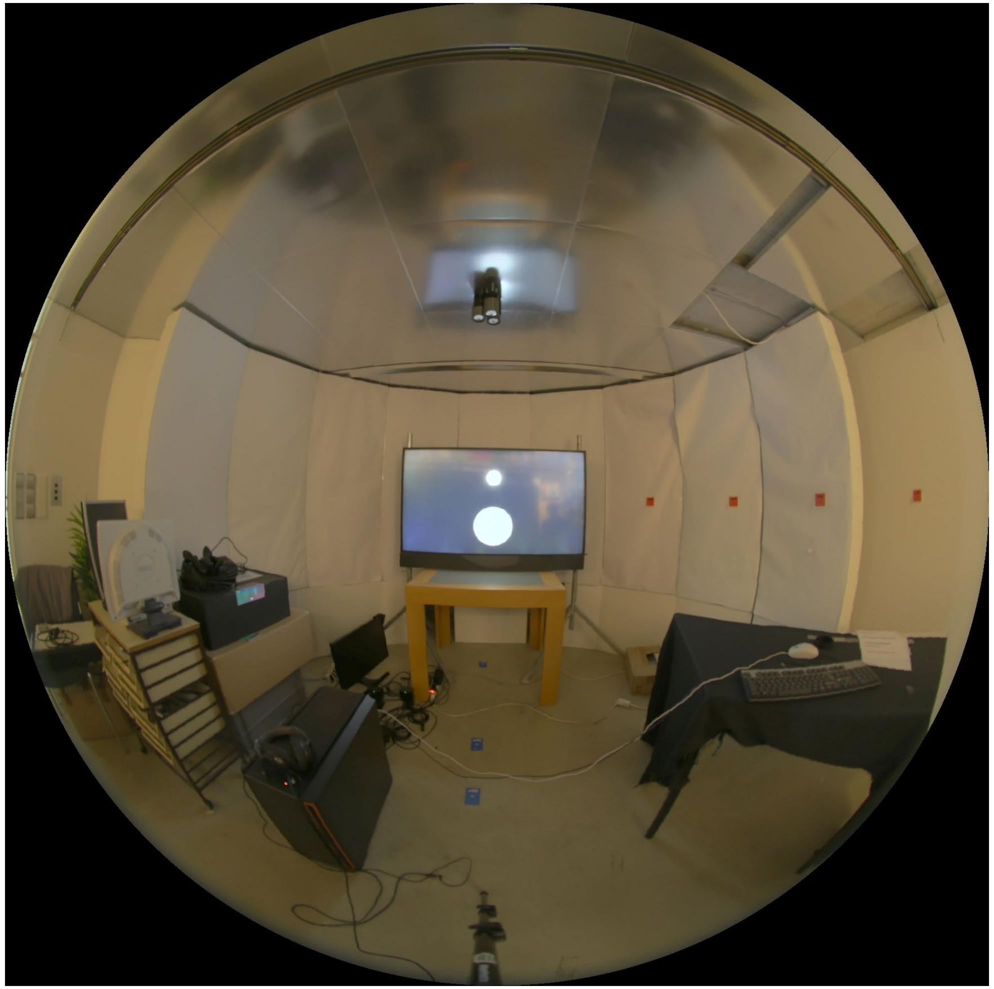
Two discs one above the other: horizontal view directions

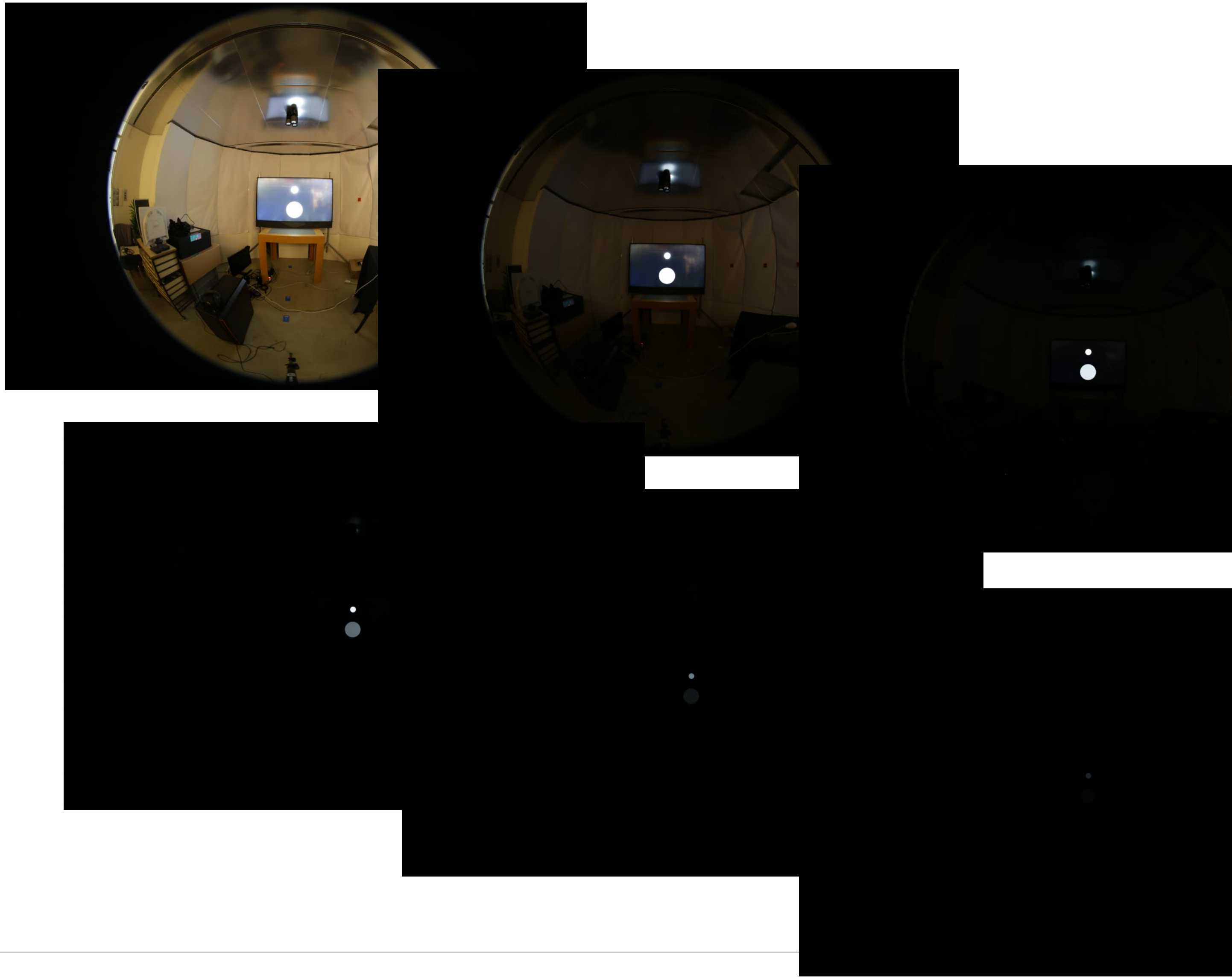




Peripheral field of view: Experimental setup 1

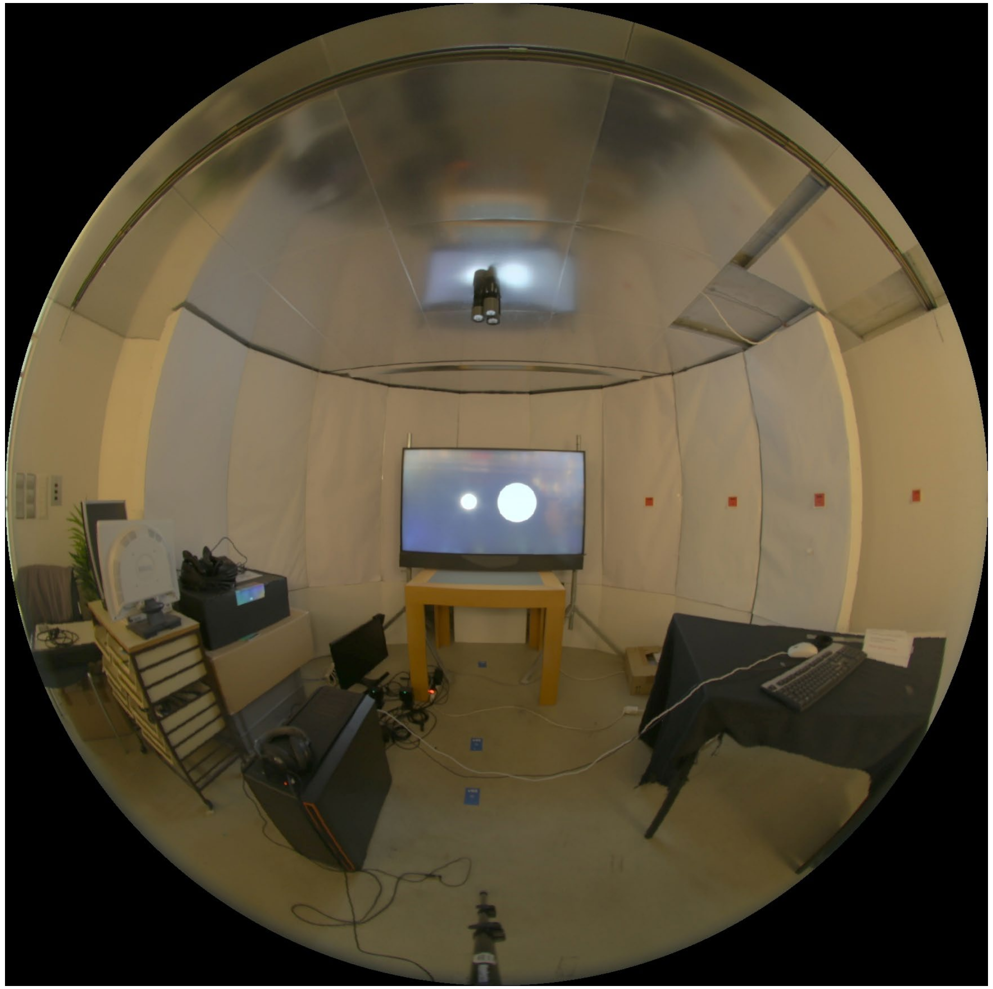
Two discs one above the other: horizontal view directions

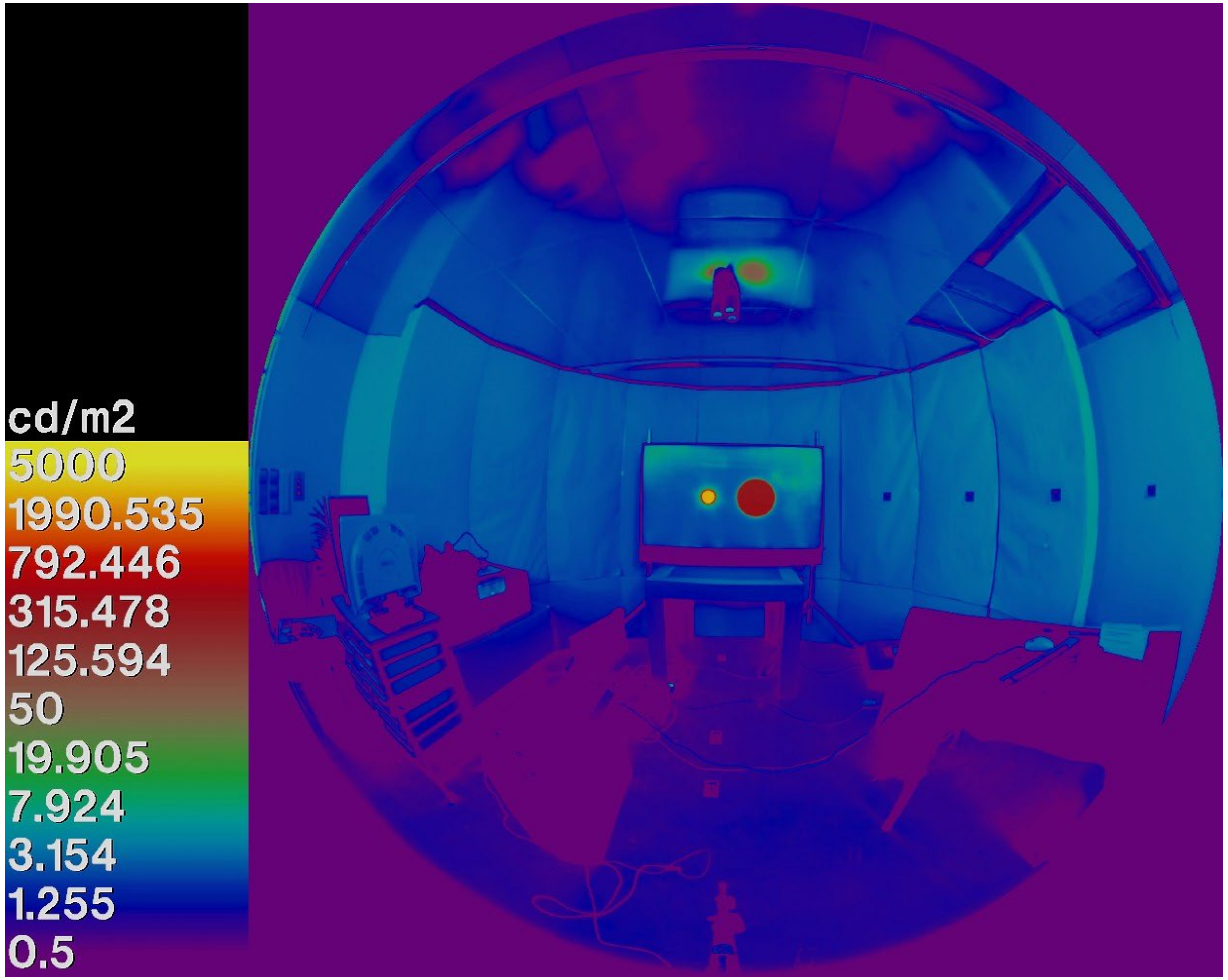




Peripheral field of view: Experimental setup 1

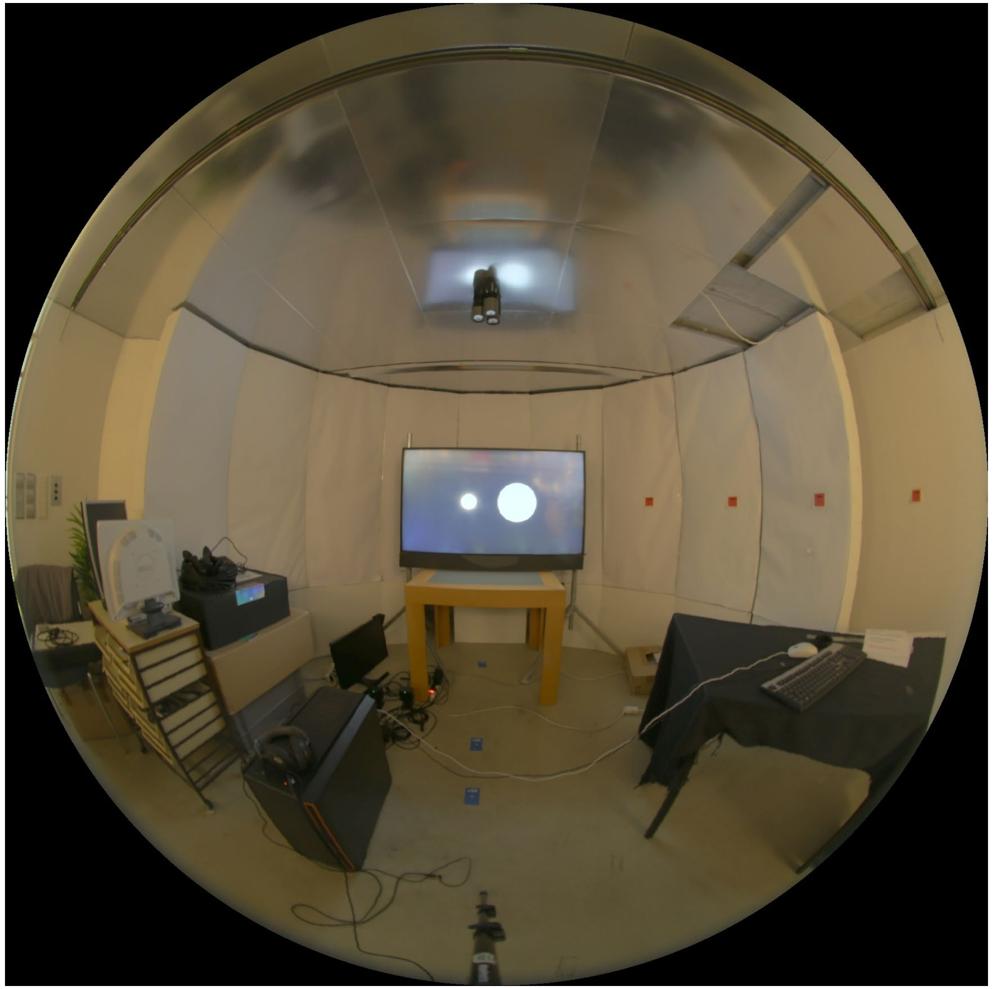
Two discs side by side: vertical view directions

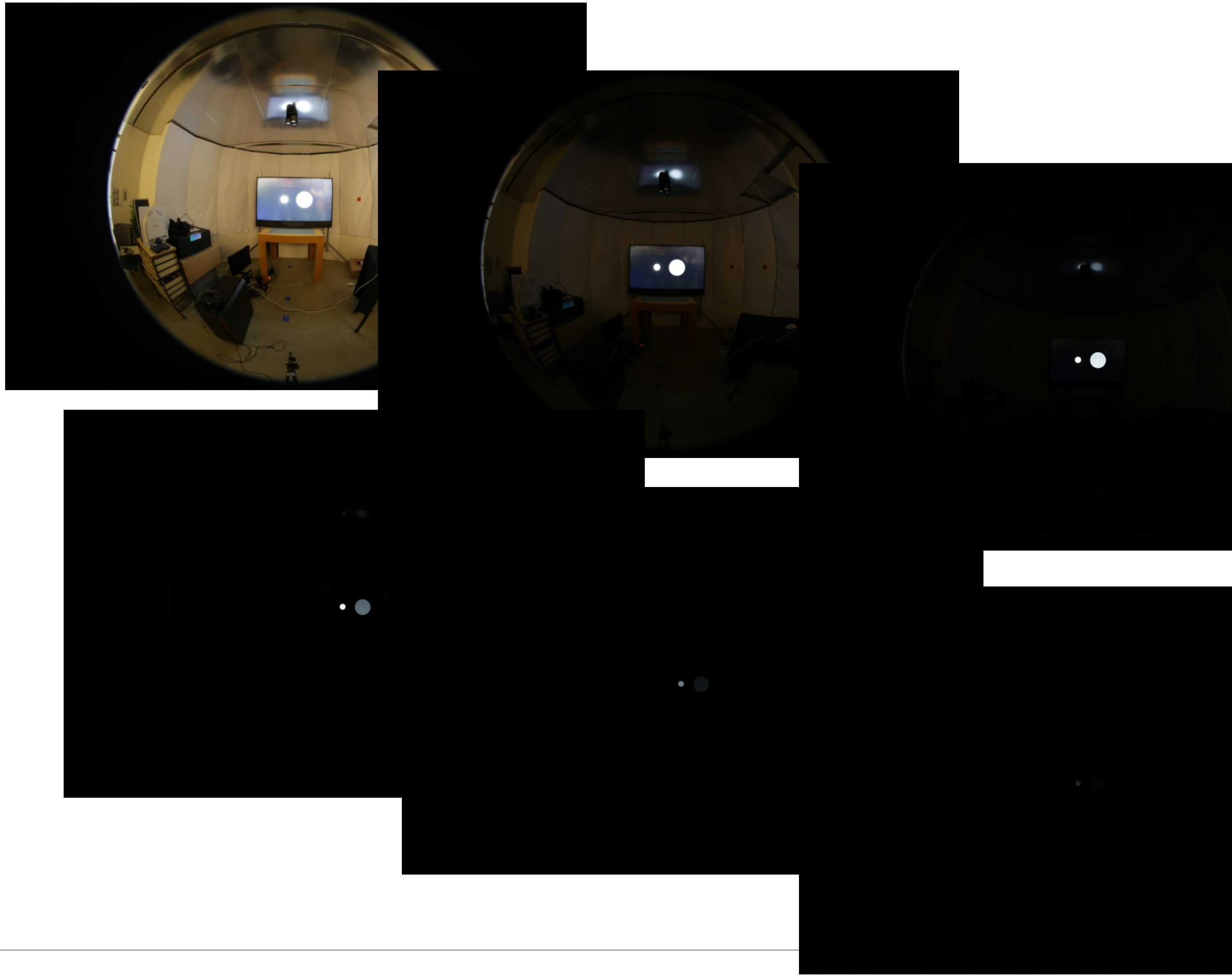




Peripheral field of view: Experimental setup 1

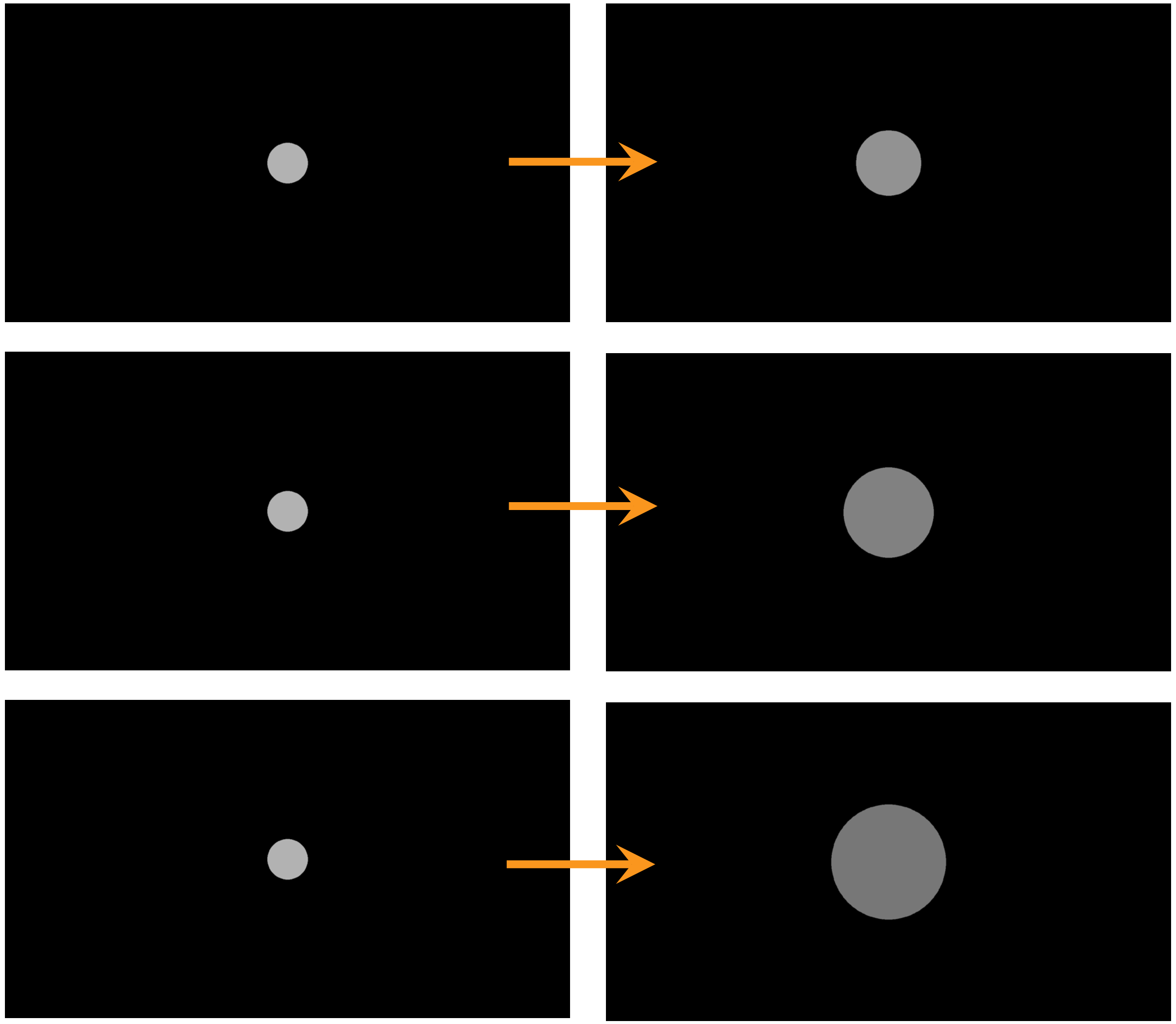
Two discs side by side: vertical view directions





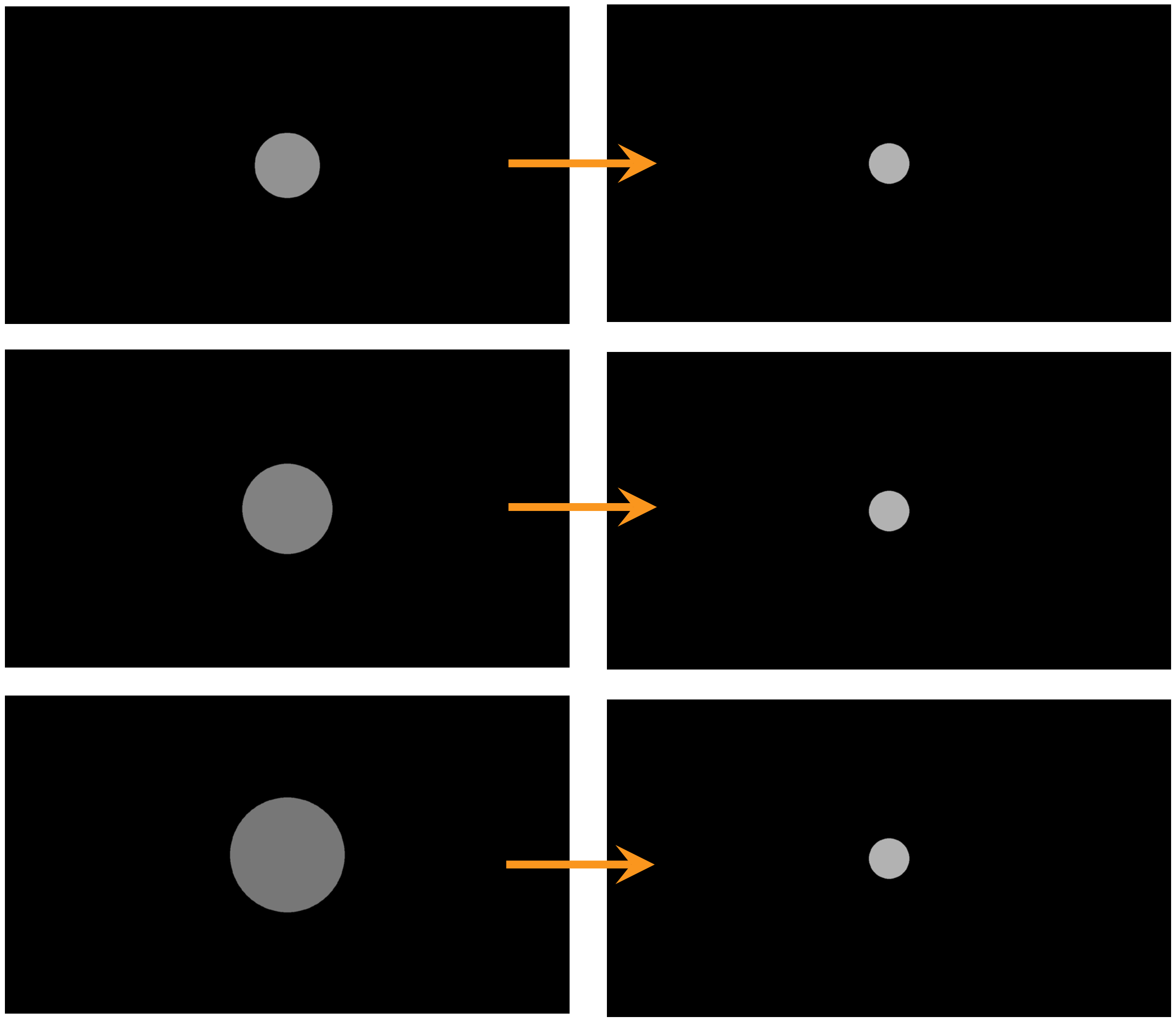
Experimental setup 2: disc in the center gets larger or smaller

Disc gets continuously larger



Experimental setup 2: disc in the center gets larger or smaller

Disc gets continuously smaller

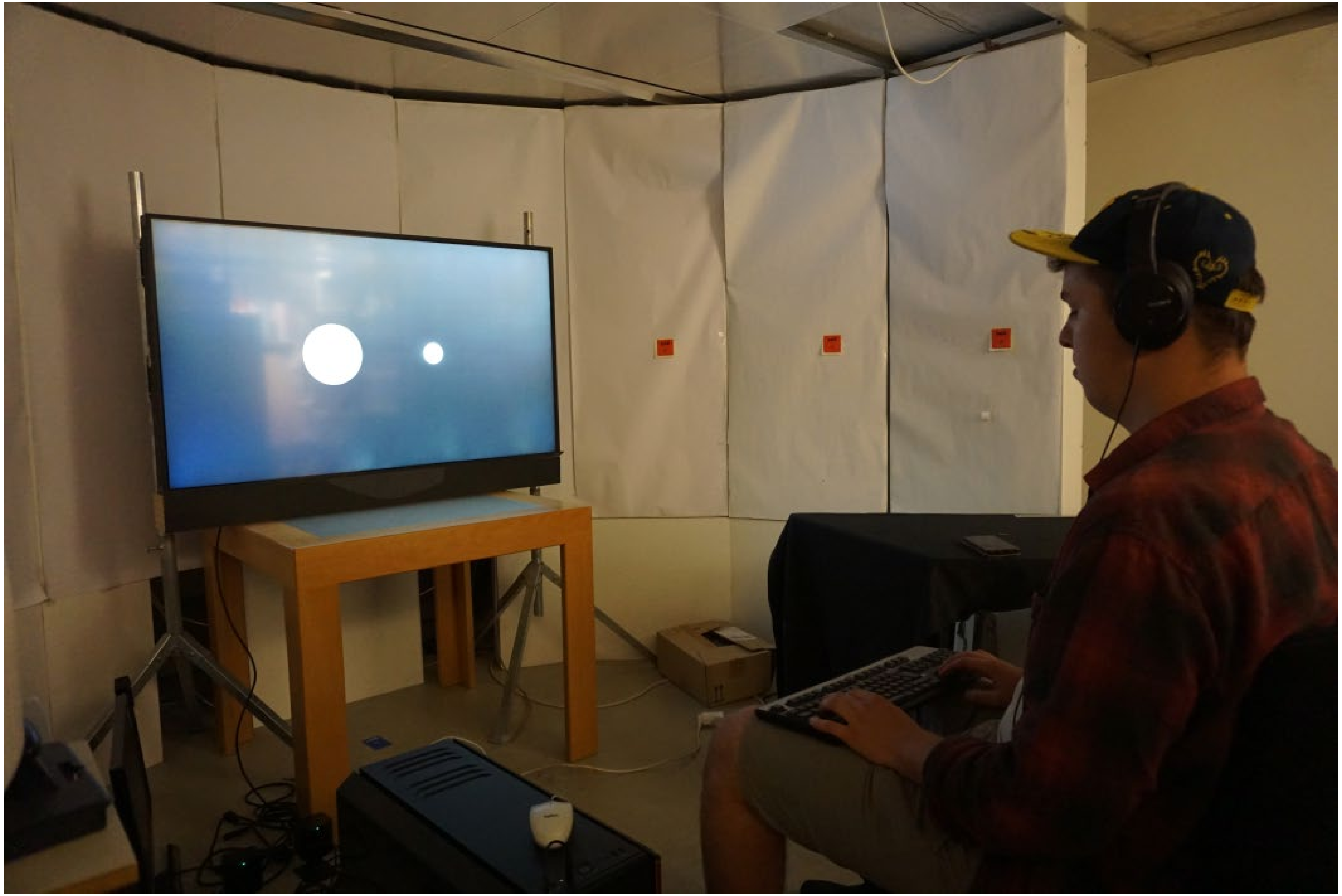


Current status

14 internal subjects

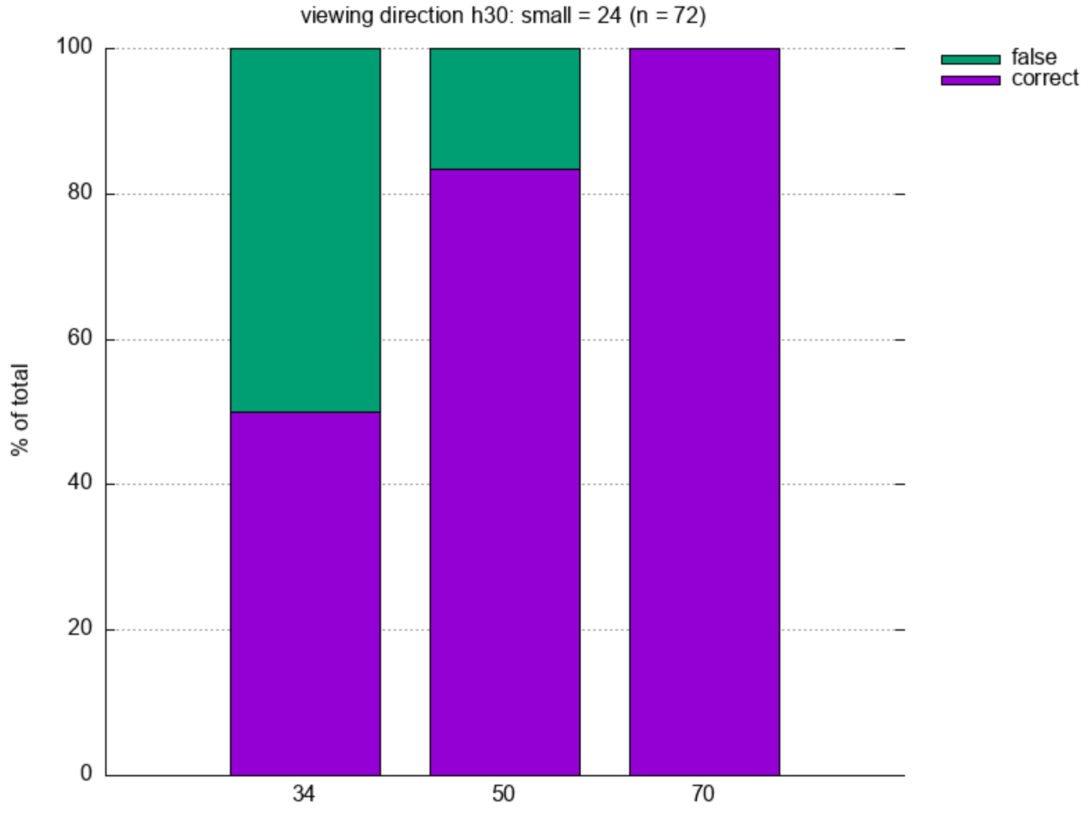
44 test runs total

→ 25.344 answers

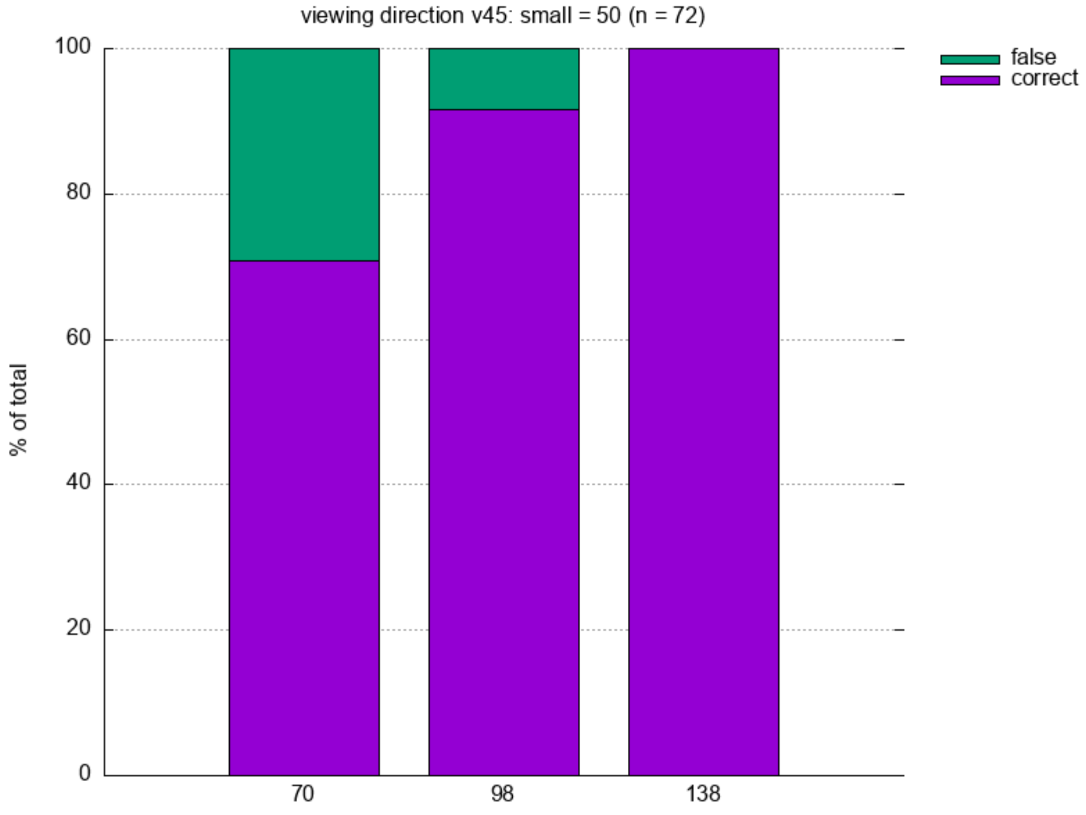


Two discs at the same time: exemplary results [work in progress…]

Viewing direction 30° to the right, subject TOFI

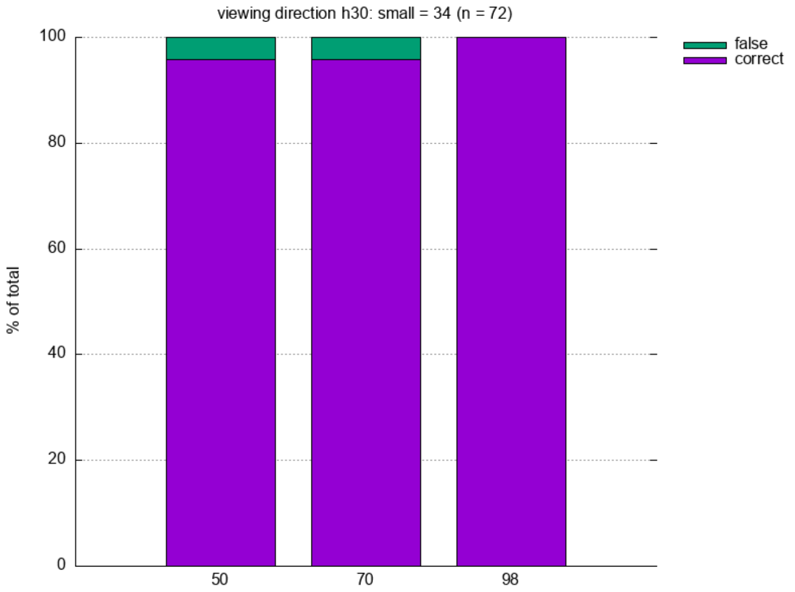


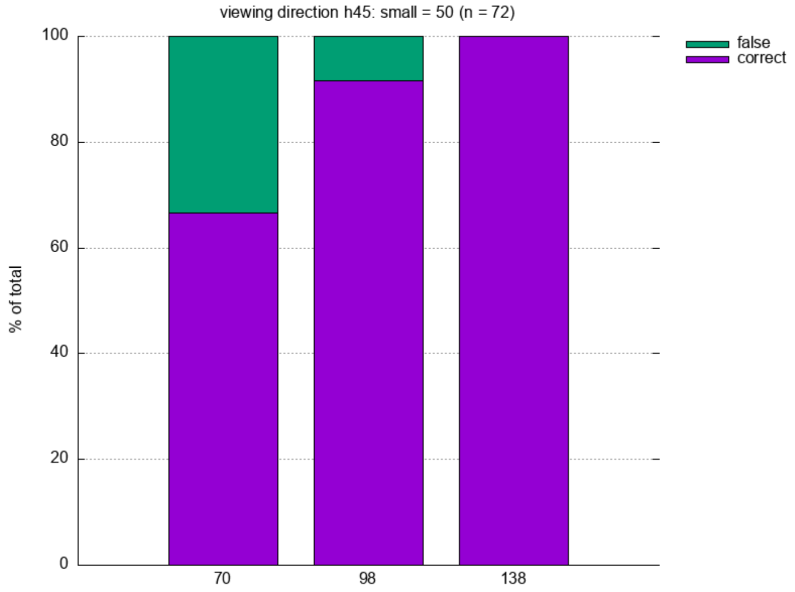
Viewing direction 45° down, subject TOFI

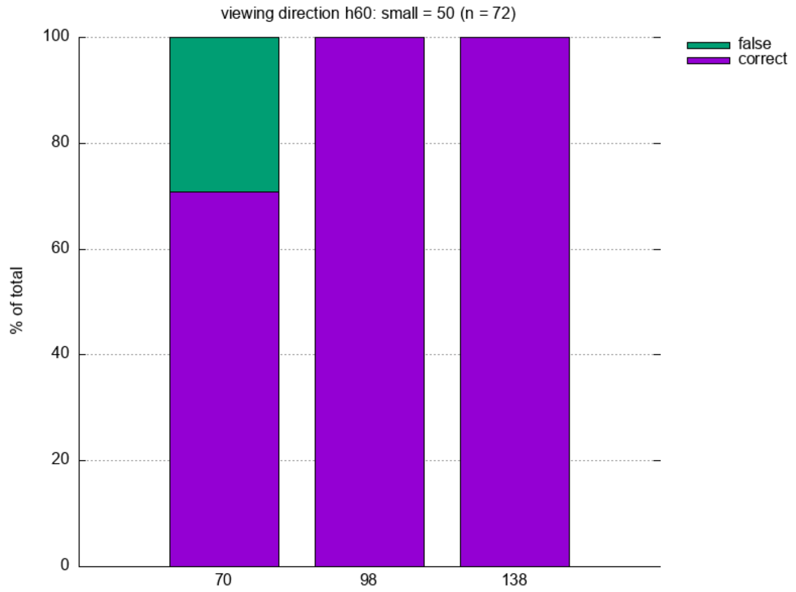


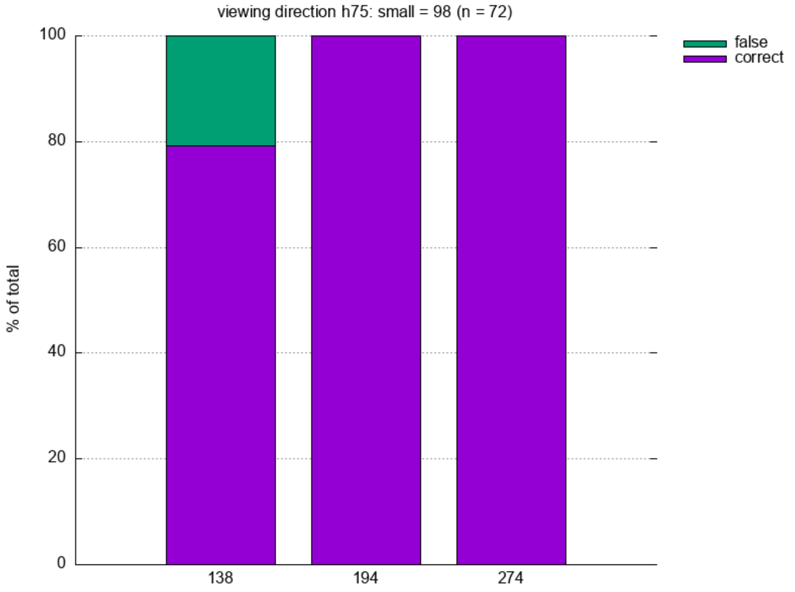
px	24	34	50	70	98	138	194	274	390
α [°]	0.22	0.31	0.46	0.64	0.89	1.26	1.77	2.49	3.55

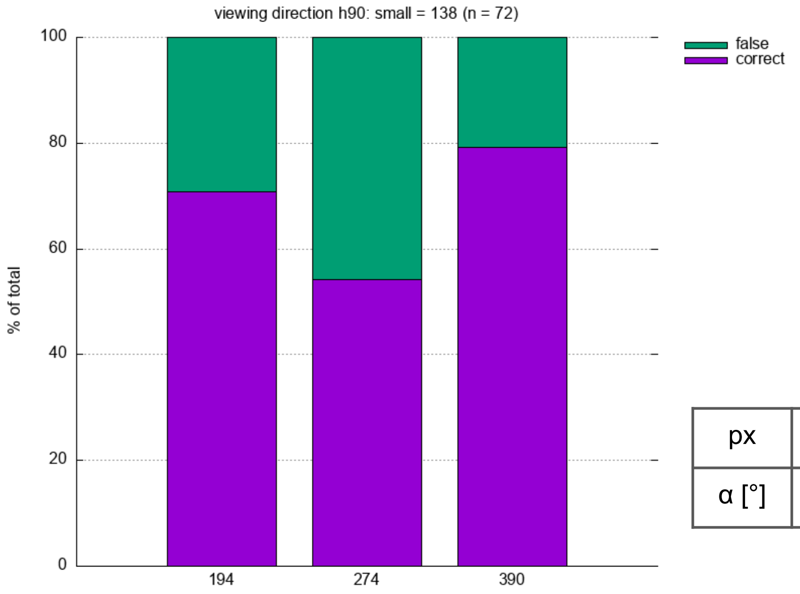
Two discs at the same time: exemplary results [work in progress…]







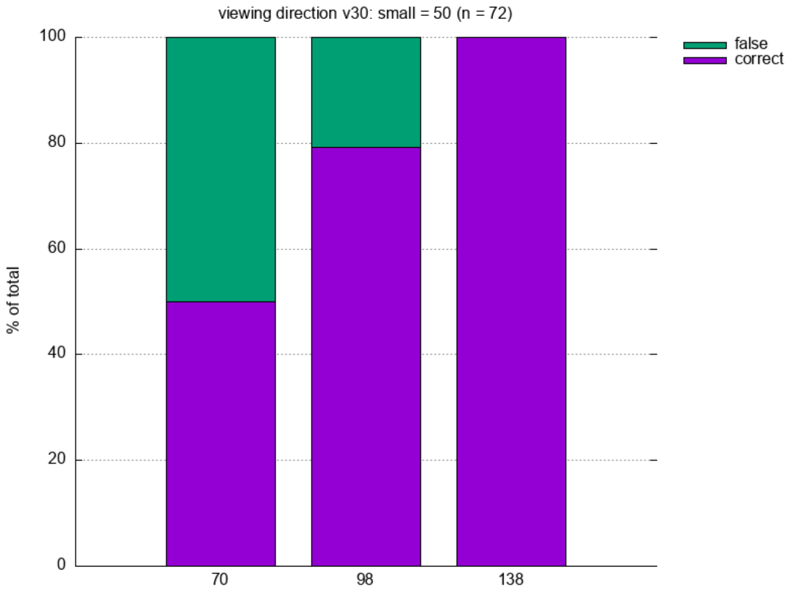


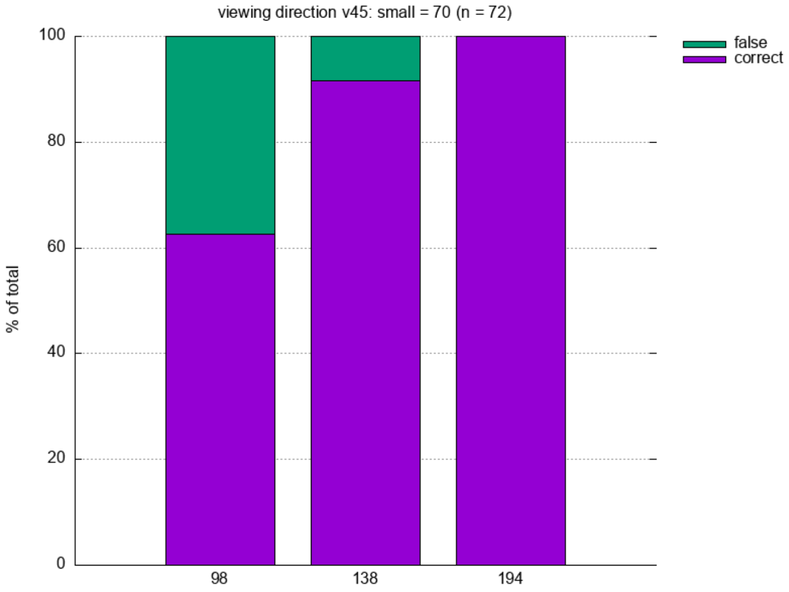


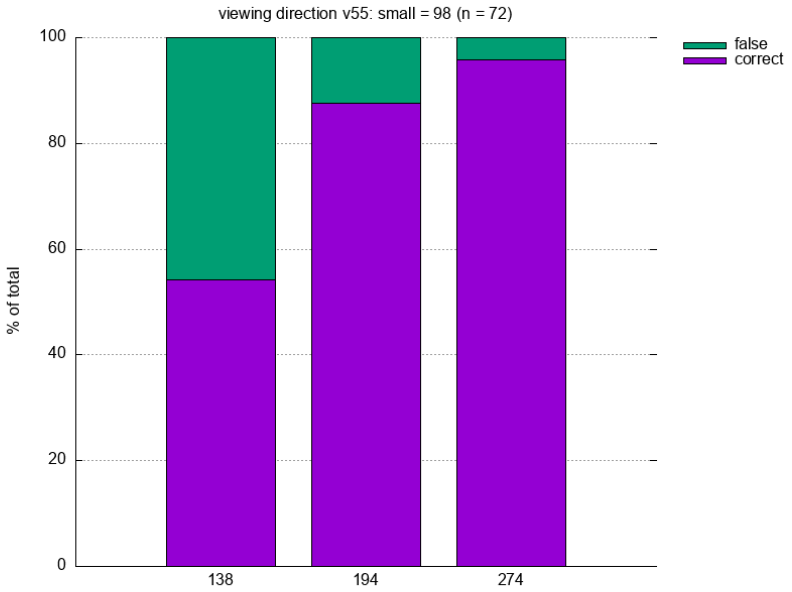
Horizontal viewing directions (30°, 45°, 60°, 75°, 90°), subject DGM

px	24	34	50	70	98	138	194	274	390
α [°]	0.22	0.31	0.46	0.64	0.89	1.26	1.77	2.49	3.55

Two discs at the same time: exemplary results [work in progress…]



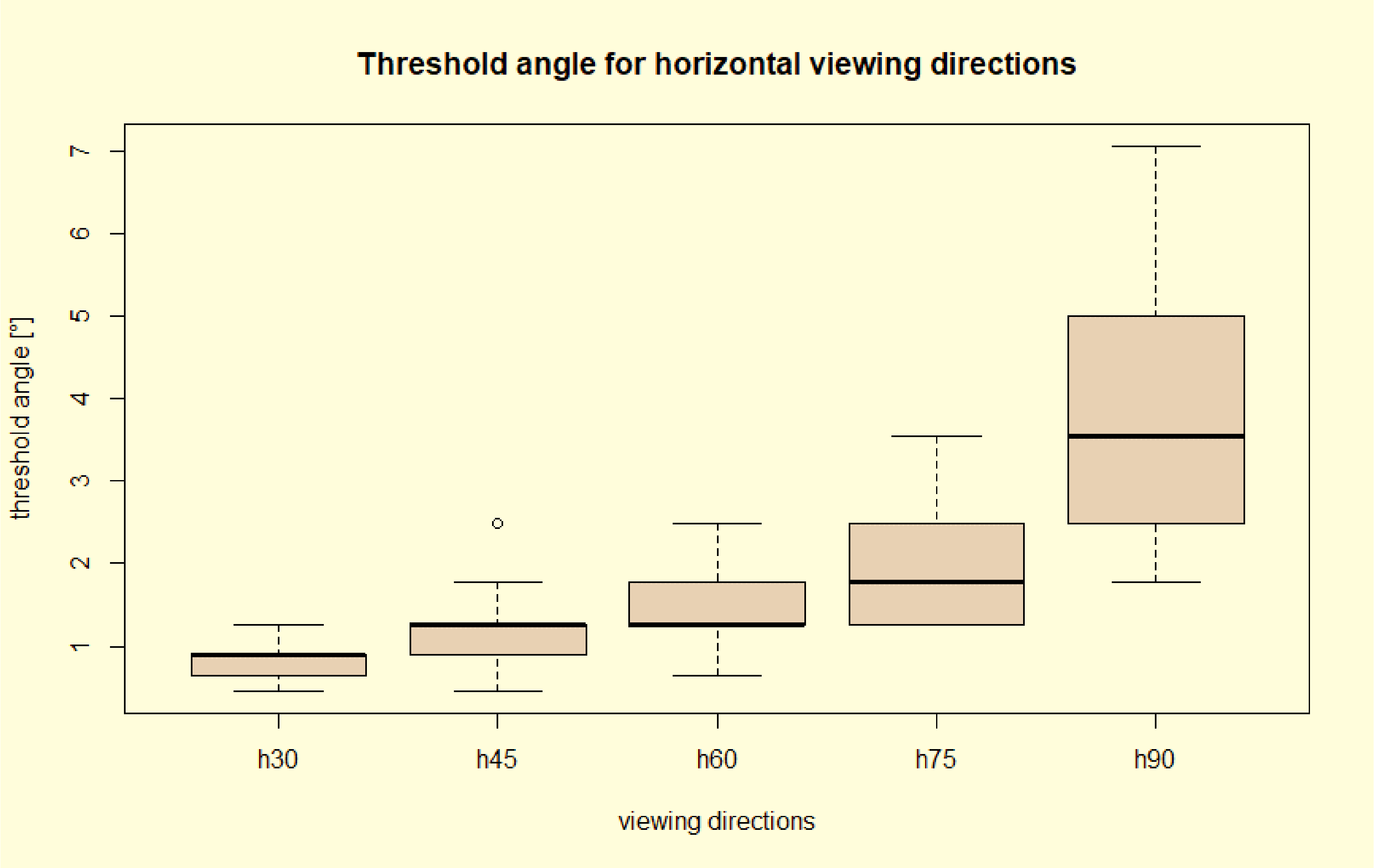




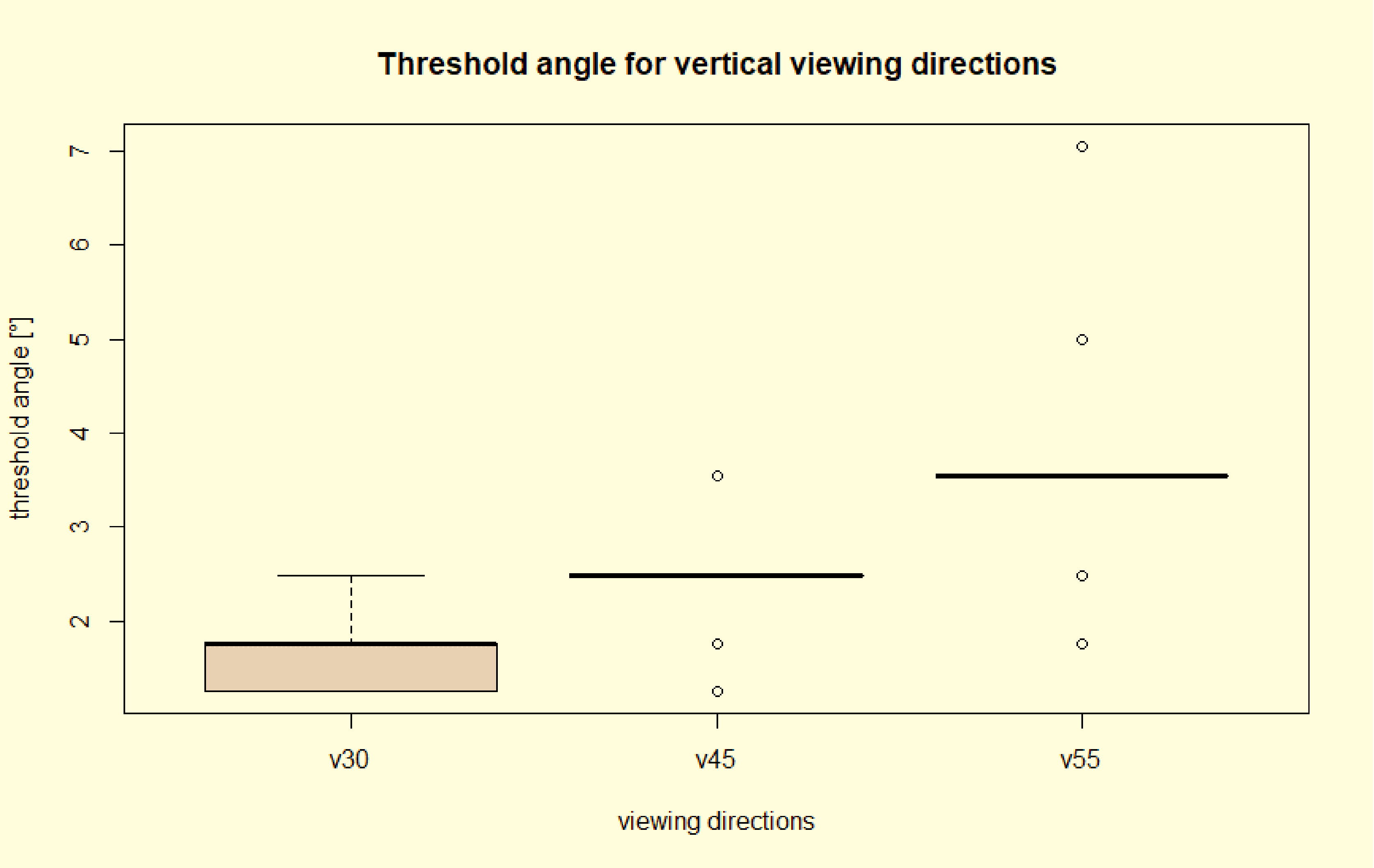
Vertical viewing directions (30°, 45°, 55°), subject DGM

px	24	34	50	70	98	138	194	274	390
α [°]	0.22	0.31	0.46	0.64	0.89	1.26	1.77	2.49	3.55

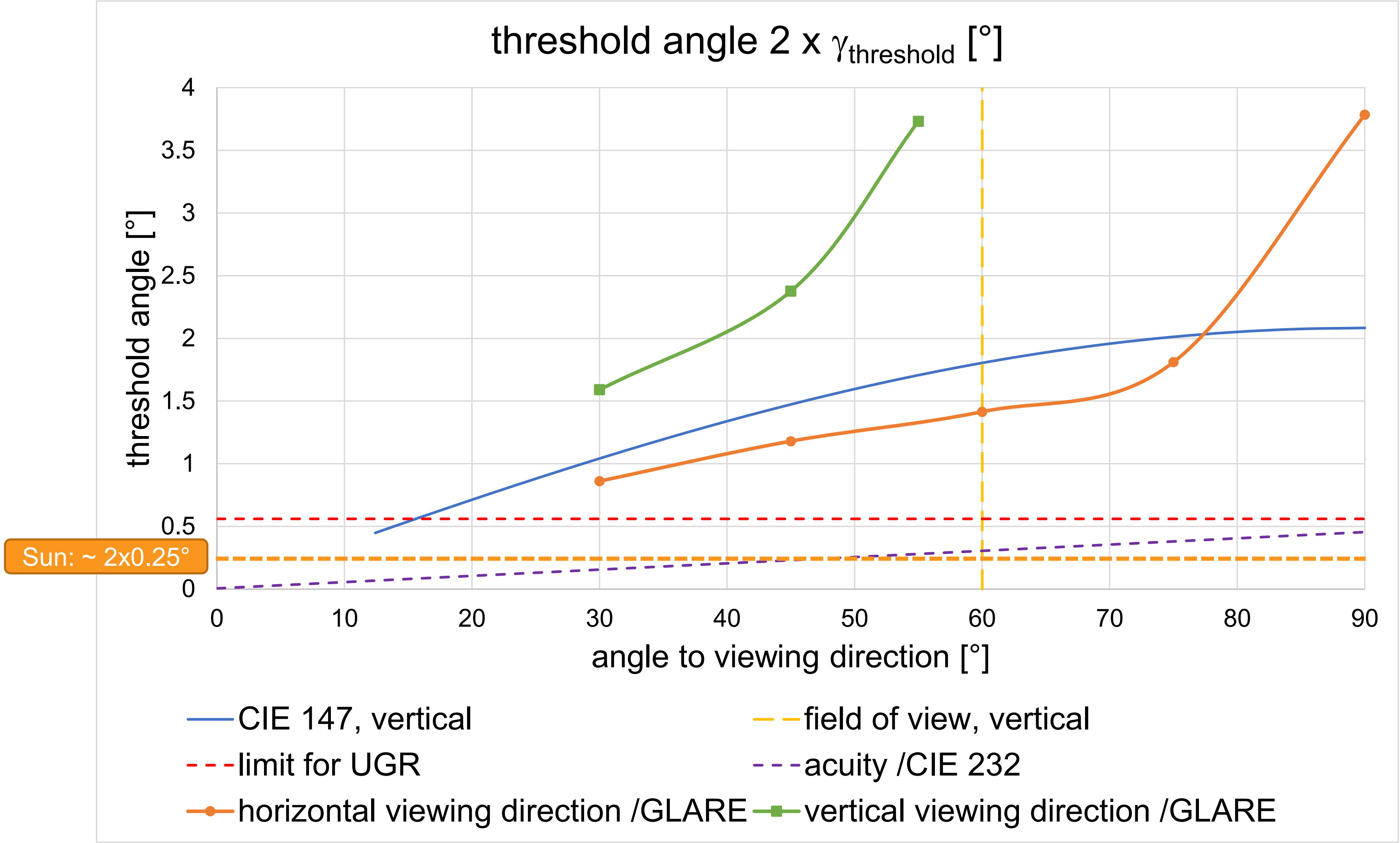
First results: horizontal viewing directions (30°, 45°, 60°, 75°, 90°) [work in progress…]



First results: vertical viewing directions (30°, 45°, 55°) [work in progress…]



First results: Threshold angles (cone 2 x $\gamma_{threshold}$) [work in progress…]

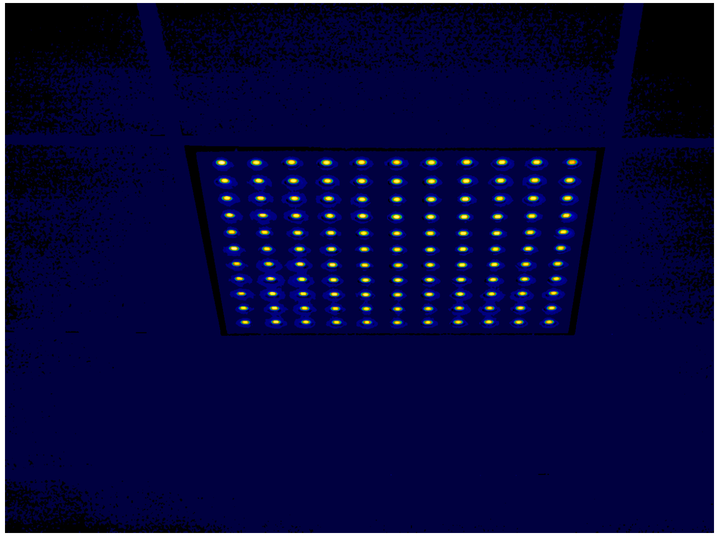


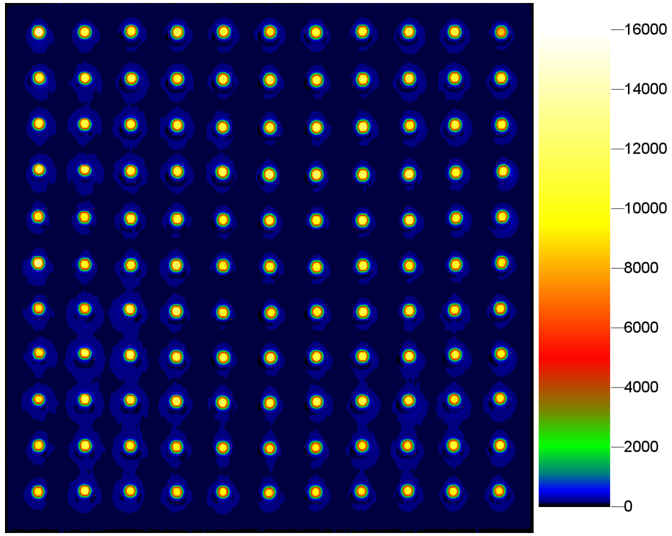
Next steps

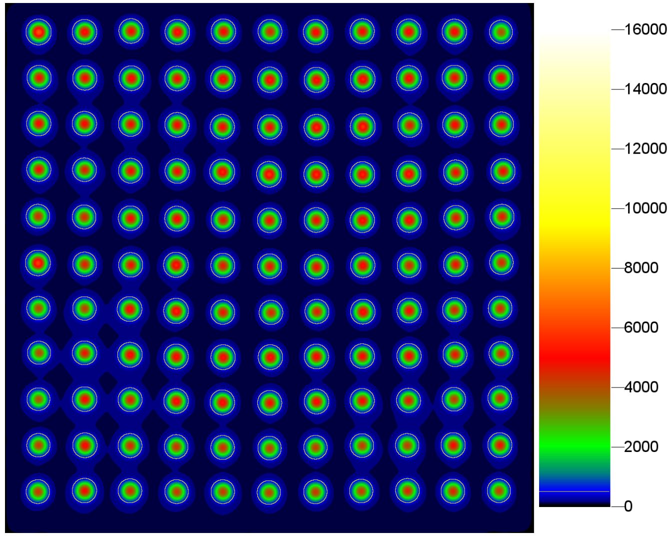
- Finish studies
- Work out proposal for pre-processing algorithm to be applied to luminance images
- Evaluate algorithm using available data sets
  - Cross-validation study (Jan Wienold et al., LRT 2019)
- Implement in software
  - in evalglare or
  - separate pre-processing tool (in Radiance)

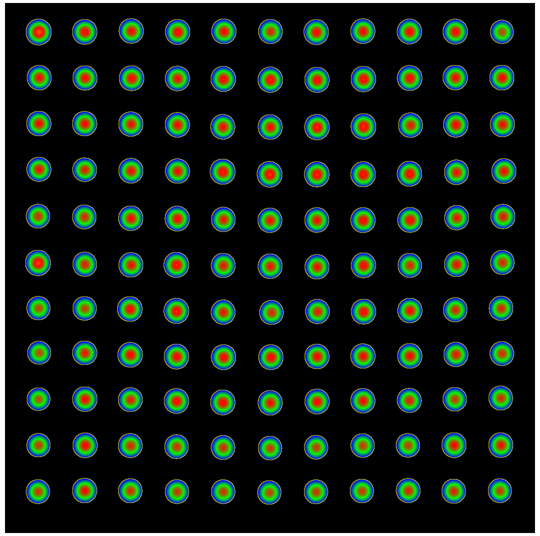
Approach: Averaging or applying gaussian blur on luminance images before calculating DGP

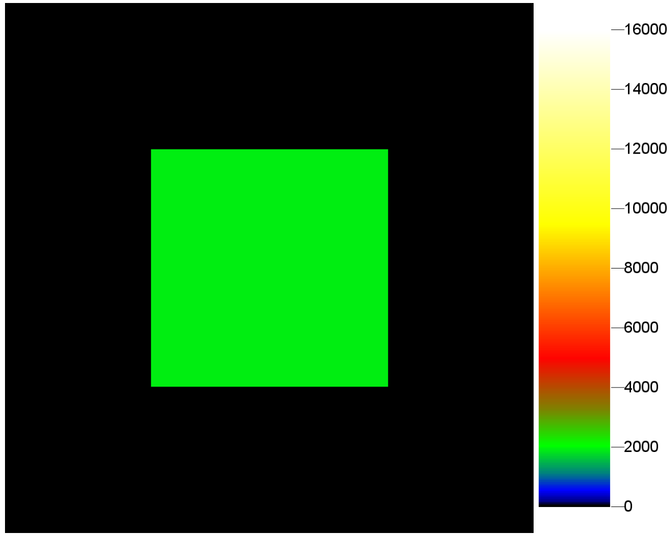
Borrowing from approach in CIE232?





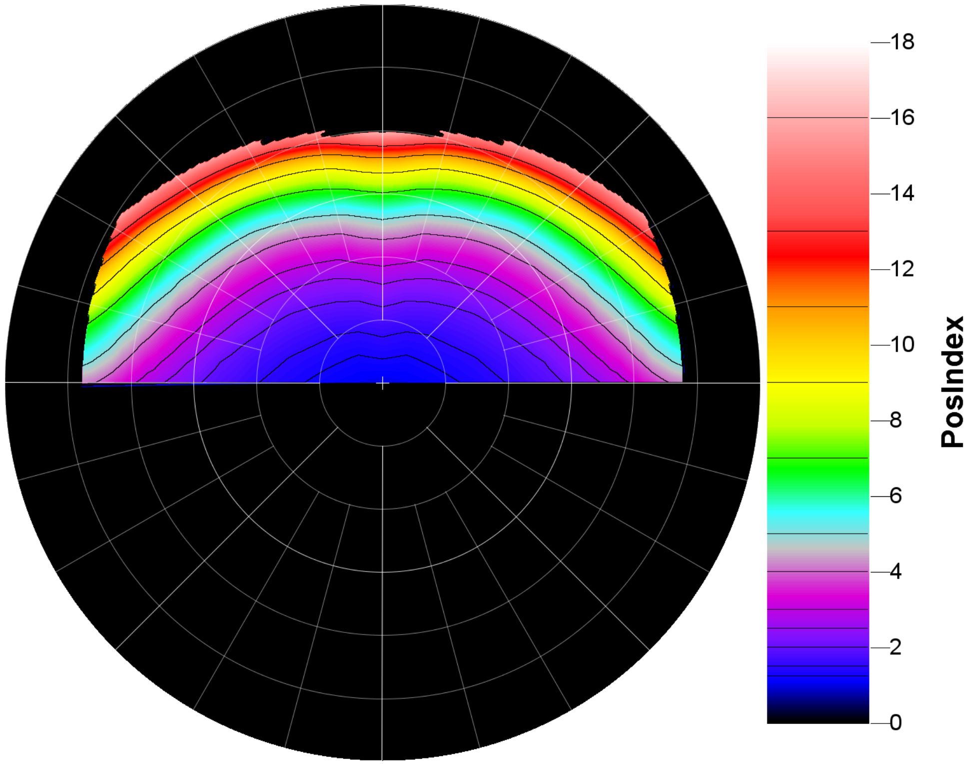


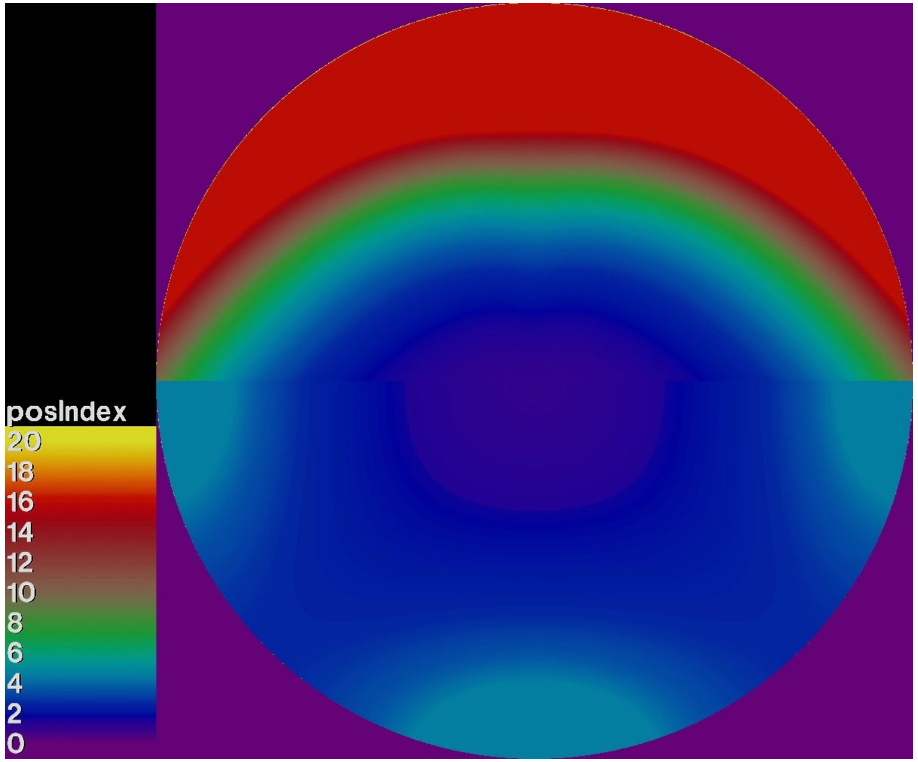




Approach: Averaging or applying gaussian blur on luminance images before calculating DGP

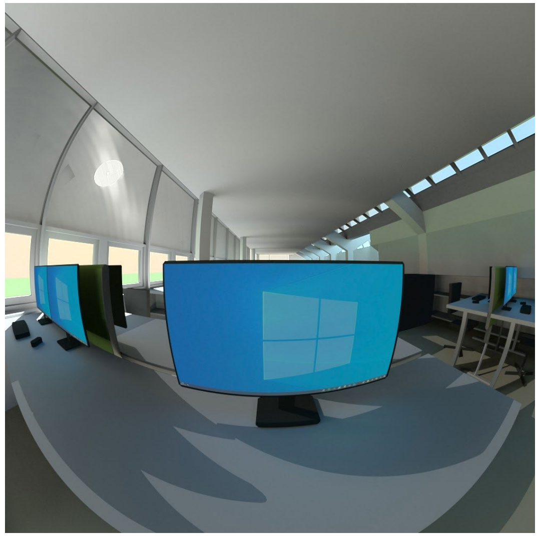
Directional varying averaging or blurring, similar to Position Index

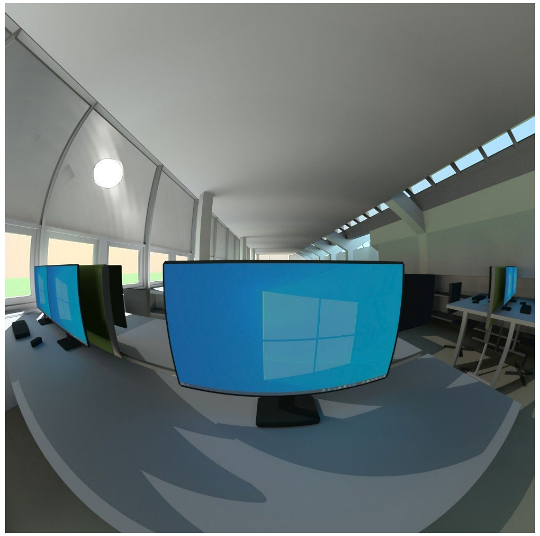


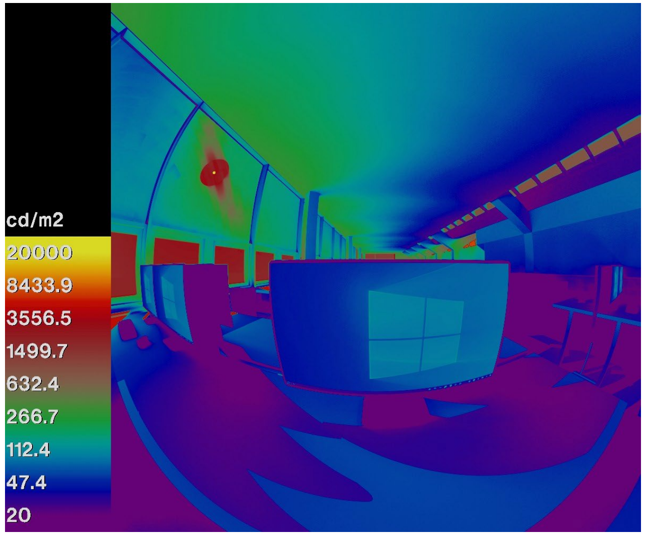


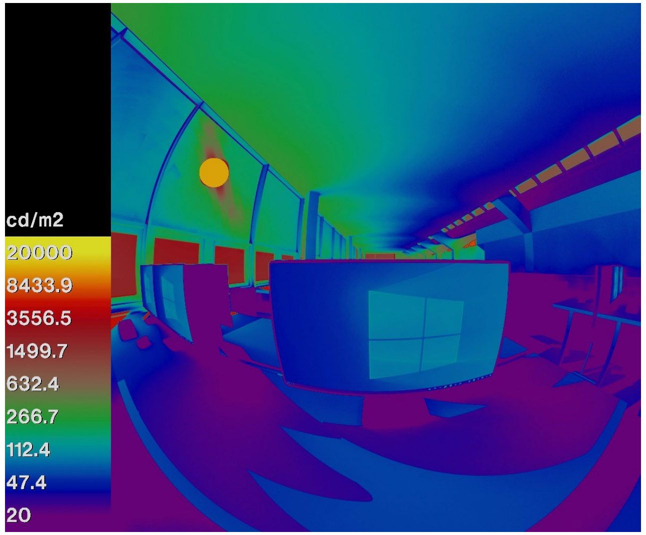
Approach: Averaging or applying gaussian blur on luminance images before calculating DGP

Example:
averaging in cone of 2 x 5°









Discussion

- Movement in experimental setup 2
  - High sensitivity for movement in the peripheral area
- Absolute values
  - Far from (il)luminance values we have with the sun in the field of view
- Update DGP formula (fit to new data including sun)?
- …

Acknowledgment

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FFG
Promoting Innovation.

Thank you!