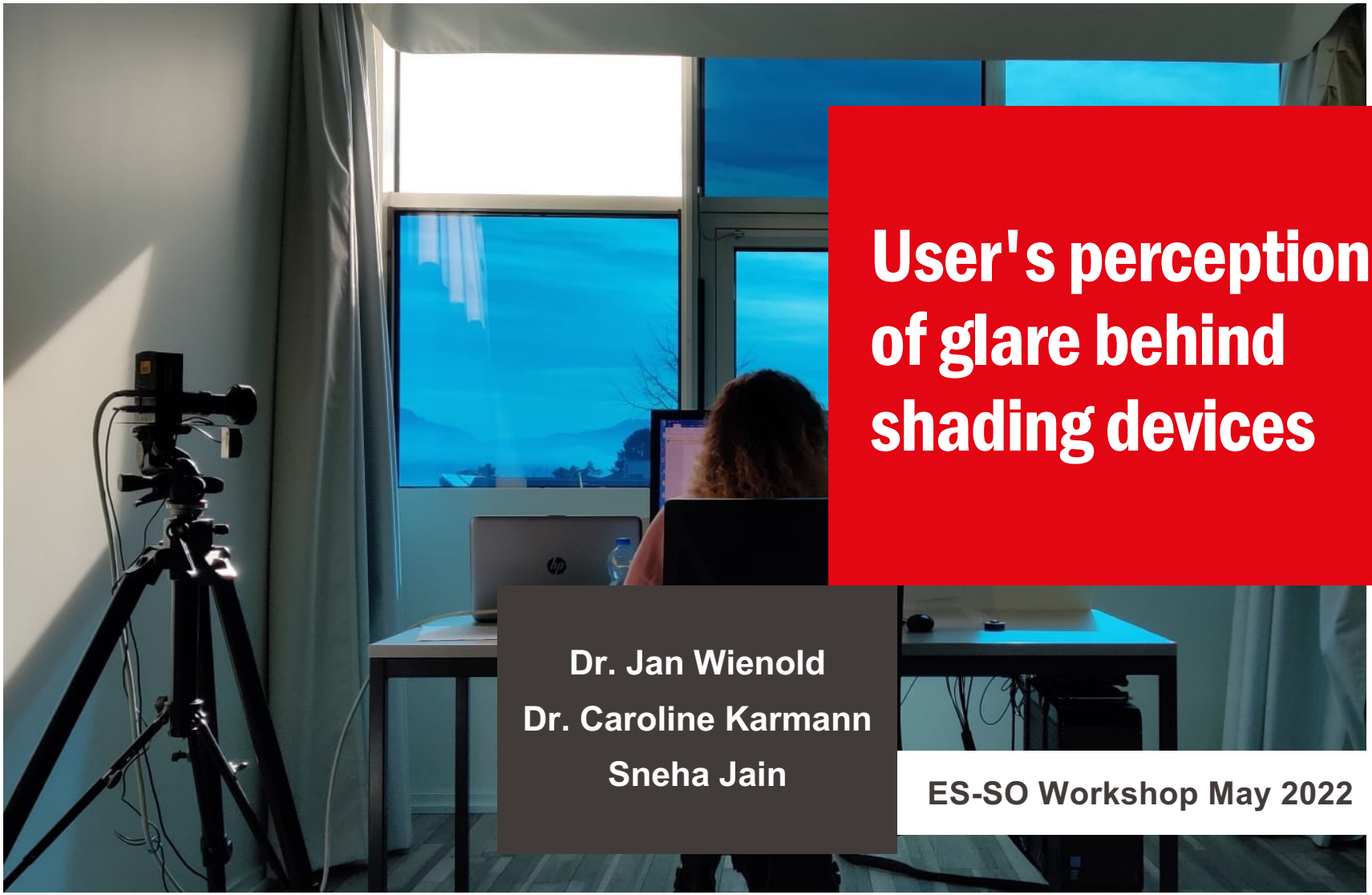
EPFL



User's perception of glare behind shading devices

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ES-SO Workshop May 2022

LIPID
Laboratory of Integrated
Performance in design

Visual comfort under Electrochromic windows

What are the transmittance levels required for glare protection when sun is visible through EC glazing?

Are current glare metrics able to predict glare in low-light EC glazing scenarios with sun in FOV of observer?

Glare from Electrochromic windows

What is the subjective perception under EC glazing?

Are current glare metrics capable of predicting glare in such situations?

Glare from Electrochromic windows

What is the subjective perception under EC glazing?

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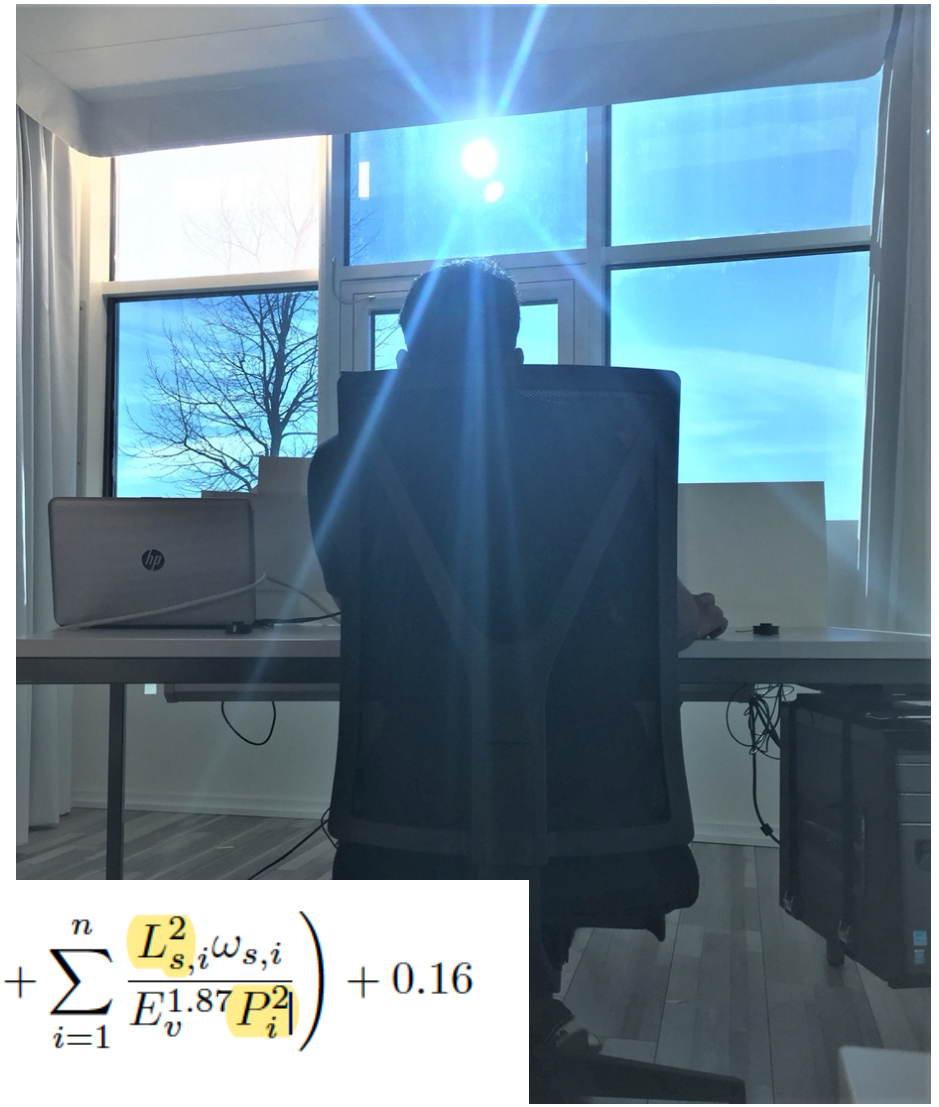
User assessment study

Independent variables	1. Luminance of glare source 2. Viewing direction in relation to glare source
Response variable	Discomfort glare perception
Number of participants	20



$$DGP = 5.87 * 10^{-5} E_v + 9.18 * 10^{-2} log\left(1 + \sum_{i=1}^{n} \frac{L_{s,i}^2 \omega_{s,i}}{E_v^{1.87} P_i^2}\right) + 0.16$$

EC glazing Transmittance

Daylight window	3.7%	3.7%
3.7%	0.14% Sun Window	3.7%

Visual Scene 0.14C

Daylight window	3.7%	3.7%
3.7%	0.6% Sun Window	3.7%

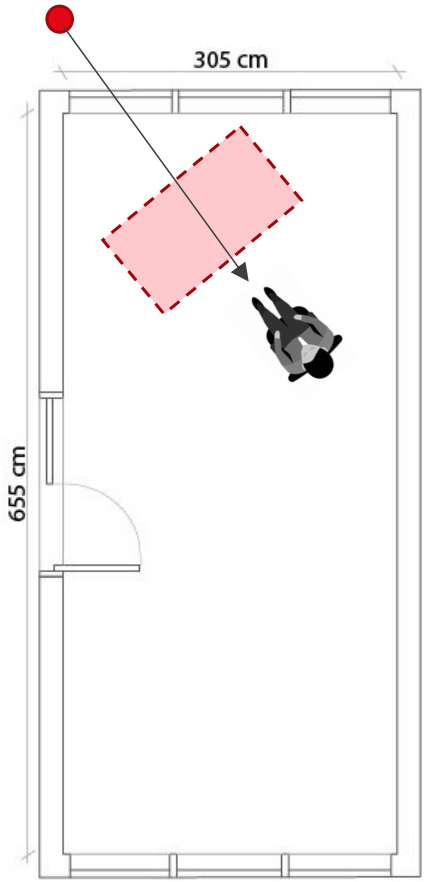
Visual Scene 0.6C/0.6P

Daylight window	3.7%	3.7%
3.7%	1.6% Sun Window	3.7%

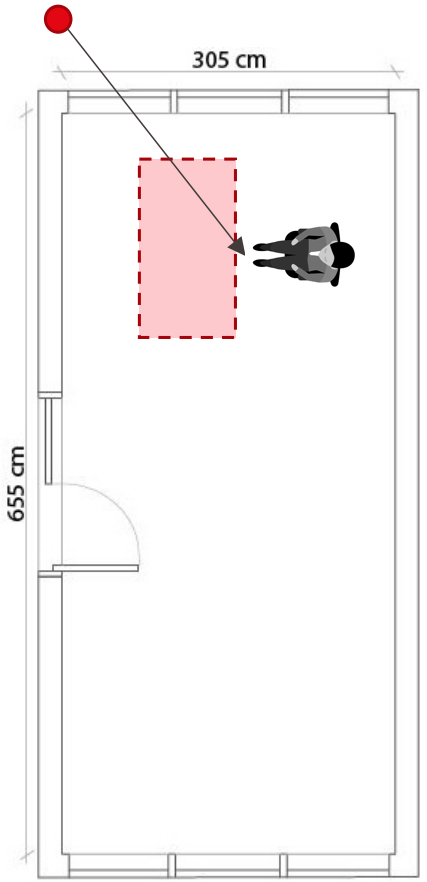
Visual Scene 1.6C

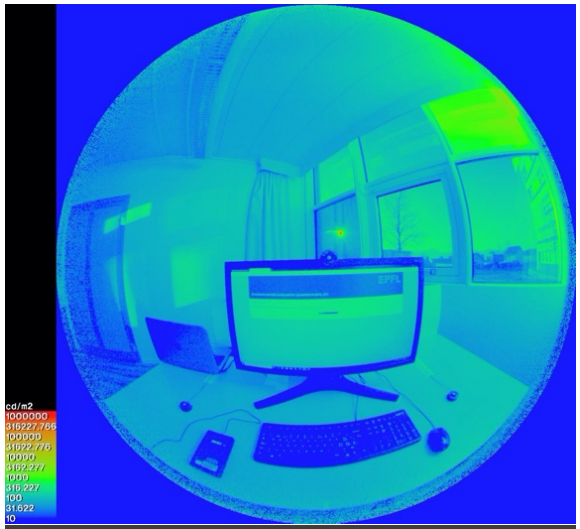
Viewing direction in relation to sun

1.
"C" Sun close to central FOV of participant
→ critical

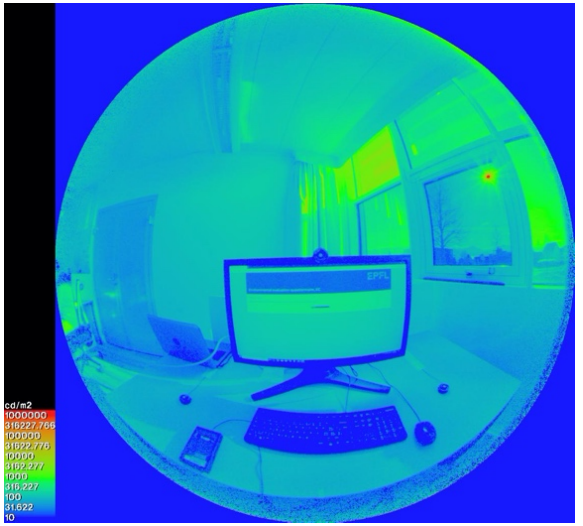


2.
"P" Sun in peripheral FOV of participant
→ non-critical

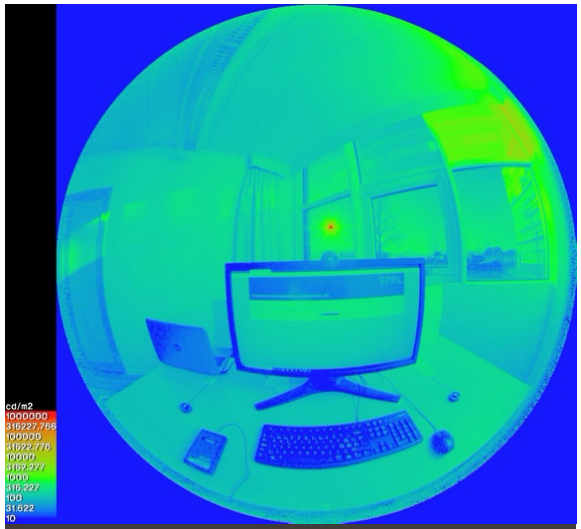




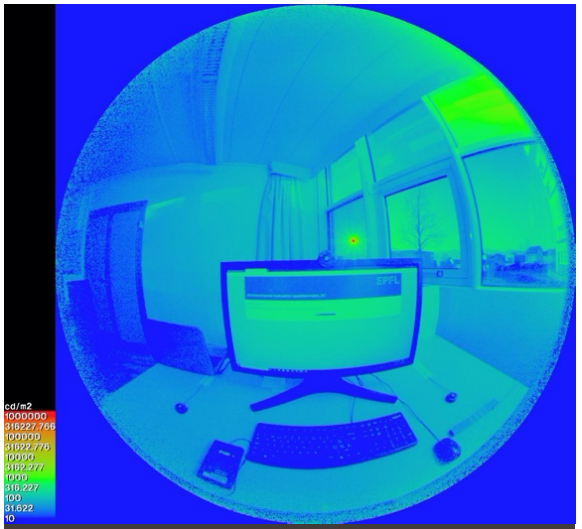
Visual condition 0.14C



Visual condition 0.6P

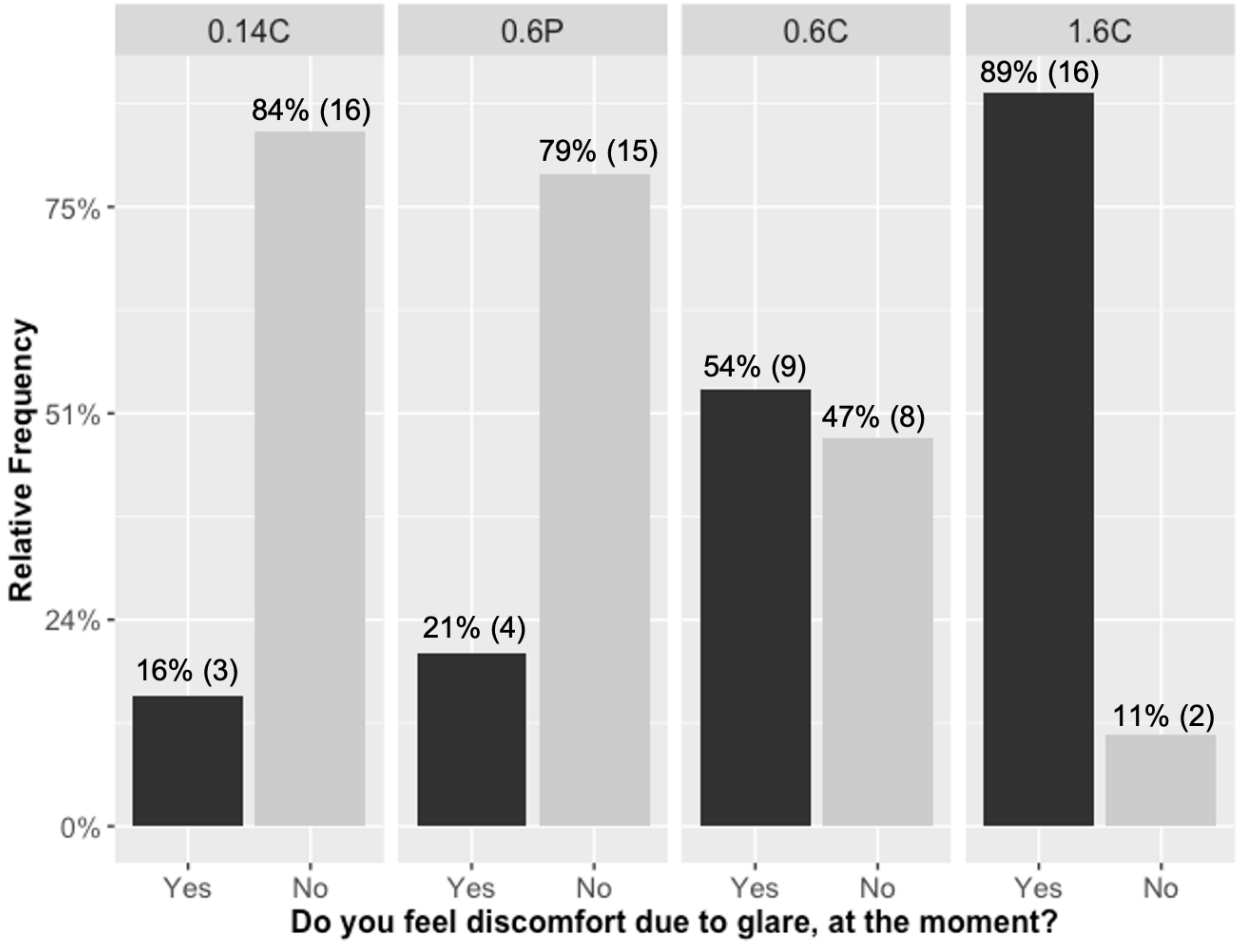


Visual condition 1.6C



Visual condition 0.6C

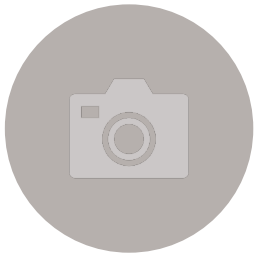
Results - Subjective perception of glare



Glare from Electrochromic windows

What is the subjective perception under EC glazing?

How to simulate?

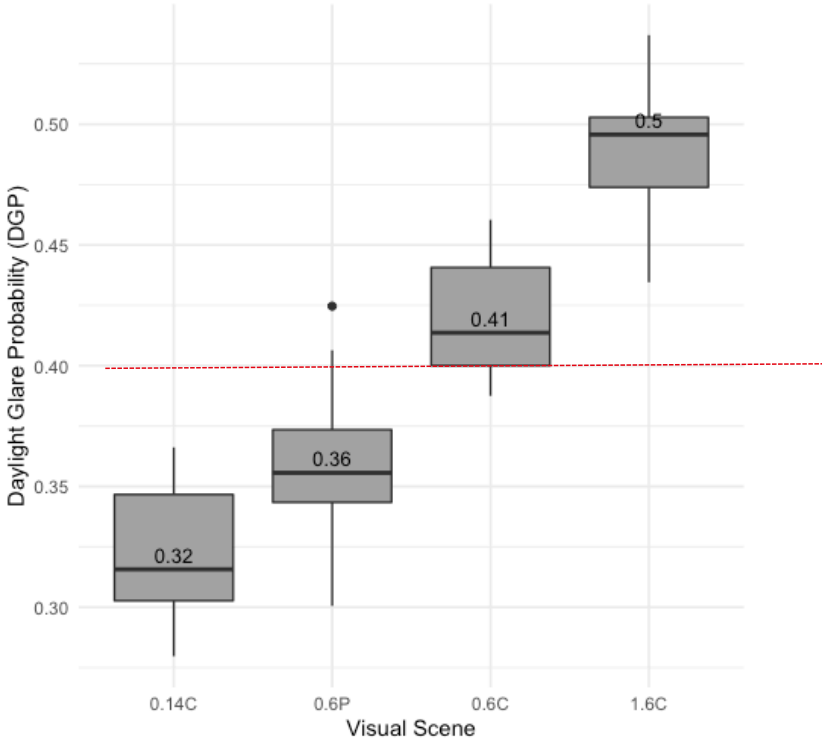


How to measure?

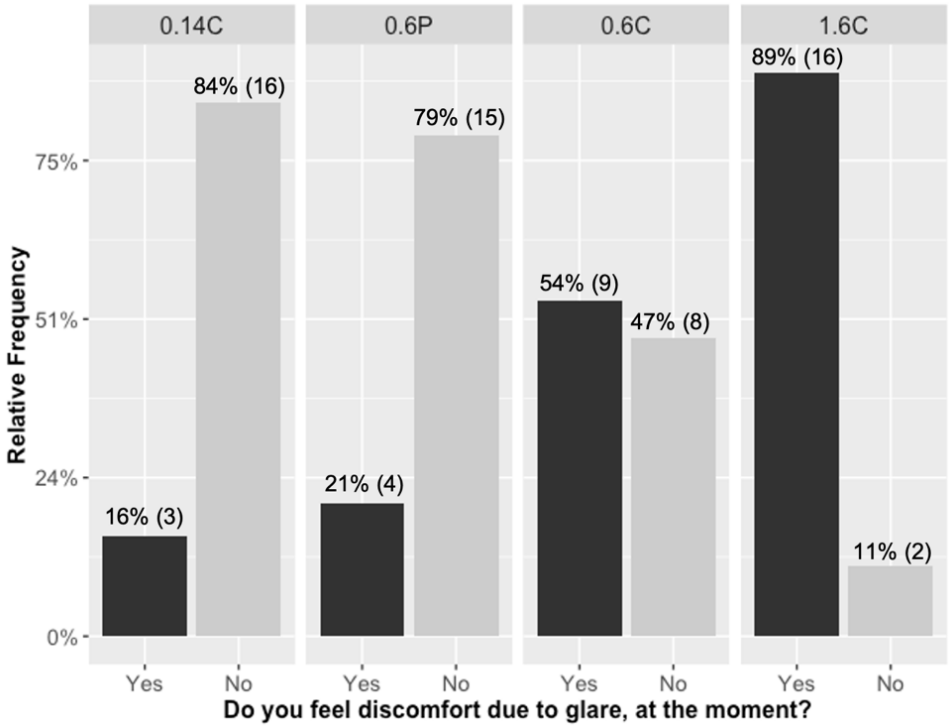
Are current glare metrics capable of predicting glare in such situations?

Results

DGP Distribution



Subjective perception of glare



⇒ DGP follows user perception reasonably well

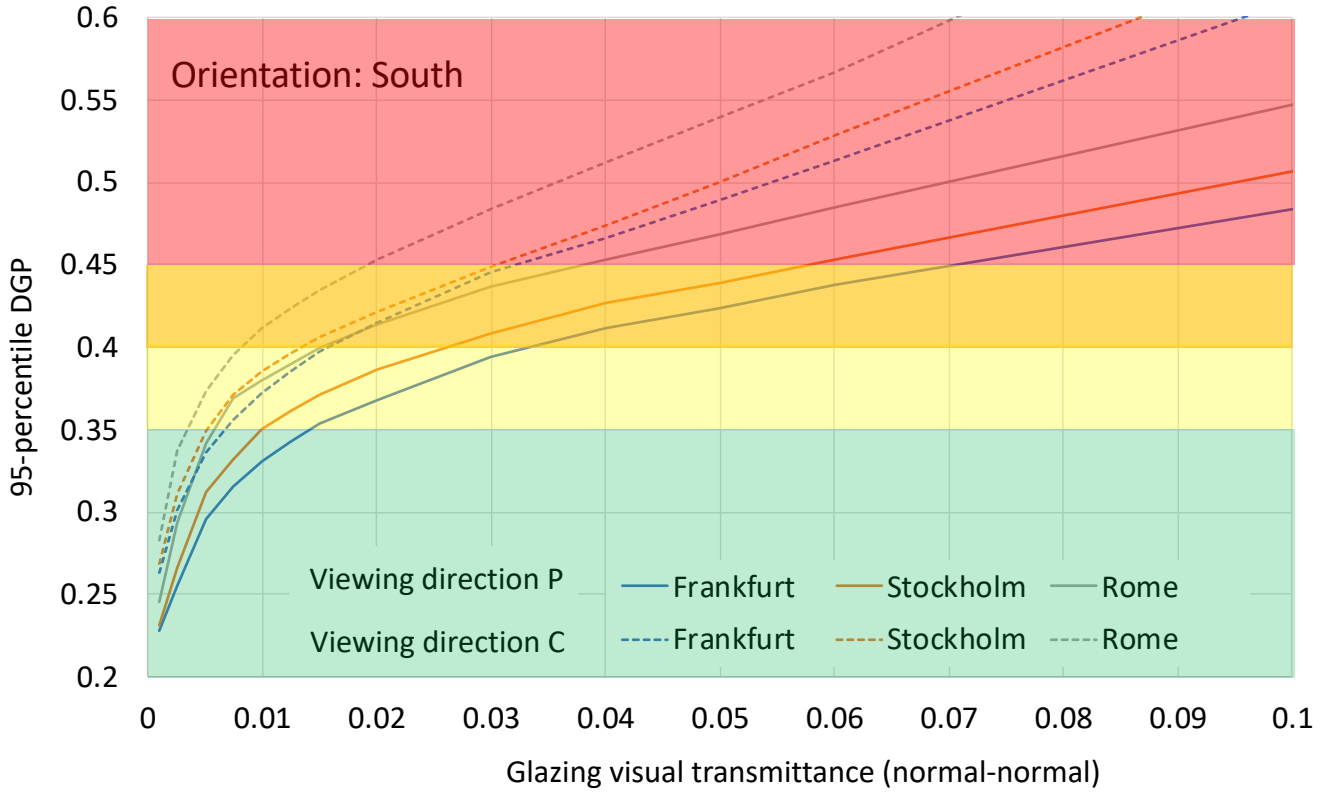
Glare metrics performance under EC glazing*

	DGP	E_v	CGI	UGP	DGI
Spearman's rank correlation coefficient	0.59	0.43	0.58	0.58	0.56
AUC	0.86	0.69	0.87	0.88	0.84

- Metrics that possess positional sensitivity performed better.
- Solely saturation-based metrics (Ev) are not suitable to predict glare for low transmittance glazing with sun visible through the façade.

*Results are valid only when using CIE 1988 2º standard observer photopic luminous efficiency function

How much does it matter throughout the year ?
Results of annual glare simulations according to EN17037



Calculated with a new and highly accurate annual glare simulation method AGC (<1min for full year calc 1h steps)

Preprint of

BuildSim Nordic 2022
22nd-23rd August
Copenhagen, Denmark
IBPSA NORDIC
International Building Performance Simulation Association

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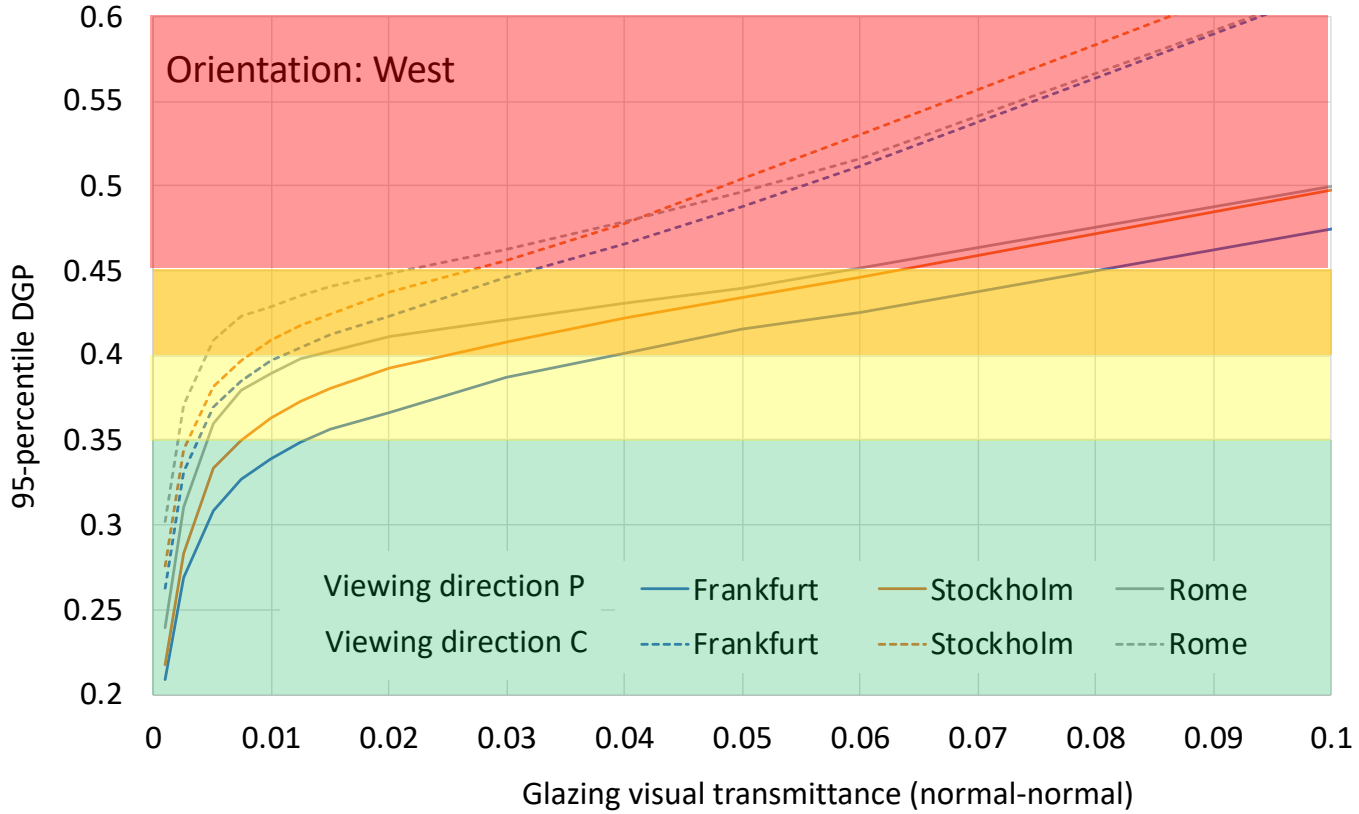

Preprint of

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EC - conclusions

A τ_v of 0.6% is sufficient to control glare in noncritical direction (comfort condition).

However, for critical viewing direction a τ_V of 0.14% is required to achieve comfortable conditions.

For scene 0.6C, 54% experienced discomfort glare, however, only 12% found the glare disturbing on 4-pt Osterhaus-Baily scale.

Considering annual behavior according to EN17037, a τ_V of 0.5% can maintain the best glare protection class for the parallel viewing direction and the medium glare protection class for the critical viewing direction.

EC - conclusions

These results confirm the strong angular dependency of glare perception, expressed by the position index P in the glare metrics.

These findings are valid only for blue-tinted EC and might differ for other colored or color-neutral systems.

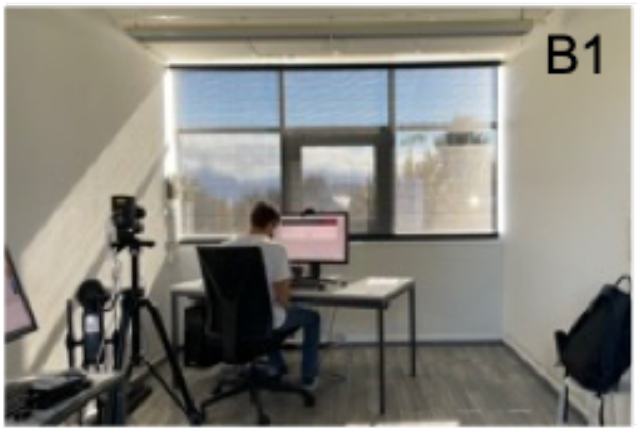
DGP more or less reliable for blue tinted glazing (using V(λ)).

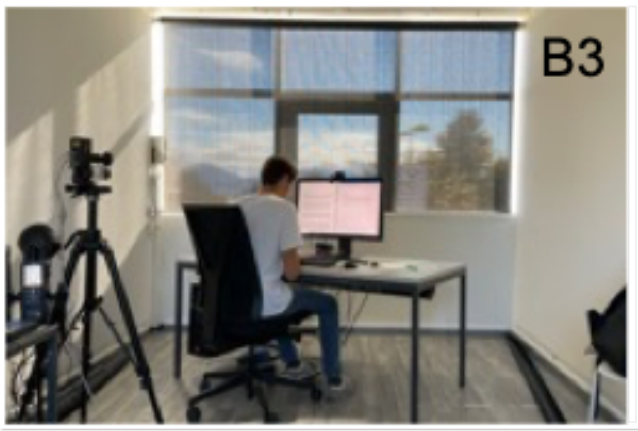
Publication (open access):

Jain, S., Karmann, C., Wienold, J.
Behind electrochromic glazing: Assessing user's perception of glare from the sun in a controlled environment.
(2022) Energy and Buildings, 256, art. no. 111738

DOI: 10.1016/j.enbuild.2021.111738

Fabric testing: Same facility and similar protocol





4 Fabric types tested

Different glare categories according to EN17037

EN14501: Glare classes

Class	Influence on visual comfort				
	0	1	2	3	4
	very little effect	little effect	moderate effect	good effect	very good effect

$\tau_{v,\,n\text{-}dif}$	$\tau_{v,\,n\text{-}n}$					
	$\tau_{v,\,n\text{-}n} = 0{,}00$	$0{,}00 < \tau_{v,\,n\text{-}n} \leq 0{,}01$	$0{,}01 < \tau_{v,\,n\text{-}n} \leq 0{,}02$	$0{,}02 < \tau_{v,\,n\text{-}n} \leq 0{,}03$	$0{,}03 < \tau_{v,\,n\text{-}n} \leq 0{,}05$	$\tau_{v,\,n\text{-}n} > 0{,}05$
$\tau_{v,\,n\text{-}dif} \leq 0{,}03$	4	4	3	3	1	0
$0{,}03 < \tau_{v,\,n\text{-}dif} \leq 0{,}06$	4	3	2	2	1	0
$0{,}06 < \tau_{v,\,n\text{-}dif} \leq 0{,}10$	4	3	2	1	0	0
$0{,}10 < \tau_{v,\,n\text{-}dif} \leq 0{,}15$	3	2	1	1	0	0
$0{,}15 < \tau_{v,\,n\text{-}dif} \leq 0{,}20$	2	2	1	1	0	0
$0{,}20 < \tau_{v,\,n\text{-}dif} \leq 0{,}25$	1	1	0	0	0	0
$0{,}25 < \tau_{v,\,n\text{-}dif}$	0	0	0	0	0	0

Fabric testing: Glare class and lab-measurements

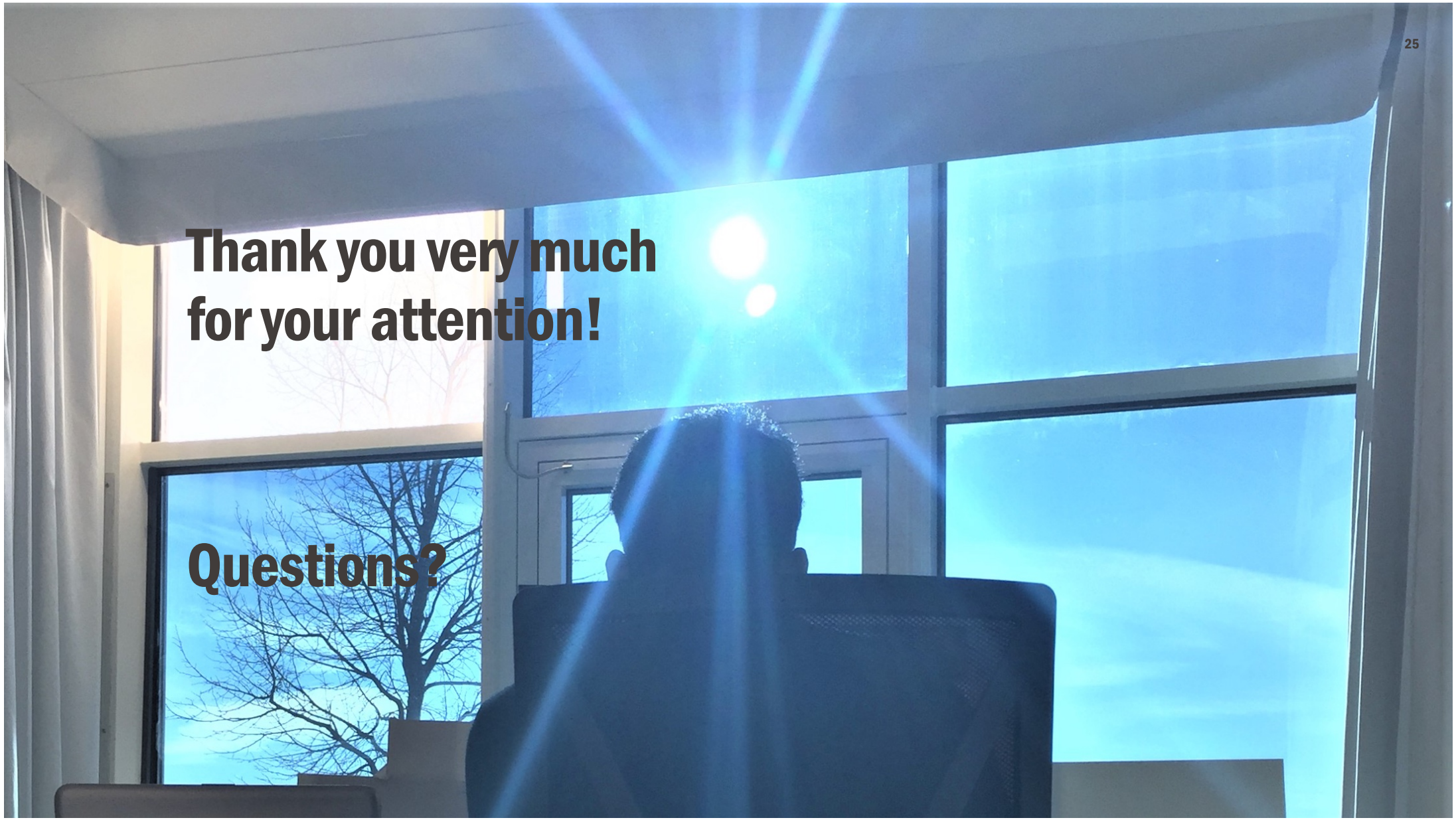
		EN14501	Manufacturers data[a]			Measured data (spectrometer / integrative sphere)			Measured data (goniophotometer)			
Fabric type	Color	**Glare class**	$\tau_{v,n\text{-}h}$	$tv_{dif\text{-}h}$	OF	$\tau_{v,n\text{-}n}$	$\tau_{v,n\text{-}dif}$	$\tau_{v,n\text{-}h}$	**$\tau_{v,n\text{-}h}$ (6°)**	$\tau_{v,n\text{-}dif}$	$\tau_{v,n\text{-}h}$	**Cut-off angle**
B1	black	**4***	0.018	0.002	1%	0.018	0.001	0.019	**0.011**	0.004	0.015	**36°**
B3[b]	black	**3**	0.023	0.017	3%	0.027	0.003	0.030	**0.024**	0.006	0.030	**70°**
L3	grey	**1**	0.054	0.045	3%	0.036	0.032	0.068	**0.040**	0.039	0.079	**62°**
B5	black	**0**	0.071	0.053	5%	0.065	0.004	0.069	**0.066**	0.006	0.072	**61°**

Fabric - conclusions

- For tested fabrics OF 1 and 3, users' perception is quite similar, whereas to OF 5 large difference
- Glare categories do not 100% reproduce this, whereas DGP does
- «Switches» between categories for small differences of $\tau_{v,n,n}$ can cause misclassifications
- DGP reliable for tested conditions

Acknowledgement

This study is funded by the Swiss National Foundation project (SNF) grant for the project “Visual comfort without borders: interactions on discomfort glare” number 200020_182151.



Thank you very much for your attention!

Questions?